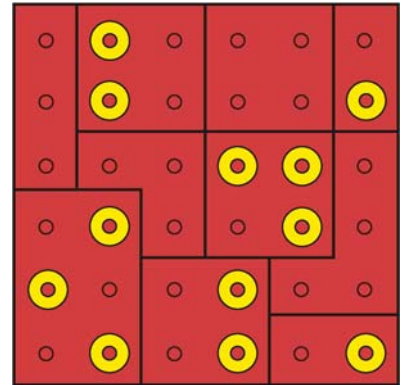# Survey Methods and Practices

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Survey Methods and Practices

Note of appreciation

Preface

I am very proud of the Statistics Canada publication *Survey Methods and Practices*. It is a real achievement and marks the culmination of the efforts of a large number of staff at Statistics Canada, particularly in the Survey Methodology Divisions, and I should like to express my sincere thanks and appreciation to them all.

This publication has benefited from courses given to Statistics Canada staff, workshops given to clients and courses given on censuses and surveys to African and Latin American statisticians. Of particular note is Statistics Canada's unique and innovative Survey Skills Development Course, which has been given on more than 80 occasions to over 2,000 staff at Statistics Canada, as well as to staff from other national statistical agencies. It was given particular impetus by the production of the *Survey Skills Development Manual* for the National Bureau of Statistics of China under the auspices of the Canada – China Statistical Co-operation Program.

The main use of this publication will be in support of the Survey Skills Development Course and I feel that it will become required reading and a reference for all employees at Statistics Canada involved in survey-related work. I hope it will also be useful to statisticians in other agencies, as well as to students of survey design and methods courses for whom it could serve as a source of insights into survey practices.

Ottawa   Dr. Ivan P. Fellegi
October 2003   Chief Statistician of Canada

Foreword

This manual is primarily a practical guide to survey planning, design and implementation. It covers many of the issues related to survey taking and many of the basic methods that can be usefully incorporated into the design and implementation of a survey. The manual does not replace informed expertise and sound judgement, but rather is intended to help build these by providing insight on what is required to build efficient and high quality surveys, and on the effective and appropriate use of survey data in analysis.

It originated as part of the Canada – China Statistical Co-operation Program, funded by the Canadian International Development Agency. The manual developed for that program was designed to assist the National Bureau of Statistics of China as part of its national statistical training program. It was accompanied by a Case Study that covered the main points of the manual through the use of a hypothetical survey. The China manual and Case Study were revised and modified to yield this manual for use at Statistics Canada, particularly as a companion reference and tool for the Statistics Canada Survey Skills Development Course.

Although the main focus of the manual is the basic survey concepts useful to all readers, some chapters are more technical than others. The general reader may selectively study the sections of these technical chapters by choosing to skip the more advanced material noted below.

The first five chapters cover the general aspects of survey design including:
- an introduction to survey concepts and the planning of a survey (Chapter 1);
- how to formulate the survey objectives (Chapter 2);
- general considerations in the survey design (Chapter 3), such as:
    - whether to conduct a sample survey or a census;
    - how to define the population to be surveyed;
    - different types of survey frames;
    - sources of error in a survey;
- methods of collecting survey data (Chapter 4), such as:
    - self-enumeration, personal interview or telephone interview;
    - computer-assisted versus paper based questionnaires;
and
- how to design a questionnaire (Chapter 5).

Chapters 6, 7 and 8 cover more technical aspects of the design of a sample survey:
- how to select a sample (Chapter 6);
- how to estimate characteristics of the population (Chapter 7);
- how to determine the sample size and allocate the sample across strata (Chapter 8).

In Chapter 7, the more advanced technical material begins with section *7.3 Estimating the Sampling Error of Survey Estimates*. In Chapter 8, the formulas used to determine sample size, requiring more technical understanding, begin with section *8.1.3 Sample Size Formulas*.

Chapter 9 covers the main operations involved in data collection and how data collection operations can be organised.

Chapter 10 discusses how responses to a questionnaire are processed to obtain a complete survey data file. The more technically advanced material begins with section *10.4.1 Methods of Imputation*.

Chapter 11 covers data analysis. The more technically advanced material in this chapter is covered in section *11.4 Testing Hypotheses About a Population: Continuous Variables.*

Chapter 12 deals with how data are disseminated to users and avoiding disclosure of individual data or data for a particular group of individuals.

Chapter 13 treats the issues involved in planning and managing a survey. This chapter is a non-technical chapter, aimed at potential survey managers or those who would be interested in or who are involved in planning and managing a survey.

In addition to these 13 chapters, there are two appendices. Appendix A addresses the use of administrative data – data that have been collected by government agencies, hospitals, schools, etc., for administrative rather than statistical purposes. Appendix B covers quality control and quality assurance, two methods that can be applied to various survey steps in order to minimise and control errors.

Acknowledgements

Various Statistics Canada reference documents and publications were used in developing this manual. Some key documents include:
- *Survey Sampling, a non-Mathematical Guide*, by A. Satin and W. Shastry,
- *Statistics Canada Quality Guidelines,*
- course material for *Surveys: from Start to Finish (416),*
- course material for *Survey Sampling: An Introduction (412),*

- course material for *Survey Skills Development Course (SSDC).*

Other Statistics Canada documents are listed at the end of each chapter, as appropriate.

Table of Contents

Chapter 1 - Introduction to Surveys

1.0 Introduction

What is a survey? *A survey is any activity that collects information in an organised and methodical manner about characteristics of interest from some or all units of a population using well-defined concepts, methods and procedures, and compiles such information into a useful summary form*. A survey usually begins with the need for information where no data – or insufficient data – exist. Sometimes this need arises from within the statistical agency itself, and sometimes it results from a request from an external client, which could be another government agency or department, or a private organisation. Typically, the statistical agency or the client wishes to study the characteristics of a population, build a database for analytical purposes or test a hypothesis.

A survey can be thought to consist of several interconnected steps which include: defining the objectives, selecting a survey frame, determining the sample design, designing the questionnaire, collecting and processing the data, analysing and disseminating the data and documenting the survey.

The life of a survey can be broken down into several phases. The first is the planning phase, which is followed by the design and development phase, and then the implementation phase. Finally, the entire survey process is reviewed and evaluated.

The purpose of this chapter is to provide an overview of the activities involved in conducting a statistical survey, with the details provided in the following chapters and appendices. To help illustrate the teaching points of this manual, the reader is encouraged to read the Case Study manual which takes the reader through the planning, design and implementation of a fictitious statistical survey.

1.1   Steps of a Survey

It may appear that conducting a survey is a simple procedure of asking questions and then compiling the answers to produce statistics. However, a survey must be carried out step by step, following precise procedures and formulas, if the results are to yield accurate and meaningful information. In order to understand the entire process it is necessary to understand the individual tasks and how they are interconnected and related.

The steps of a survey are:
-    formulation of the Statement of Objectives;
-    selection of a survey frame;
-    determination of the sample design;
-    questionnaire design;
-    data collection;
-    data capture and coding;
-    editing and imputation;
-    estimation;
-    data analysis;
-    data dissemination;
-    documentation.

A brief description of each step follows.

1.1.1   Formulation of the Statement of Objectives

One of the most important tasks in a survey is to formulate the Statement of Objectives. This establishes not only the survey's broad information needs, but the operational definitions to be used, the specific topics to be addressed and the analysis plan. This step of the survey determines what is to be included in the survey and what is to be excluded; what the client needs to know versus what would be nice to know.

How to formulate objectives and determine survey content is explained in **Chapter 2 - Formulation of the Statement of Objectives.**

1.1.2   Selection of a Survey Frame

The survey frame provides the means of identifying and contacting the units of the survey population. The frame is in the form of a list, for example:
-    a physical list such as a data file, computer printout or a telephone book;
-    a conceptual list, for example a list of all vehicles that enter the parking lot of a shopping centre between 9:00 a.m. and 8:00 p.m. on any given day;
-    a geographic list in which the units on the list correspond to geographical areas and the units within the geographical areas are households, farms, businesses, etc.

Usually, the statistical agency has the choice of using an existing frame, supplementing an existing frame or creating a new one. The frame chosen determines the definition of the survey population and can affect the methods of data collection, sample selection and estimation, as well as the cost of the survey and the quality of its outputs. Survey frames are presented in **Chapter 3 - Introduction to Survey Design**.

1.1.3   Determination of the Sample Design

There are two kinds of surveys: sample surveys and census surveys. ***In a sample survey, data are collected for only a fraction (typically a very small fraction) of units of the population while in a census survey, data are collected for all units in the population***. Two types of sampling exist: non-probability sampling and probability sampling. Non-probability sampling provides a fast, easy and inexpensive way of selecting units from the population but uses a subjective method of selection. In order to make inferences about the population from a non-probability sample, the data analyst must assume that the sample is representative of the population. This is often a risky assumption given the subjective method of selection. Probability sampling is more complex, takes longer and is usually more costly than non-probability sampling. However, because units from the population are randomly selected and each unit's probability of selection can be calculated, reliable estimates can be produced along with estimates of the sampling error and inferences can be made about the population. Since non-probability sampling is usually inappropriate for a statistical agency, this manual focuses on probability sampling.

There are many different ways to select a probability sample. The sample design chosen depends on such factors as: the survey frame, how variable the population units are and how costly it is to survey the population. The sample design in part determines the size of the sample, which impacts directly on survey costs, the time required to complete the survey, the number of interviewers required and other important operational considerations. There is no magical solution and no perfect recipe for determining sample size. Rather, it is a process of trying to fulfil as many requirements as possible – one of the most important being the quality of the estimates – as well as operational constraints.

The relative strengths and weaknesses of sample surveys and censuses are covered in **Chapter 3 - Introduction to Survey Design**. Non-probability and probability sample designs are presented in **Chapter 6 - Sample Designs**. Guidelines for determining the required sample size are covered in **Chapter 8 - Sample Size Determination and Allocation**.

1.1.4   Questionnaire Design

A questionnaire (or form) is a group or sequence of questions designed to obtain information on a subject from a respondent. Questionnaires play a central role in the data collection process since they have a major impact on data quality and influence the image that the statistical agency projects to the public. Questionnaires can either be in paper or computerised format.

Problems faced during questionnaire design include: deciding what questions to ask, how to best word them and how to arrange the questions to yield the information required. The goal is to obtain information in such a way that survey respondents understand the questions and can provide the correct answers easily in a form that is suitable for subsequent processing and analysis of the data. While there are well-established principles for questionnaire design, crafting a good questionnaire remains an art requiring ingenuity, experience and testing. If the data requirements are not properly transformed into a structured data collection instrument of high quality, a 'good' sample can yield 'bad' results.

Questionnaire design is covered in **Chapter 5 - Questionnaire Design**.

1.1.5   Data Collection

Data collection is the process of gathering the required information for each selected unit in the survey. The basic methods of data collection are self-enumeration, where the respondent completes the questionnaire without the assistance of an interviewer, and interviewer-assisted (either through personal or telephone interviews). Other methods of data collection include direct observation, electronic data reporting and the use of administrative data.

Data collection can be paper-based or computer-assisted. With paper-based methods, answers are recorded on printed questionnaires. With computer-assisted methods, the questionnaire appears on the screen of the computer and the answers are entered directly into the computer. One benefit of computer-assisted methods is that *data capture – the transformation of responses into a machine-readable format* – occurs during collection, thereby eliminating a post-collection processing activity. Another benefit is that invalid or inconsistent data can be identified more easily than with a paper questionnaire.

Methods of data collection are covered in **Chapter 4 - Data Collection Methods**. The use of administrative data is discussed in **Appendix A - Administrative Data.** Data collection activities, including such interviewer activities as listing, tracing, and methods of organising data collection are covered in **Chapter 9 - Data Collection Operations**.

1.1.6   Data Capture and Coding

After the data are collected, they are coded and, if a computer-assisted collection method was not used, captured. *Coding is the process of assigning a numerical value to responses to facilitate data capture and processing in general*. Some questions have coded response categories on the questionnaire, others

are coded after collection during a manual or automated process. Data capture and coding are expensive and time-consuming activities that are critical to data quality since any errors introduced can affect the final survey results. Therefore, emphasis should be placed on error prevention in the early stages. Two methods of monitoring and controlling errors are quality assurance and quality control. The purpose of quality assurance is to anticipate problems and prevent them while the purpose of quality control is to ensure that the number of errors that occur are within acceptable limits.

Data capture and coding are covered in **Chapter 10 - Processing**. Quality issues are covered in **Appendix B - Quality Control and Quality Assurance**.

1.1.7   Editing and Imputation

Editing is the application of checks to identify missing, invalid or inconsistent entries that point to data records that are potentially in error. The purpose of editing is to better understand the survey processes and the survey data in order to ensure that the final survey data are complete, consistent and valid. Edits can range from simple manual checks performed by interviewers in the field to complex verifications performed by a computer program. The amount of editing performed is a trade-off between getting every record 'perfect' and spending a reasonable amount of resources (time and money) achieving this goal.

While some edit failures are resolved through follow-up with the respondent or a manual review of the questionnaire, it is nearly impossible to correct all errors in this manner, so imputation is often used to handle the remaining cases. ***Imputation is a process used to determine and assign replacement values to resolve problems of missing, invalid or inconsistent data***.

Although imputation can improve the quality of the final data, care should be taken in order to choose an appropriate imputation methodology. Some methods of imputation do not preserve the relationships between variables or can actually distort underlying relationships in the data. The suitability of the method chosen depends on the type of survey, its objectives and the nature of the error.

Editing and imputation are covered in **Chapter 10 - Processing**.

1.1.8   Estimation

Once the data have been collected, captured, coded, edited and imputed, the next step is estimation. ***Estimation is the means by which the statistical agency obtains values for the population of interest so that it can draw conclusions about that population based on information gathered from only a sample of the population***. An estimate may be a total, mean, ratio, percentage, etc.

For a sample survey, the basis of estimation is the unit's weight, which indicates the average number of population units it represents. A population total can be estimated, for example, by summing the weighted values of the sampled units. The initial design weight is determined by the sample design. Sometimes, adjustments are made to this weight, for example, to compensate for units that do not respond to the survey (i.e., total nonresponse) or to take into account auxiliary information. Nonresponse adjustments may also be applied to data from a census survey.

Sampling error occurs in sample surveys since only a portion of the population is enumerated and the sampled units do not have exactly the same characteristics as all of the population units that they represent. An estimate of the magnitude of the sampling error for each estimate should always be

provided to indicate to users the quality of the data.

Estimation of summary statistics is covered in **Chapter 7 - Estimation**. Estimating sampling error is discussed in **Chapter 7 - Estimation** and **Chapter 11 - Analysis of Survey Data**.

1.1.9   Data Analysis

Data analysis involves summarising the data and interpreting their meaning in a way that provides clear answers to questions that initiated the survey. Data analysis should relate the survey results to the questions and issues identified by the Statement of Objectives. It is one of the most crucial steps of a survey since the quality of the analysis can substantially affect the usefulness of the whole survey.

Data analysis may be restricted to the survey data alone or it may compare the survey's estimates with results obtained from other surveys or data sources. Often, it consists of examining tables, charts and various summary measures, such as frequency distributions and averages to summarise the data. Statistical inference may be used in order to verify hypotheses or study the relationships between characteristics, for instance, using regression, analysis of variance or chi-square tests.

Data analysis is covered in **Chapter 11 - Data Analysis**.

1.1.10 Data Dissemination

Data dissemination is the release of the survey data to users through various media, for example, through a press release, a television or radio interview, a telephone or facsimile response to a special request, a paper publication, a microfiche, electronic media including the Internet or a microdata file on a CD, etc..

Delivery and presentation of the final results is very important. It should be easy for the users to find, understand, use and interpret the survey results correctly. Results from the survey should be summarised and the strengths and weaknesses of the data indicated, with important details highlighted through a written report that includes tables and charts.

Before disseminating data, a data quality evaluation should be performed in order to help assess and interpret the survey results and the quality of the survey and to inform users so that they can judge for themselves the usefulness of the data. It may also provide valuable input to improve the survey (if repeated) or other surveys. This evaluation, and its accompanying report, should include a description of the survey methodology along with measures and sources of error.

As part of the dissemination process, many statistical agencies are required by law to protect the confidentiality of respondents' information. ***Disclosure control refers to those measures taken to protect disseminated data so that the confidentiality of respondents is not violated***. It involves, for instance, identifying and eliminating (or modifying) table cells that risk revealing information about an individual. Usually, some data have to be suppressed or modified. Before choosing a disclosure control method, various methods should be compared with respect to their impact on the survey results and an individual's risk of disclosure.

Data dissemination is covered in **Chapter 12 - Data Dissemination**.

1.1.11 Documentation

Documentation provides a record of the survey and should encompass every survey step and every survey phase. It may record different aspects of the survey and be aimed at different groups, such as management, technical staff, designers of other surveys and users. For example, a report on data quality provides users a context for informed use of the data. A survey report that includes not only what decisions were made, but also why they were made provides management and technical staff with useful information for future development and implementation of similar surveys. During implementation, documentation of procedures for staff helps to ensure effective implementation.

How to organise a report and guidelines for writing are covered in **Chapter 12 - Data Dissemination**.

1.2   Life Cycle of a Survey

The survey steps presented above are not necessarily sequential: some are conducted in parallel, others – for example, editing – are repeated at different times throughout the survey process. Every step must first be planned, then designed and developed, implemented and ultimately evaluated. The phases in the life of a survey are described below.

1.2.1   Survey Planning

The first phase of the survey process is planning. But before any planning can take place, a management and planning structure must be selected and implemented. One commonly used structure is the project or survey team approach, whereby an interdisciplinary survey team is given responsibility for the planning, design, implementation, and evaluation of the survey and of its planned products. The interdisciplinary team is composed of members having different technical skills; for example, a statistician, a computer programmer, an expert in the field of study, a data collection expert, etc.

Survey planning should be conducted in stages of increasing detail and exactitude. At the preliminary, or survey proposal stage, only the most general notion of the data requirements of the client may be known. Once a survey proposal has been formulated, it is important to determine whether a new survey is necessary, keeping in mind options, costs and priorities of the client and the statistical agency. Sometimes much or all of the information desired can be obtained from administrative files of governments, institutions and agencies. Alternatively, it may be possible to add questions to an existing survey's questionnaire or, it may be possible to redesign an existing survey.

If it is decided that alternative data sources cannot meet the information needs, the team proceeds to formulate the Statement of Objectives and to develop some appreciation of frame options, the general sample size, precision requirements, data collection options, schedule and cost. A decision about the feasibility of the survey is usually made at this point.

After the objectives of the survey are clear, each team member prepares the component plans associated with his or her responsibility within the team. During this stage, planning becomes a more complex matter. The advantages and disadvantages of alternative methodologies should be examined and compared in terms of: coverage, mode of data collection, frequency, geographical detail, response burden, quality, cost, resources required and timeliness.

In the later stages of the survey process, plans are revised, elaborated and refined, and more detailed aspects are examined. Each and every activity and operation needs some form of plan for design, development and implementation. Planning continues throughout the entire survey process with modifications being made as required.

The details of planning are covered in **Chapter 13 - Survey Planning and Management**.

1.2.2   Design and Development

Having established a broad methodological framework, it is possible to carry out detailed work on the various steps of a survey in, what is referred to as, the design and development phase. The overall objective of this phase is to find the set of methods and procedures that achieve an appropriate balance of quality objectives and resource constraints.

It is during this phase that any required pretests or pilot surveys are carried out to assess, for example, the adequacy of the questionnaire, suitability of the survey frame, operational procedures, etc. All field materials (e.g., interviewer training and instruction manuals, sample control documents) are prepared for the data collection stage. Software programs for computer administered questionnaires are developed, or adapted, and tested. Sample selection and estimation procedures are finalised in the form of specifications. Specifications for coding, data capture, editing and imputation are all prepared to set the stage for data processing.

To be effective, procedures should be designed to control and measure the quality at each step of the survey (using quality assurance and quality control procedures) and to assess the quality of the final statistical products.

1.2.3   Implementation

Having ensured that all systems are in place, the survey can now be launched. This is the implementation phase. All survey control forms and manuals are printed, along with the questionnaire (if paper questionnaires are used). Interviewers are trained, the sample is selected and information is collected, all in a manner established during the development phase. Following these activities, data processing begins. Processing activities include data capture, coding, editing and imputation. The result is a well-structured and complete data set from which it is possible to produce required tabulations and to analyse survey results. These results are then checked for confidentiality and disseminated. At every step, data quality should be measured and monitored using methods designed and developed in the previous phase.

1.2.4   Survey Evaluation

Survey evaluation is an ongoing process throughout the survey. Every step of the survey should be evaluated in terms of its efficiency, effectiveness and cost, particularly in the case of repeated surveys, so that improvements in their design and implementation can be made over time. This involves assessments of the methods used, as well as evaluations of operational effectiveness and cost performance. These evaluations serve as a test of the suitability of the technical practices. They also serve to improve and guide implementation of specific concepts or components of methodology and operations, within and across surveys. They support the activities and provide measures and assessments of the quality limitations of the program data. As well, each survey step is evaluated to provide insight into

shortcomings or problems in other steps of the survey. For example, editing and imputation can provide information on problems with the questionnaire.

Evaluations of previous surveys or pilot surveys are important when planning a new statistical activity: they can help formulate realistic survey objectives, provide an idea of the expected quality of the data and essential information for survey design and data processing.

1.3   Summary

What is a survey? A survey is any activity that collects information in an organised and methodical manner. It is usually motivated by the need to study the characteristics of a population, build a database for analytical purposes or test a hypothesis.

What are the steps of a survey? A survey is a much more complex procedure than simply asking questions and compiling answers to produce statistics. Numerous steps must be carried out following precise methods and procedures, if the results are to yield accurate information. These steps include formulating the survey objectives, determining the sample design, designing the questionnaire, performing data collection, processing and tabulating data and disseminating results.

How are the steps implemented? Execution of a survey can be described as a life cycle with four phases. The first phase is planning during which the survey objectives, methodology, budget and schedule of activities are established. The next phase is the design and development of the survey steps. The third phase is the implementation of the survey steps. During implementation, quality is measured and monitored in order to ensure that the processes are working as planned. Finally, the survey steps are reviewed and evaluated.

Bibliography

Cochran, W.G. 1977. *Sampling Techniques.* John Wiley and Sons, New York.

Des Raj. 1972. *The Design of Sample Surveys.* McGraw-Hill Series in Probability and Statistics, New York.

Moser C.A. and G. Kalton. 1971. *Survey Methods in Social Investigation*. Heinemann Educational Books Limited, London.

Särndal, C.E., B. Swensson and J. Wretman. 1992. *Model Assisted Survey Sampling*. Springer-Verlag, New York.

Satin, A. and W. Shastry. 1993. *Survey Sampling: A Non-Mathematical Guide – Second Edition*. Statistics Canada. 12-602E.

Statistics Canada. 1987. *Quality Guidelines*. Second Edition.

Statistics Canada. 1998. *Statistics Canada Quality Guidelines*. Third Edition. 12-539-X1E.

Chapter 2 - Formulation of the Statement of Objectives

2.0   Introduction

The first task in planning a survey is to specify the objectives of the survey as thoroughly and as clearly as possible. A clear Statement of Objectives guides all subsequent survey steps. These steps should be planned to ensure that the final results meet the original objectives.

Suppose that a survey on poverty is to be conducted. It is not enough to indicate that the purpose of the survey is to provide information on, for example, 'housing conditions of the poor'. Such a vague statement may serve as a broad description of the survey's general theme, but ultimately it must be expanded into more specific language. What is meant by 'housing conditions'? Does it refer to the building, its age or need of repair, or does it refer to crowding (e.g., the number of people per square metre)? What precisely is meant by 'poor'? Is poverty to be measured in terms of income, expenditures, debts, or all of these?

The statistical agency, in consultation with the client, first needs to define the information needs and primary users and uses of the data more completely and precisely. Broadly, what information is required on housing conditions for the poor? Who needs the data and for what purpose? Suppose that the client requesting the survey is City Council. City Council suspects that housing conditions of the poor to be inadequate and expects to have to build new subsidised housing. City council may want to know how many new houses would be are required and how much they would cost. It may want to ask the poor where they would want the new housing. The city may also expect to vary the subsidy depending on the poverty of the family, thereby requiring data for different levels of poverty.

Next, specific operational definitions need to be developed, including a definition of the target population. These definitions indicate who or what is to be observed and what is to be measured. In the case of 'poor', the definition might be all families with a gross income below a certain level. The terms 'family' and 'income' must also be defined. Coverage of the population needs to be defined: what geographic area is the client interested in – which areas within the city? And what is the reference period – last week, last year?

The statistical agency also needs to know what specific topics are to be covered by the survey. Does the client want information by income group, the type of dwelling (e.g., apartment building, single detached house, etc.), the age of the dwelling, the number of people living in the dwelling, etc.? What level of detail is necessary for each topic and what is to be the format of the results? This usually takes the form of proposed analysis tables. For a sample survey, the level of detail possible is a function of the size of the sampling error in the estimates as well as operational constraints such as available time, budget, personnel and equipment. These quality targets and operational constraints will heavily influence the scope of the survey.

The Statement of Objectives may be revised many times by the statistical agency, in consultation with the client, during the planning, design and development of the survey.

The purpose of this chapter is to illustrate how to formulate the Statement of Objectives.

2.1   A Multi-Step Process for Developing the Statement of Objectives

Developing the Statement of Objectives is a multi-step, iterative process involving the statistical agency, the client and the users (if different than the client). The steps in the process are to determine:
- the information needs;
- the users and uses of the data;
- the main concepts and the operational definitions;
- the survey content;
- the analysis plan.

To illustrate these steps, consider the following example. The city's Regional Transit Authority (RTA) has been instructed by the City Council to take steps to facilitate the use of public transit by senior citizens (referred to as 'seniors'). Since the RTA does not have current information on seniors' needs or travel habits, it has approached the statistical agency to help gather new data. The following paragraph is the RTA's initial statement of the situation:

> *To facilitate the use of public transit by the city's seniors, the RTA is considering modifying its existing service. Possible changes include, for example, purchasing special buses, modifying existing buses, adding new routes, or possibly subsidising fares. Before proceeding with expensive purchases and alterations, the RTA requires information on the transportation needs of seniors so that it can tailor its budget and improvements to their needs.*

2.1.1   The Information Needs (State the Problem)

The first step is to describe in broad terms the information needs of the client. The statistical agency should begin by identifying the problem and stating it in general terms. Why has a survey been suggested? What are the underlying issues and in what context have they been raised?

In the RTA example, the City Council first instructed the RTA to 'take steps to facilitate the use of public transit by seniors'. In the initial statement, the RTA interpreted this as a need to modify existing service to 'facilitate the use of public transit by the city's seniors'. But what is the objective that must be directly addressed to help the RTA achieve that goal?

> The RTA requires information on the *transportation needs* of *seniors* and if and how they are currently *being met*.

The overall information needs of the survey have now been identified. It is important to return to this statement at every step of the survey to ensure that the survey objectives are met.

2.1.2   The Users and Uses of the Data

The next questions to ask are: Who are the main users of the data? What will the information be used for? The statistical agency needs to know who the users are because their input is very important during the planning phase of a survey. (The ultimate users of the data are not always the client, although this is often the case.) The uses of the data must be identified to specify more precisely the information needs. This is done in consultation with the client and data users. What types of policy issues are to be addressed? Will the survey information be used to describe a situation or to analyse relationships? What type of decisions might be made using the data and what might be the consequences? If possible, potential respondents

should also be consulted since they could identify issues and concerns that are important to them which could affect survey content.

According to the RTA, 'the RTA requires information on the transportation needs of seniors so that it can tailor its budget and improvements to the needs of seniors.' Specifically, the information may be used by transportation planners at the RTA to:
- purchase special buses;
- modify existing buses;
- add new routes;
- subsidise fares.

The information needs of the survey have now been identified, along with who will use the data and what it will be used for; this is particularly important. For example, suppose that the RTA expects to have to add new routes, then the RTA may want to ask seniors where they would like these routes. If the RTA expects to have to modify existing buses, then it may want to know what modifications seniors would prefer. If the RTA expects to have to purchase special buses, it may want to know what special buses seniors require. If the RTA is considering subsidising fares, it may want to ask seniors what they would consider to be an affordable fare. The results expected, therefore, and the consequences of the results determine the survey content.

2.1.3   Concepts and Operational Definitions

In order to identify the data required to meet the survey's objectives, the statistical agency needs clear and precise definitions. These definitions may specify exclusions, such as homeless individuals or individuals living in institutions, etc. To the extent possible, recognised standard definitions should be used. This will facilitate communication with the data users and respondents, as well as ensure consistency across surveys. The statistical agency may be required to develop some standard definitions, for example, for dwelling, household, family, etc.

In order to determine the operational definitions, there are three questions that should be asked: Who or What? Where? and When? One of the first concepts to be defined is the survey's target population. ***The target population is the population for which information is desired***. It is the collection of units that the client is interested in studying. Depending on the nature and the goal of the survey, these units usually will be individuals, households, schools, hospitals, farms, businesses, etc. Returning to the RTA example, the following questions should be asked when defining the survey's target population:

i.   Who or what is the client interested in?

Here, the statistical agency needs to consider the type of units that comprise the target population and the units' defining characteristics. For the RTA survey, it has been stated that the client is interested in the use and needs of public transit by seniors. Explicit definitions of *seniors*, *public transit* and *use* are required. Suppose that seniors are defined as persons aged 65 years or over. (The client should clarify with the RTA what the RTA's own definition of seniors is for the purposes of urban transportation.) There may be several forms of public transit: buses, trains, subways and special needs vehicles. Suppose that the client is only interested in buses. Another question is whether the client is only interested in seniors who currently use buses, or all seniors? The client may be interested in all seniors.

ii.   Where are the units of interest?

This refers to the geographical location of the units (i.e., seniors). The client may only be interested in the use of public buses operating in the city metropolitan area (as defined by a recent census, for example; again, a clear definition is required), or perhaps the area over which the RTA has jurisdiction (i.e., the area served by the existing network of public bus routes). So, the client must decide if it all seniors are part of the target population, or just those living in a particular region.

iii.   What is the reference period for the survey? (When?)

What time period do the data refer to? (When?) The answer appears to be 'now' since the RTA's statement refers to current needs. In practice, this could mean that seniors are asked about their use of public buses during a recent reference period (week, month, etc.). Should seniors be surveyed for more than one period or asked about several different reference periods?

An important consideration with respect to the reference period is seasonality. Certain activities are related to the time of the week, month or year. Therefore, conclusions that refer to a specific time frame may not be valid for other time frames. For example, if the RTA questionnaire asks seniors about their use of the transit system during the week, the survey results may not be valid for weekends.

In addition to the target population, many other concepts must be defined. The following are examples of three related concepts commonly used by household surveys at Statistics Canada:

> ***A dwelling is any set of living quarters that is structurally separate and has a private entrance outside the building or from a common hall or stairway inside the building***.

> ***A household is any person or group of persons living in a dwelling. A household may consist of any combination of: one person living alone, one or more families, a group of people who are not related but who share the same dwelling***.

> ***A family is a group of two or more persons who live in the same dwelling and who are related by blood, marriage (including common-law) or adoption. A person living alone or who is related to no one else in the dwelling where he or she lives is classified as an unattached individual***.

For more details on how to define the target and survey populations see **Chapter 3 - Introduction to Survey Design**.

2.1.4   Survey Content

A clear Statement of Objectives ensures that the survey content is appropriate and clearly defined. Having determined the overall information needs, the users and uses, and the operational definitions, the statistical agency next needs to know what specific topic areas are to be covered by the survey. This is often an iterative process. The process of specifying the survey content often leads to revelations about incompleteness in the information needs and uses, or conversely, to the revelation that some needs cannot be met due to operational or definitional reasons.

Returning to the RTA example, the information that is required at a fairly general level has been identified. Now the statistical agency needs to expand on this.

For seniors, the client may also wish to determine various characteristics such as:
- age;
- sex;
- disabilities;
- household income;
- geographic location (are seniors mainly living in small areas within the city, such as retirement homes, or are they spread out throughout the city?);
- dwelling type (e.g., retirement homes, apartments, houses);
- household composition (who are they living with?).

To determine transportation needs, the client may require information on:
- number of trips last week;
- frequency of travel (by time of day; weekday versus weekend);
- modes of transportation used;
- problems using public buses;
- amount of local travel.

A desire for information on trip characteristics may lead to questions about:
- the reason for the trips;
- the geographic origin and destination of the trips;
- limitations on travel;
- special aids or assistance needed;
- the number of trips cancelled due to lack of transport.

To determine whether or not needs are currently being met, the client may have to understand such issues as:
- accessibility (How many seniors own a car, bicycle, etc.?);
- use of public buses;
- amount of money spent on public buses;
- ways to improve service;
- ways to encourage seniors to use (or more frequently use) public buses.

Note that definitions are required for all concepts not already defined. For example, what is meant by a disability? What is a trip?

The specific topics to be covered determine the variables to be collected, the questionnaire design and even the sample design. These in turn affect the choice of data collection method, for example whether or not to use interviewers, and therefore the cost of the survey.

The statistical agency must cover all aspects of the information needs, but to avoid incurring unnecessary costs or imposing undue response burden on the survey population, it should eliminate all irrelevant items that do not directly relate back to the survey's objectives.

In a later step, this description of survey content must be transformed into questions and a questionnaire. For more details, see **Chapter 5 - Questionnaire Design**.

2.1.5   The Analysis Plan (Proposed Tabulations)

Once all of the items to be measured have been identified, the next task is to determine how much detail is required for each item and the format of the results. What measures, counts, indices, etc. are needed?

Are estimates for subpopulations required? The detailed plan of the way the data are to be analysed and presented is referred to as the analysis plan and, in addition to planned analyses, requires the creation of proposed tabulations. An analysis plan greatly facilitates the design of the questionnaire.

For example, with respect to the details of the final results, is it necessary to be able to distinguish between different age groups within seniors? Does the client need to distinguish between men and women, or between different types of transportation (bus, car, bicycle, etc.)? Should continuous or categorical data be used? For example, does the client need to know what a senior's exact income is, or is a range of incomes adequate? (If the client is interested in calculating averages, then exact income is more appropriate.)

Note that the analysis plan can involve going back to and refining the operational definitions and survey content. For the RTA example, here are some possibilities for the level of detail of the results, in increasing order of detail:

Household income:
-   household income ranges (e.g., less than $15,000; $15,000 to $29,999; $30,000 to $49,999; etc.);
-   the exact number representing total household income;
-   the exact income from each source (wages or salary, pensions, investments).

Disabilities:
-   a single question on whether the senior has a physical condition that limits his/her ability to take local trips;
-   a single question on each of several distinct disabilities;
-   a series of questions to be used to determine the presence, nature and severity of each disability.

Household composition:
-   senior lives alone / does not live alone;
-   number of people in the household;
-   categories of households (single, couple, two related adults other than couples, three or more related adults, etc.);
-   each adult's age and relationship to a reference person, in order to derive the exact household composition.

Number of trips last week:
-   ranges (e.g., 0-3, 4-6, etc.);
-   the exact number;
-   the exact number by day and time of day.

Frequency of travel:
-   the percentage of trips on weekdays or weekends;
-   the exact number of trips taken on each day of the week.

Modes of transportation used:
-   mode used most often during the reference period (e.g., last week);
-   all modes of transportation used (public and private);
-   number of trips on public buses only;
-   for each trip taken, the mode of transportation that was used.

Problems using public buses:
-   factor causing the most difficulty;

- all factors causing difficulty;
- a ranking of the factors according to difficulty caused;
- for each factor, a measure of how much difficulty it causes.

In the cases presented above, the first, least detailed, breakdown may be sufficient, or it may not contain enough detail to meet the client's needs for information. The last, most detailed breakdown may contain exactly the right amount of detail, or it may be excessively detailed, and in fact be too difficult to answer. While detailed information provides greater flexibility for analysis and may permit comparison with other information sources, the statistical agency should always try to ask for information that is detailed enough to meet the analysis needs, but no more, to avoid burdening respondents.

It is a good idea to prepare a preliminary set of proposed tabulations and other key desired outputs. Determining how the results are to be presented helps define the level of detail and indeed the whole scope of the survey. Without a clear analysis plan, it may be possible at the end of the survey to generate hundreds of analysis tables, but only a few may relate directly to the survey's objectives.

The proposed tabulations should specify each variable to be presented in a table and its categories. The purpose of this step is to create and retain mock-ups of those tables that will form the analysis. Specification at this level allows the statistical agency to begin drafting questions for the survey questionnaire.

For example, for the RTA survey, the population could be partitioned into two or more groups (e.g., to compare seniors with a disability to seniors without a disability).

Single item summaries (frequency distributions, means, medians, etc.) could be produced, such as:
- percentage of trips taken on each day of the week (Table 1);
- average number of trips taken on public buses;
- average amount of money spent on transportation last week;
- percentage of seniors by most frequent reason for trip.

Table 1: Trips Taken by Day of the Week

Day of Week	Number of Trips	% of Total Trips
Sunday		
Monday		
Tuesday		
Wednesday		
Thursday		
Friday		
Saturday		
Total		

Cross tabulations of possible interest could include:
- number of trips by mode of transportation (Table 2);
- number of buses taken by starting and ending points;
- distribution of reasons for not using public transportation by characteristic of person (e.g., disabled, etc.).

Other relationships that could be investigated include:
- average amount spent on transportation for each income group;
- median income of housebound seniors.

Table 2: Number of Trips by Mode of Transportation

Mode of Transportation	Number of Trips	% of Total Trips
Public transportation		
Bus		
Subway		
Other		
Private transportation		
Car/truck		
Bicycle		
Walk		
Other		
Total		

2.2   Constraints that Affect the Statement of Objectives

There are many requirements and constraints that can affect a survey's Statement of Objectives. One relates to the quality of the estimates. How precise should the survey results be? This refers to the magnitude of sampling error that is acceptable for the most important variables. Precise, detailed results often require very large samples, sometimes larger than the client can afford. As a result, the client may decide to relax the precision requirements or produce more aggregate, less detailed data.

Factors affecting precision, and therefore the sample size, include the following:
- the variability of the characteristic of interest in the population;
- the size of the population;
- the sample design and method of estimation;
- the response rate.

In addition, operational constraints influence precision. Sometimes, these are the most influential factors:
- How large a sample can the client afford?
- How much time is available for development work?
- How much time is available to conduct the entire survey?
- How quickly are the results required after collection?
- How many interviewers are needed? How many interviewers are available?
- How many computers are available? Are computer support staff available?

Precision is discussed in more detail in **Chapter 3 - Introduction to Survey Design**, **Chapter 6 - Sample Designs**, **Chapter 7 - Estimation** and **Chapter 8 - Sample Size Determination and Allocation**.

Other factors that impact the Statement of Objectives include:
- Can the required variables be measured with the available techniques?
- Will acquiring the desired results be too much of a burden on the respondents?
- Could confidentiality of the respondent be compromised given the level of detail of the disseminated results?
- Will the survey have any negative consequences on the reputation of the survey agency?

These considerations are all aspects of planning a survey. See **Chapter 13 - Survey Planning and Management** for more details.

2.3   Summary

Without a clear idea of the information needs, the statistical agency risks tackling the wrong problem, producing incomplete or irrelevant results and wasting time and resources; the survey's activities could simply annoy or inconvenience many respondents, without producing any useful information. For these reasons, the survey's objectives must be clearly defined during the planning phase.

The following list summarises the most important questions and items to be considered when developing a survey's objectives and information needs:
- What are the overall information needs of the survey?
- Who will use the data and how will they use it?
- What definitions will be used by the survey?
- What are the specific topic areas to be covered by the survey?
- Has an analysis plan with proposed tabulations been prepared?
- What is the required precision of the estimates?
- What are the operational constraints?

Formulation of the survey's objectives may continue to be refined during the design and development of, particularly, the questionnaire (see **Chapter 5 - Questionnaire Design)**.

Bibliography

Brackstone, G.J. 1991. Shaping Statistical Services to Satisfy User Needs. *Statistical Journal of the United Nations,* ECE 8: 243-257.

Brackstone, G.J. 1993. Data Relevance: Keeping Pace with User Needs. *Journal of Official Statistics,* 9: 49-56.

Fink, A. 1995. *The Survey Kit*. Sage Publications, California.

Fowler, F.J. 1984. *Survey Research Methods*. 1. Sage Publications, California.

Kish, L. 1965. *Survey Sampling*. John Wiley and Sons, New York.

Levy, P. and S. Lemeshow. 1991. *Sampling of Populations*. John Wiley and Sons, New York.

Moser C.A. and G. Kalton. 1971. *Survey Methods in Social Investigation*. Heinemann Educational Books Limited, London.

Satin, A. and W. Shastry. 1993. *Survey Sampling: A Non-Mathematical Guide – Second Edition*, Statistics Canada. 12-602E.

Statistics Canada. 1998. Policy on Standards. *Policy Manual*. 2.10.

Chapter 3 - Introduction to Survey Design

3.0   Introduction

Once the survey's objectives have been clearly defined, the survey design needs to be considered. Some key questions here are: should a sample survey or a census be conducted? Can the population that the client is interested in be surveyed? What might be the principal sources of error in the survey and what impact could these errors have on the results?

The decision of whether to conduct a census or a sample survey is based on numerous factors including: the budget and resources available, the size of the population and subpopulations of interest, and the timeliness of the survey results.

The survey frame ultimately defines the population to be surveyed, which may be different from the population targeted by the client. Before deciding upon a particular frame, the quality of various potential frames should be assessed, in particular to determine which one best covers the target population.

A survey is subject to two types of errors: sampling error and nonsampling errors. Sampling error is present only in sample surveys. Nonsampling errors are present in both sample surveys and censuses and may arise for a number of reasons: the frame may be incomplete, some respondents may not accurately report data, data may be missing for some respondents, etc.

The purpose of this chapter is to introduce these key survey design considerations. For more information on how to design a sample survey, see **Chapter 6 - Sample Designs**.

3.1   Census versus Sample Surveys

There are two kinds of surveys – census and sample surveys. The difference lies in the fact that *a census collects information from all units of the population*, while *a sample survey collects information from only a fraction (typically a very small fraction) of units of the population*. In both cases, the information collected is used to calculate statistics for the population as a whole and, usually, for subgroups of the population.

The main reason for selecting a sample survey over a census is that sample surveys often provide a faster and more economical way of obtaining information of sufficient quality for the client's needs. Since a sample survey is a smaller scale operation than a census, it is also easier to control and monitor. However, in some cases, a census may be preferable or necessary. (For a formal definition of quality, see **Appendix B - Quality Control and Quality Assurance**).

The following list covers the most important factors when deciding between a census and a sample survey:

i.   Survey errors

There are two types of survey errors – sampling error and nonsampling errors.

Sampling error is intrinsic to all sample surveys. *Sampling error arises from estimating a population characteristic by measuring only a portion of the population rather than the entire population*.

Sampling error is usually measured by estimating the extent to which sample estimates, based upon all possible samples of the same size and using the same method of sampling (sample design), differ from one another. The magnitude of the sampling error can be controlled by the sample size (it decreases as the sample size increases), the sample design and the method of estimation.

A census has no sampling error since all members of the population are enumerated. It might seem that results from a census should be more accurate than results from a sample survey. However, all surveys are subject to ***nonsampling errors – all errors that are unrelated to sampling,*** censuses even more so than sample surveys, because sample surveys can often afford to allocate more resources to reducing nonsampling errors. These errors can lead to biased survey results. Examples of nonsampling errors are measurement errors and processing errors.

See Section 3.4 for more details on sources of survey errors. See **Chapter 7 - Estimation** and **Chapter 11 - Analysis of Survey Data** for details on how to calculate sampling error.

ii.   Cost

Since all members of the population are surveyed, a census costs more than a sample survey (data collection is one of the largest costs of a survey). For large populations, accurate results can usually be obtained from relatively small samples. For example, each month approximately 130,000 residents are surveyed by the Canadian Labour Force Survey. With the Canadian population at approximately 30 million, this corresponds to a sample size of less than 0.5% of the population. Conducting a census would be considerably more expensive.

iii.   Timeliness

Often the data must be gathered, processed and results disseminated within a relatively short time frame. Since a census captures data for the entire population, considerably more time may be required to carry out these operations than for a sample survey.

iv.   Size of the population

If the population is small, a census may be preferable. This is because in order to produce estimates with small sampling error it may be necessary to sample a large fraction of the population. In such cases, for minimal additional cost, data can be available for the entire population instead of just a portion of it. By contrast, for large populations, a census is very expensive, so a sample survey is usually preferable.

For more details on factors affecting sample size, see **Chapter 8 - Sample Size Determination and Allocation**.

v.   Small area estimation

Related to the previous point, when survey estimates are required for small geographic areas, or areas with small populations, a census may be preferable. For example, a national survey may be required to produce statistics for every city in the country. A sample survey could provide national statistics with small sampling error, but depending on the sample size, there may be too few respondents to produce estimates with small sampling error for all cities. Since a census surveys everyone and has no sampling error, it can provide estimates for all possible subgroups in the population.

It is not always necessary to conduct either a census *or* a sample survey. Sometimes the two are combined. For small area estimates, for example, a sample survey could be conducted in the larger cities and a census in the smaller cities.

vi.   Prevalence of attributes

If the survey is to estimate the proportion of the population with a certain characteristic, then if the characteristic is common, a sample survey should be sufficient. But if the characteristic is rare, a census may be necessary. This is related to the size of the subpopulation with the characteristic.

For example, suppose that the client wishes to determine the percentage of senior citizens in the population and believes this percentage to be around 15%. A sample survey should be able to estimate this percentage with small sampling error. However, for rarer attributes, occurring in less than 1% of the population, a census might be more appropriate. (This assumes that the survey frame cannot identify such individuals in advance.)

It is possible, of course, that prior to conducting the survey, absolutely nothing is known about the prevalence of the attribute in question. In this case it is advisable to conduct a preliminary study – a feasibility study or pilot survey.

vii.   Specialised needs

In some instances, the information required from a survey cannot be directly asked of a respondent, or may be burdensome for the respondent to provide. For example, a health survey may require data on blood pressure, blood type, and the fitness level of respondents, which can only be accurately measured by a trained health professional. If the nature of the data collected requires highly trained personnel or expensive measuring equipment or places a lot of burden on the respondents, it may be impossible to conduct a census. In some specific fields (quality control in a manufacturing process, for example), the destructive nature of certain tests may dictate that a sample survey is the only viable option.

viii.   Other factors

There are other reasons to conduct a census. One is to create a survey frame. For example, many countries conduct a census of the population every five or ten years. The data generated by such a census can be used as a survey frame for subsequent sample surveys that use the same population.

Another reason to conduct a census is to obtain benchmark information. Such benchmark information may be in the form of known counts of the population, for example, the number of men and women in the population. This information can be used to improve the estimates from sample surveys (see **Chapter 7 - Estimation)**.

3.2   Target and Survey Populations

Chapter 2 - Formulation of the Statement of Objectives presented how to define concepts and operational definitions. It stated that one of the first concepts to be defined is the *target population – the population for which information is desired*.

The following factors are essential in defining the target population and operational definitions in general:

- the type of units that comprise the population and the defining characteristics of those units (Who or What?);
- the geographical location of the units (Where?);
- the reference (time) period under consideration (When?).

In order to define the target population, the statistical agency begins with a conceptual population for which no actual list may exist. For example, the conceptual population may be all farmers. In order to define the target population, 'farmers' must be defined. Is a person with a small backyard garden a farmer? What is the distinction between a farmer and a casual gardener? What if the farm operator did not sell any of his products? The target population might ultimately be defined as all farmers in Canada with revenues above a certain amount in a given reference year.

The survey population is the population that is actually covered by the survey. It may not be the same as the target population, though, ideally, the two populations should be very similar. It is important to note that conclusions based on the survey results apply only to the survey population. For this reason, the survey population should be clearly defined in the survey documentation.

Various reasons can explain the differences between the two populations. For example, the difficulty and high cost of collecting data in isolated regions may lead to the decision to exclude these units from the survey population. Similarly, members of the target population who are living abroad or are institutionalised may not be part of the survey population if they are too difficult or costly to survey.

The following examples illustrate the differences that can occur between the target population and the survey population.

Example 3.1:

Survey of Household Income and Expenditures

Target population: Entire resident population of Canada on April 30, 1997.

Survey population: Population of Canada on April 30, 1997, excluding people living in institutions or with no fixed address.

For this survey, it was decided that it would be too difficult to survey people with no fixed address (it has been attempted with little success). In addition, institutionalised people may not be mentally or physically able to respond to questions. Many of these people may not be willing to respond, and even if they were willing often the questions asked are not applicable to their situation which could require the development of modified survey instruments. Also, special arrangements would be necessary to gain access to selected institutions.

3.3   Survey Frame

Once the client and statistical agency are satisfied with the definition of the target population, some means of accessing the units of the population is required. ***The survey frame*** (also called the sampling frame when applied to sample surveys) ***provides the means of identifying and contacting the units of the survey population***. This frame ultimately defines the survey population: if the survey frame does not include unlisted telephone numbers, for example, then neither does the survey population.

Example 3.2:

Census of Manufacturing

Target population: All manufacturing establishments operating in Canada in April 2002.

Survey population: All manufacturing establishments with employees operating in Canada in April 2002.

Manufacturing establishments may be owner operated, with or without employees. In this example, the only frame available is for establishments with employees, so those without employees are excluded from the survey population.

(Note that often the target population is redefined to correspond to the population that can be practically surveyed. This is the approach used throughout the rest of this manual: the target population refers to the population that the survey expects to cover, given practical and operational constraints and the survey frame used.)

In addition to being the vehicle for accessing the survey population units, another reason why a frame is required is that, for sample surveys, the statistical agency must be able to calculate the ***inclusion probability*** that a population unit is in the sample. If probability sampling is used, these probabilities make it possible to draw conclusions about the survey population – which is the purpose of conducting the survey. (See **Chapter 6 - Sample Designs** for a definition of probability sampling.)

Note that reference has been made to units in a survey. Three different types of units exist:
-   the *sampling unit* (the unit being sampled);
-   the *unit of reference* (the unit about which information is provided);
-   the *reporting unit* (the unit that provides the information).

For some surveys, these are all the same; often they are not. For example, for a survey of children, it may not be practical for the unit of reference – a child – to be the reporting unit. A common sample design for household surveys is to use a frame that lists households in the survey population (such a frame may provide the best coverage of all children in the target population). A survey using such a frame would sample households and ask a parent to report for the unit of analysis, the child.

The survey frame should include some or all of the following items:

i.   Identification data

Identification data are the items on the frame that uniquely identify each sampling unit, for example: name, exact address, a unique identification number.

ii.   Contact data

Contact data are the items required to locate the sampling units during collection, for example: mailing address or telephone number.

iii.   Classification data

Classification data are useful for sample selection and possibly for estimation. For example, if people living in apartments are to be surveyed differently than people living in houses, then the frame must

classify different types of dwellings (i.e. apartments, single homes, etc.). Classification data may also include a size measure to be used in sampling, for example the number of employees working at a business or the number of acres owned by a farm. Other examples of classification data are: geographical classification (e.g. province, census division or census subdivision), standard occupational classification (SOC) or standard industrial classification (e.g. SIC or the North American Industrial Classification System, NAICS).

iv.   Maintenance data

Maintenance data are required if the survey is to be repeated at another time, for example: dates of additions or changes to data on the frame.

v.   Linkage data

Linkage data are used to link the units on the survey frame to a more up-to-date source of data, for example, to update the survey frame.

In summary, the survey frame is a set of information, which serves as a means of access to select units from the survey population. As a minimum, identification and contact data are necessary to conduct the survey. However, classification, maintenance and linkage data are also desirable. Apart from being a sampling tool, it will be shown in subsequent chapters that data on the frame can be used to edit and impute missing or inconsistent data and to improve sampling and estimation.

Details of sample designs are covered in **Chapter 6 - Sample Designs**. Estimation is addressed in **Chapter 7 - Estimation**. Editing and imputation are covered in **Chapter 10 - Processing**.

3.3.1   Types of Frames

There are two main categories of frames: list and area frames. When no one frame is adequate, multiple frames may be used.

3.3.1.1 List Frame

A list frame can be defined as a conceptual list or a physical list of all units in the survey population. A conceptual list frame is often based on a population that comes into existence only when the survey is being conducted. An example of a conceptual list frame is a list of all vehicles that enter the parking lot of a shopping centre between 9:00 a.m. and 8:00 p.m. on any given day.

Physical list frames – actual lists of population units – can be obtained from different sources. Lists are kept by various organisations and levels of government for administrative purposes. Such administrative data are often the most efficient sources of frame maintenance data. Examples of list frames are:
- Vital statistics register (e.g., a list of all births and or deaths in the population);
- Business register (e.g., a list of all businesses in operation);
- Address register (e.g., a list of households with civic addresses);
- Telephone directory (i.e., a list of all households with published telephone numbers);
- Customer or client lists (i.e., a list of all customers or clients of a business);
- Membership lists (i.e., a list of all members of an organisation).

When using administrative data to build a list frame, the following factors should be considered:

i.   Cost

Administrative sources often provide an inexpensive starting point for constructing the frame. They are also a source of information for updating the frame.

ii.   Coverage

The administrative source should adequately cover the target population.

iii.   Up-to-date

It is important to consider how up-to-date the administrative information is. The time it takes to process the updates and the delay before they are available to the statistical agency should be considered as they might be the deciding criteria as to whether or not a specific administrative source should be used.

iv.   Definitions

The definitions used by the administrative source should correspond as closely as possible to the concepts of the survey. For example, the definition of a dwelling or a business may be different from that used by the survey.

v.   Quality

The quality of the data provided by the administrative source should meet the overall quality standards of the survey. (For example, if the administrative data have a high edit failure rate, the statistical agency may decide that the data are of insufficient quality. For more details on editing, see **Chapter 10 - Processing**)

vi.   Stability of source information

When administrative sources are used to construct a frame, the set of variables provided by the source should be as stable as possible through time. Changes in concepts, classifications, or in content at the source can lead to serious problems in frame maintenance.

vii.   Legal and formal relationships

Ideally, there should be a relationship (for example, a signed contract) between the statistical agency and the source providing the administrative information. This may be important to ensure confidentiality of the data. It is also important to ensure an open dialogue and to foster co-operation between the two partners.

viii.   Documentation

The data files should be documented with respect to the variables they contain and their layout. This is particularly important if files are held in different jurisdictions.

ix.   Accessibility/Ease of use

Is the information available electronically? How is the information organized? Do different lists have to be combined before they can be used?

For more information on the use of administrative data, see **Appendix A - Administrative Data**.

3.3.1.2 Area Frame

An area frame is a special kind of list frame where the units on the frame are geographical areas. The survey population is located within these geographic areas. Area frames may be used either when the survey is geographic in nature (such as measuring wildlife populations by counting the number of animals per square kilometre) or when an adequate list frame is unavailable, in which case the area frame can be used as a vehicle for creating a list frame. An inadequate list frame is often a problem. This is because populations can change over time – units are born, die, move or change name, composition or character – so any list can become out of date. Geographic boundaries, however, are more stable, often making it easier to maintain an area frame.

Area frames are usually made up of a hierarchy of geographical units. Frame units at one level can be subdivided to form the units at the next level. Large geographic areas like provinces may be composed of districts or municipalities with each of these further divided into smaller areas, such as city blocks. In the smallest sampled geographical areas, the population may be listed in order to sample units within this area.

Sampling from an area frame is often performed in several stages. For example, suppose that a survey requires that dwellings in a particular city be sampled, but there is no up-to-date list. An area frame could be used to create an up-to-date list of dwellings as follows: at the first stage of sampling, geographic areas are sampled, for example, city blocks. Then, for each selected city block, a list frame is built by listing all the dwellings in the sampled city blocks. At the second stage of sampling, a sample of dwellings is then selected. One benefit of such an approach is that it keeps the cost of creating the survey frame within reasonable bounds and it concentrates the sample in a limited number of geographic areas, making it a cost-effective way of carrying out personal interview surveys.

It is important that the geographical units to be sampled on an area frame be uniquely identifiable on a map and that their boundaries be easily identifiable by the interviewers. For this reason, city blocks, main roads and rivers are often used to delineate the boundaries of geographical units on an area frame.

Sampling from area frames is discussed in more detail in **Chapter 6 - Sample Designs**. Listing for an area frame is discussed in **Chapter 9 - Data Collection Operations**.

3.3.1.3 Multiple Frame

A multiple frame is a combination of two or more frames, (a combination of list and area frames or of two or more list frames).

Multiple frames are typically used when no single frame can provide the required coverage of the target population. For example, the Canadian Community Health Survey (CCHS) uses the Labour Force Survey's (LFS) area frame plus a random digit dialling (RDD) frame.

The main advantage of a multiple frame is that it can provide better coverage of the target population. However, one of its main disadvantages is that it can result in the same sampling unit appearing several times on the frame. Ideally, a unit should only appear on one of the frames used to construct the multiple frame. In practice, though, a unit often appears on more than one of these frames. There are several ways to handle overlap between component frames:
- remove overlap during frame creation;
- resolve the problem during sample selection (or in the field);
- correct the problem at estimation.

For more information on this advanced subject, see Bankier (1986). For more information on RDD, see **Chapter 4 - Data Collection Methods**.

3.3.2 Frame Defects

Several potential frame defects are described below:

i. Undercoverage

Undercoverage results from exclusions from the frame of some units that are part of the target population. Often, this is due to a time lag in processing the data that were used to construct the frame. Between the time the frame is completed and the survey is conducted, some new units are 'born' into the population. Any unit that joins the target population after the frame has been completed has no chance of being selected by the survey. This leads to underestimation of the size of the target population and may bias the estimates. Procedures are required to measure the extent of undercoverage and, if necessary, correct for it.

ii. Overcoverage

Overcoverage results from inclusions on the frame of some units that are not part of the target population. This is often due to a time lag in the processing of frame data. Between the time the frame is completed and the survey is conducted, some units in the population 'die' (a unit has died if it is no longer part of the target population). Any unit that is on the frame – including these out-of-scope dead units – has a chance of being selected by the survey. Unless such units are properly classified on the frame as out-of-scope, the sampling strategy may be less statistically efficient and the results may be biased.

iii. Duplication

Duplication occurs when the same unit appears on the frame more than once. For example, on a business frame, the same business could be listed once under its legal name and once under its trading name. This is often a problem with multiple frames. Duplication tends to result in an overestimation of the size of the target population and may cause some bias in the estimates. Often, duplicate units are only detected during the collection stage of a survey.

iv. Misclassification

Misclassification errors are incorrect values for variables on the frame. Examples might be a man who is incorrectly classified as a woman, or a retail business that is classified as a wholesaler. This can result in inefficient sampling. It can also lead to undercoverage (or overcoverage) since if, for example, only retailers are sampled, then those misclassified as wholesalers will be missed. Errors in identification or contact data can lead to difficulties tracing the respondent during collection.

For information on statistical efficiency and sample designs, see **Chapter 6 - Sample Designs**.

3.3.3 Qualities of a Good Frame

What constitutes a good frame? The quality of a frame should be assessed based on four criteria:

i.   Relevance

Relevance should be measured as the extent to which the frame corresponds and permits accessibility to the target population. The more it differs from the target population, the larger the difference between the survey and target populations. The degree to which it allows the comparison of data results across different survey programs should also be evaluated. Also, the utility of the frame for other surveys covering the same target population is a critical measure of its relevance.

ii.   Accuracy

Accuracy should be assessed with respect to different characteristics. First, coverage errors should be evaluated (undercoverage, overcoverage and duplication). What is the extent of missing, out-of-scope or duplicate units on the frame? Second, classification errors should be investigated. Are all units classified? If so, are they properly classified? Close attention should be paid to the contact data. Is it complete? If so, is it correct and accurate? The impact of the accuracy of the data will be felt during the collection and the processing stages of the survey. Accuracy of the data on the frame greatly affects the quality of the survey's output.

iii.   Timeliness

Timeliness should be measured in terms of how up-to-date the frame is with respect to the survey's reference period. If the information on the frame is substantially out-of-date (due to the source of the data used to create the frame, or due to the length of time necessary to build the frame), then some measures have to be implemented in order to improve timeliness.

iv.   Cost

Cost can be measured in different ways. First, the total costs incurred to obtain and construct the frame should be determined. Second, the cost of the frame should be compared to the total survey cost. Third, the cost of maintaining the frame should be compared to the total survey program budget. To improve their cost effectiveness, frames are often used by several surveys.

In addition to these important criteria, the following features are also desirable:

a.   Standardised concepts and procedures

The information present on the frame should use standardised concepts, definitions, procedures and classifications that are understood by the client and the data user. This is especially important if these concepts, definitions, procedures and classifications are used by other surveys. The frame should also permit stratification that is efficient (statistically and in terms of the cost of collection).

b.   The frame should be easy to update using administrative and survey sources.

This is a way of ensuring that it remains up-to-date and its coverage complete.

c.   The frame should be easy to use.

Few frames meet all of the above requirements. The goal is to pick the frame that best meets these criteria. It is important to realise that the survey frame has a direct impact on many steps of the survey. For instance, it affects the method of data collection. If the frame does not provide telephone numbers,

then telephone interviews cannot be conducted. It also affects the method of sampling. And, of course, the quality of the frame has an impact on the final survey results.

3.3.4   Tips and Guidelines

In order to choose and make the best use of the frame, the following tips and guidelines are useful:

i.   When deciding which frame to use (if several are available), assess different possible frames at the planning stage of the survey for their suitability and quality.

ii.   Avoid using multiple frames, whenever possible. However, when no single existing frame is adequate, consider a multiple frame.

iii.   Use the same frame for surveys with the same target population or subset of the target population. This avoids inconsistencies across surveys and reduces the costs associated with frame maintenance and evaluation.

iv.   Incorporate procedures to eliminate duplication and to update for births, deaths, out-of-scope units and changes in any other frame information in order to improve and/or maintain the level of quality of the frame.

v.   Incorporate frame updates in the timeliest manner possible.

vi.   Emphasise the importance of coverage, and implement effective quality assurance procedures on frame-related activities. This helps minimise frame errors.

vii.   Monitor the quality of the frame coverage periodically by matching to alternate sources and/or by verifying information during data collection.

viii.   Determine and monitor coverage of administrative sources through contact with the source manager, in particular when these sources are outside the control of the survey.

ix.   Include descriptions of the target and survey population, frame and coverage in the survey documentation.

x.   Implement map checks for area frames, through field checks or by using other map sources, to ensure clear and non-overlapping delineation of the geographic areas used in the sampling design.

3.4   Survey Errors

In a perfect world, it would be possible to select a perfect sample and design a perfect questionnaire, it would also be possible to have perfect interviewers gather perfect information from perfect respondents. And no mistakes would be made recording the information or converting it into a form that could be processed by a computer.

Obviously, this is not a perfect world and even the most straightforward survey encounters problems. These problems, if not anticipated and controlled, can introduce errors to the point of rendering survey results useless. Therefore, every effort should be made in the planning, design and development phases of

the survey to anticipate survey errors and to take steps to prevent them. And during the implementation phase, quality control techniques should be used to control and minimise the impact of survey errors. For a discussion of quality control and quality assurance, see **Appendix B - Quality Control and Quality Assurance**.

Survey errors come from a variety of different sources. They can be classified into two main categories: *sampling error* and *nonsampling error*.

3.4.1   Sampling Error

Sampling error was defined earlier as the error that results from estimating a population characteristic by measuring a portion of the population rather than the entire population. Since all sample surveys are subject to sampling error, the statistical agency must give some indication of the extent of that error to the potential users of the survey data. For probability sample surveys, methods exist to calculate sampling error. These methods derive directly from the sample design and method of estimation used by the survey.

The most commonly used measure to quantify sampling error is sampling variance. ***Sampling variance measures the extent to which the estimate of a characteristic from different possible samples of the same size and the same design differ from one another***. For sample designs that use probability sampling, the magnitude of an estimate's sampling variance can be estimated on the basis of observed differences of the characteristic among sampled units (i.e. based on differences observed in the one sample obtained). The estimated sampling variance thus depends on which sample was selected and varies from sample to sample. The key issue is the magnitude of an estimate's estimated sampling variance relative to the size of the survey estimate: if the variance is relatively large, then the estimate has poor precision and is unreliable.

Factors affecting the magnitude of the sampling variance include:

i.   The variability of the characteristic of interest in the population

The more variable the characteristic in the population, the larger the sampling variance.

ii.   The size of the population

In general, the size of the population only has an impact on the sampling variance for small to moderate sized populations.

iii.   The response rate

The sampling variance increases as the sample size decreases. Since nonrespondents effectively decrease the size of the sample, nonresponse increases the sampling variance. Nonresponse can also lead to bias (see 3.4.2.3).

iv.   The sample design and method of estimation

Some sample designs are more efficient than others in the sense that, for the same sample size and method of estimation, one design can lead to smaller sampling variance than another.

For more details on how to estimate sampling variance, see **Chapter 7 - Estimation, Chapter 8 - Sample Size Determination and Allocation** and **Chapter 11 - Analysis of Survey Data**. For a

discussion of bias and mean square error, see **Chapter 11 - Analysis of Survey Data**. For details on sample designs and probability sampling, see **Chapter 6 - Sample Designs**.

3.4.2 Nonsampling Errors

Aside from sampling error, a survey is also subject to a wide variety of errors not related to the process of sampling. These errors are commonly called nonsampling errors. ***Nonsampling errors can be defined as errors arising during the course of virtually all survey activities, apart from sampling***. They are present in both sample surveys and censuses (unlike sampling error, which is only present in sample surveys). Nonsampling errors can be classified into two groups:

i.   Random errors

Random errors are errors whose effects approximately cancel out if a large enough sample is used, leading to increased variability.

ii.   Systematic errors

Systematic errors are errors that tend to go in the same direction and thus accumulate over the entire sample, leading to a bias in the final results. Unlike sampling variance or random errors, this bias is not reduced by increasing the size of the sample. Systematic errors are the principal cause of concern in terms of a survey's data quality. Unfortunately, nonsampling errors are often extremely difficult and sometimes impossible to measure.

Nonsampling errors arise primarily from the following sources:
- coverage;
- measurement;
- nonresponse;
- processing.

3.4.2.1 Coverage Error

Coverage errors consist of omissions, erroneous inclusions, duplications and misclassifications of units in the survey frame. Since they affect every estimate produced by the survey, they are one of the most important types of error; in the case of a census they may be the main source of error. Coverage errors may cause a bias in the estimates and the effect can vary for different sub-groups of the population. These errors tend to be systematic and are usually due to undercoverage, which is why statistical agencies try to reduce their incidence as much as possible.

3.4.2.2 Measurement Error

Measurement error is the difference between the recorded response to a question and the 'true' value. It can be caused by the respondent, the interviewer, the questionnaire, the data collection method or the measuring tool.

One of the main causes of measurement error is misunderstanding on the part of the respondent or interviewer. Misunderstanding may result from:
- the use of technical jargon;

-    the lack of clarity of the concepts (i.e., use of non-standard concepts);
-    poorly worded questions;
-    inadequate interviewer training;
-    false information given (i.e., recall error, or lack of ready sources of information);
-    a language barrier;
-    poor translation (when several languages are used).

The method of data collection can also affect measurement error. For example, interviewer-assisted methods (using well-trained interviewers) can result in smaller measurement error than self-enumeration methods, where the respondent has no assistance in completing the questionnaire.

In direct measurement surveys, the interviewer collects data through observation or by taking measurements (e.g. pricing surveys). Here, measurement error may be due to the interviewer or the measurement tool. For example, in a survey of people's weight, if the measuring scale is not properly calibrated, the weights will not be correctly measured.

If the measurement errors are scattered randomly about the true value, this will affect the precision of the survey's estimates: as the variability increases, the precision decreases. If the measurement errors are systematically skewed to reflect certain values or categories, a bias will be introduced and the survey estimates will be misleading. For example, systematic error would occur if an interviewer were instructed to measure the height of school children and took these measurements while the children had their shoes on, in which case all heights would be systematically overestimated.

Note that measurement error is sometimes referred to as response error and the terms are often used interchangeably. Response error is discussed in detail in **Chapter 5 - Questionnaire Design**. Methods of data collection are covered in **Chapter 4 - Data Collection Methods**.

3.4.2.3 Nonresponse Error

There are two types of nonresponse: item (or partial) nonresponse and total nonresponse. ***Item nonresponse occurs when information is provided for only some items***, such as when the respondent responds to only part of the questionnaire. ***Total nonresponse occurs when all or almost all data for a sampling unit are missing***.

Nonresponse can create several problems in a survey. The main problem is that nonrespondents often have different characteristics from respondents, which can result in biased survey estimates if nonresponse is not corrected for properly. For example, in a literacy survey, if most nonrespondents are illiterate, this could bias the survey results. If the nonresponse rate is high, bias can be so severe as to invalidate the survey results. The second problem with total nonresponse is that it reduces the effective size of the sample, since fewer units than expected answered the survey. As a result, the sampling variance increases and the precision of the estimates decreases. If the response rate can be predicted in advance, the initial sample size should be inflated accordingly. While increasing the sample size reduces the sampling variance and therefore corrects for nonresponse that is randomly distributed, it does not reduce any bias introduced by systematic nonresponse.

Total nonresponse may occur for reasons such as no one being at home, or a refusal or the inability of the selected person to participate in the survey. A poor explanation as to the purpose of the survey or its intended use can also result in nonresponse. Poor or out-of-date frame data is another factor: the identification data of the survey unit might be inadequate to locate it. Also, sometimes a particular unit is selected for many different surveys or for a repeated survey, and over time refuses to answer the surveys

due to response burden. Finally, if the respondent data is considered to be unusable, it may be treated as nonresponse.

Item nonresponse may occur when the respondent does not know the answer to a question, refuses to answer a question, forgets to answer or follows the wrong flow through the questionnaire. Sometimes the respondent cannot provide the answer due to an illness or language difficulties. A poorly designed questionnaire can also lead to item nonresponse. The concepts presented to the respondent on the questionnaire or during the interview might be difficult to understand or be poorly defined. The interview might be too long or contain an illogical flow of questions. As a result, respondents may get discouraged and stop answering before the end of the interview or they might simply follow the wrong flow of questions.

Interviewers can also contribute to total or item nonresponse. Poor interviewing techniques prevent some interviewers from establishing a good rapport with the respondent who might as a result refuse to participate or, if they agree to participate, quickly lose interest in the survey. Some interviewers introduce item nonresponse errors because they do not follow instructions or do not read the questions as worded.

Finally, data collection procedures can be a source of nonresponse. Nonresponse is often followed-up by interviewers in order to obtain some responses (e.g. convert a refusal). Inadequate follow-up of nonrespondents, or follow-up at the wrong time can prevent nonresponse from being corrected. Data lost from a computer file or a lost questionnaire can also result in 'nonresponse' errors. (Lost data, even if the actual number of cases is small, is a major source of concern because of the potential infringement of the confidentiality of respondent data.)

For the treatment of total nonresponse, see **Chapter 7 - Estimation**. For the treatment of item nonresponse see **Chapter 10 - Processing**. For details questionnaire design, see **Chapter 5 - Questionnaire Design**. For details on field procedures, see **Chapter 9 - Data Collection Operations**.

3.4.2.4 Processing Error

Processing transforms survey responses obtained during collection into a form that is suitable for tabulation and data analysis. It includes all data handling activities after collection and prior to estimation. Since it is a mixture of automated and manual activities, it is time-consuming, resource-intensive and potentially a source of errors. For example, processing errors can occur during data coding, data capture, editing or imputation. Like all other errors, they can be random in nature, and inflate the variance of the survey's estimates, or systematic, and introduce bias.

Coding is the process of assigning a numerical value to responses to facilitate data capture and processing in general. Coding entails either assigning a code (e.g. occupation code) to a given response or comparing the response to a set of codes and selecting the one that best describes the response.

For closed questions (questions with pre-determined response categories), codes are often assigned before interviewing takes place. For open questions (where the respondent provides the answer in his or her own words), coding may be either manual or automated. The quality of the coding depends on the completeness and quality of the response to the open question, and the way in which the answer is coded. Manual coding of open questions requires interpretation and judgement and hence is subject to error. Two different coders could code the same answer differently. Inexperienced and poorly trained coders are particularly prone to making coding errors. In an automated coding operation, errors can result from an error in the program or because the program may not properly take into account all information that is

available. If the coding is programmed and automatically performed, an error in the program will systematically be repeated and will introduce a bias (e.g. misclassification of occupation).

Data capture is the transformation of responses into a machine-readable format. Data capture errors result when the data are not entered into the computer exactly as they appear on the questionnaire. This can be caused by the complexity of alphanumeric data and by the lack of clarity in the answer provided. The physical layout of the questionnaire itself or the coding documents can cause data capture errors. The method of data capture may also result in errors (data capture may be a manual operation or it may be automated, for example, using an optical scanner).

Editing is the application of checks to identify missing, invalid or inconsistent entries that point to data records that are potentially in error. Imputation is a process used to determine and assign replacement values to resolve problems of missing, invalid or inconsistent data. Errors arising from editing and imputation often occur together since these two processes are very closely linked.

Editing and imputation errors can be caused by the poor quality of the original data or by its complex structure. When the editing and imputation processes are automated, errors can also be the result of faulty programs that were insufficiently tested. The choice of an inappropriate imputation method can introduce bias. Errors can also result from incorrectly changing data that were found to be in error, or by erroneously changing correct data.

Processing errors are often monitored and controlled using quality control techniques. For more details see **Appendix B - Quality Control and Quality Assurance**. For more detail on processing activities, see **Chapter 10 - Processing**.

3.5   Summary

This chapter presented some key points to consider when planning the design of a survey. The distinction between a survey and a census was explained as were the advantages and disadvantages of both. Next, the difference between the target population and the survey population was presented. A section on survey frames presented different types of frames that can be used in a survey, the qualities of a good frame as well as defects often encountered and ways to deal with them. Finally, the different types and sources of errors in a survey were explained. Sampling error was briefly discussed (this will be covered in more detail in subsequent chapters) while emphasis was placed on nonsampling errors: coverage error, measurement error, nonresponse error and processing error.

How to plan and manage a survey in general, including the stages of survey planning, will be presented in **Chapter 13 - Survey Planning and Management**. How to design how the sample should be selected from the population is presented in **Chapter 6 - Sample Designs.**

Bibliography

Bankier, M. 1986. Estimators Based on Several Stratified Samples with Applications to Multiple Frame Surveys. *Journal of the American Statistical Association,* 81-396.

Biemer, P.P., R.M. Groves, L.E. Lyberg, N.A. Mathiowetz and S. Sudman, eds. 1991. *Measurement Errors in Surveys*. John Wiley and Sons, New York.

Cialdini, R., M. Couper and R.M. Groves. 1992. Understanding the Decision to Participate in a Survey. *Public Opinion Quarterly,* 56: 475-495.

Cox, B.G., D.A. Binder, B.N. Chinnappa, A. Christianson, M.J. Colledge, P.S. Kott, eds. 1995. *Business Survey Methods.* John Wiley and Sons, New York.

Food and Agriculture Organization of the United Nations (FAO). 1996. *Multiple Frame Agriculture Surveys. Volume 1: Current Surveys Based on Area and List Sampling Methods*. FAO, Rome.

Fuller, W. 1987. *Measurement Error Models*. John Wiley and Sons, New York.

Gosselin, J.-F., B.N. Chinnappa, P.D. Ghangurde and J. Tourigny. 1978. Coverage. *A Compendium of Methods of Error Evaluation in Censuses and Surveys*. Statistics Canada. 13-546E: 7-9.

Groves, R.M. 1989. *Survey Errors and Survey Costs*. John Wiley and Sons, New York.

Hartley, H.O. 1962. Multiple Frame Surveys. *Proceedings of the Social Statistics Section.* American Statistical Association. 203-206.

Laniel, N. and H. Finlay. 1991. Data Quality Concerns with Sub-Annual Business Survey Frames. *Proceedings of the Section on Survey Research Methods.* American Statistical Association. 202-207.

Lessler, J.T. and W.D. Kalsbeek, 1992. *Nonsampling Errors in Surveys*. John Wiley and Sons, New York.

Linacre, S.J. and D.J. Trewin. 1989. Evaluation of Errors and Appropriate Resource Allocation in Economic Collections. *Proceedings of the Annual Research Conference*. U.S. Bureau of the Census. 197-209.

Lyberg, L., P. Biemer, M. Collins, E. de Leeuw, C. Dippo, N. Schwarz and D. Trewin, eds. 1997. *Survey Measurement and Process Quality*. John Wiley and Sons, New York.

Statistics Canada. 1998. *Quality Guidelines*. Third Edition. 12-539-XIE.

Swain, L., J.D. Drew, B. Lafrance and K. Lance. 1992. The Creation of a Residential Address Register for Coverage Improvement in the 1991 Canadian Census. *Survey Methodology,* 18(1): 127-141.

Swain, L. and D. Dolson. 1997. Current Issues in Household Survey Nonresponse at Statistics Canada. *Statistics in Transition,* 3: 439-468.

Chapter 4 - Data Collection Methods

4.0   Introduction

Data collection is the process of gathering the required information for each selected unit in the survey. During data collection, members of the population – be they individuals or organisations – are located and contacted and their participation in the survey is sought. A questionnaire is then administered and answers recorded. This process is expensive, time consuming, requires extensive resources and has a direct impact on data quality. Since it is the general public's main contact with the statistical agency, it contributes to the image of the statistical agency and has a broad impact on the agency's relevance and on the quality of its data.

During the planning phase of a survey, many decisions must be made regarding the method of data collection. Should the questionnaire be administered by an interviewer? If yes, should the interview be conducted in person or over the telephone? Should a combination of methods be used – should respondents fill out the questionnaire themselves and nonrespondents be followed-up with a telephone interview? Should the questionnaire be paper or computer-based? Should administrative data be used to collect some of the survey data? Should data collection for several surveys be combined?

The method of data collection should be chosen to achieve a high participation rate and collect data that are as complete and accurate as possible while minimising the burden to the respondent and satisfying the client's budget and operational constraints.

The purpose of this chapter is to present the various methods of data collection – including self-enumeration, interviewer-assisted, computer-assisted, administrative data and others – and the criteria for deciding which method is most appropriate. Data collection operations in general (with an emphasis on interviewer-assisted methods), including how to locate the sampling units, elicit co-operation and capture responses are covered in **Chapter 9 - Data Collection Operations**.

4.1   Basic Data Collection Methods

The basic methods of data collection are:

i.   Self-Enumeration

With self-enumeration, the respondent completes the questionnaire without the assistance of an interviewer. There are a variety of ways that the questionnaire can be delivered to and returned by the respondent: by post or facsimile, electronically (including the Internet) or by an enumerator. (If the questionnaire is returned by facsimile or electronically, then a secure line or encryption is needed to ensure the confidentiality of respondent data). When paper-based, this method is called Paper and Pencil Interviewing (PAPI), when computer-based it is called Computer-Assisted Self Interviewing (CASI).

ii.   Interviewer-assisted (Personal Interviews or Telephone Interviews)

a.   Personal Interviews

An interviewer assists the respondent to complete the questionnaire. The interview is conducted in person, usually at the respondent's residence or place of work, although it can be conducted in a public place

(e.g., airport, shopping centre). When paper-based, this method is called Paper and Pencil Interviewing (PAPI), when computer-based it is called Computer-Assisted Personal Interviewing (CAPI).

b.   Telephone Interviews

An interviewer assists the respondent to complete the questionnaire over the telephone. When paper-based, this method is called Paper and Pencil Interviewing (PAPI), when computer-based, it is called Computer-Assisted Telephone Interviewing (CATI).

This chapter begins with a discussion of the basic methods of data collection, assuming paper-based collection (although many of the comments made also apply to computer-assisted methods). Section 4.2 discusses the advantages and disadvantages of computer-assisted collection. Section 4.3 discusses other methods of data collection, such as the use of administrative data. For a comparison of all data collection methods, see the table at the end of the chapter.

4.1.1   Self-Enumeration

Self-enumeration methods require a very well-structured, easy to follow questionnaire with clear instructions for the respondent. A telephone number to obtain help completing the questionnaire may be included. Usually, to induce respondent participation, the questionnaire has a more elaborate visual presentation than an interviewer-assisted questionnaire. (For details on how to design a questionnaire, see **Chapter 5 - Questionnaire Design**.)

Compared with the task of managing interviews, self-enumeration is relatively easy to administer. It is also usually cheaper than interviewer-assisted methods, so larger samples can be selected. This method is useful for surveys that require detailed information since the respondent can consult personal records. This can reduce response errors by preventing the respondent from relying on memory. One form of self-enumeration uses diaries or notebooks. In a diary survey the respondent keeps records during the survey's reference period, for example, a listener's diary for radio and television surveys during a particular week, or a notebook with gas purchases for a vehicle fuel consumption survey. Self-enumeration is also useful for sensitive issues since the questionnaire can be completed in private, without an interviewer.

One disadvantage of self-enumeration is that it requires either knowledgeable or well-educated respondents or a very straight-forward survey topic. Another disadvantage is that response rates are usually lower than for interviewer-assisted methods since there is no pressure for the respondent to complete the questionnaire. At Statistics Canada, the response rate for self-enumeration surveys is typically less than 70%. (One exception is the Census of Population which has an 85% mail return rate due to a vast publicity campaign and the mandatory nature of the survey.) Often, many follow-ups – reminding respondents to complete the questionnaire – or telephone interviewers are used to obtain a good response rate (see section 4.3.4). Also, while the questionnaire can contain substantial reference material on survey concepts and guides to help in the completion of the questionnaire, this is usually not as good as having an interviewer present since many respondents do not read instructions. As a result, the quality can be worse than for interviewer-assisted methods since the respondent may miss skips, misinterpret information, etc. For this reason, self-enumeration requires follow-up after collection to correct errors.

There are a variety of ways to deliver and collect self-enumerated questionnaires. The choice of questionnaire delivery and pick-up must be examined closely, taking care to compare data quality, collection costs, length of collection period, response rates, etc., before the most suitable combination is chosen. This will depend on the survey frame that is used and the collection information that is available

on the frame: in order to mail questionnaires, name and mailing addresses must be present and the postal system must be reliable. In order to fax questionnaires, the frame must have respondent fax numbers. The most common means of delivering and returning questionnaires are:
- personal delivery / pick up of paper questionnaire;
- mail out / personal pick up of paper questionnaire;
- personal delivery / mail back of paper questionnaire;
- mail out / mail back of paper questionnaire.

When a paper questionnaire is delivered and returned by mail, self-enumeration requires a long interviewing period since this is the slowest method of data collection. In Canada, it is also the cheapest method of data collection.

4.1.2   Interviewer-Assisted Methods

The main benefit of interviewer-assisted methods is that by personalising the interview and being able to interpret questions and survey concepts, the interviewer can increase the response rate and overall quality of the data. Interviewer-assisted methods are particularly useful for survey populations with low literacy rates or when the concepts or the questionnaire are complex, or anytime self-enumeration would be difficult.

An interviewer can increase the response rate by stimulating interest in the survey and reassuring the respondent of any concerns he or she might have regarding: the confidentiality of the data, the purpose of the survey, what is expected of the respondent during the interview, how long the interview will take, how the survey findings will be used, etc. For example, some respondents may be worried that the information they give could be used to their disadvantage or they may consider the subject matter to be sensitive, or they may be worried that they do not know the 'right' answer. The interviewer can assure the respondent that the data will be secure and that the statistical agency will adhere to all security procedures to maintain confidentiality.

The overall quality of the data can be improved since the interviewer can be provided with extensive training in the survey's concepts and definitions and assist the respondent with any problems interpreting the questionnaire. The interviewer can prevent response errors and item nonresponse by immediately identifying errors and correcting them in the presence of the respondent. This also reduces follow-up which can be time-consuming for the survey agency and burdensome to the respondent. Finally, the interviewer can improve data quality by verifying that the correct sampling unit is contacted and interviewed.

Another advantage of interviewing is that it allows for more flexible collection periods: if data collection is going too slowly and needs to be accelerated, more interviewers can be hired. This is not possible with self-enumeration methods where there is little control over when the respondent completes and returns the questionnaire.

The main disadvantages of interviewer-assisted methods are that they can be expensive and difficult to manage. Some of the expenses include: interviewer salaries, interviewer training, transportation and lodging costs for interviewers (in the case of personal interviews) or office space and telephones in the case of centralised telephone interviewing. Other disadvantages of interviewer-assisted methods are that poorly trained interviewers can cause response errors and, for sensitive topics, respondents may be reluctant to answer questions (although, telephone interviews allow for some anonymity). If well-trained interviewers are unavailable and consequently interviewer bias could be a problem, self-enumeration may be preferable.

For a discussion of response errors, see **Chapter 3 - Introduction to Survey Design** and **Chapter 5 - Questionnaire Design.** The following sections present the advantages and disadvantages of personal versus telephone interviews.

4.1.2.1 Personal Interviews

With personal interviews, the interview is conducted face-to-face with the respondent. Usually, personal interviews are conducted at the person's residence or place of work. For some target populations, this is the only feasible method of data collection, for example, when telephone interviews are not possible or when the survey requires a visit to sample or locate members of the population (e.g., to complete listing of an area frame).

Personal interviews often have the highest response rates (typically around 80-95% for Statistics Canada) but are usually the most expensive method of collection because of transportation and lodging costs for interviewers. Consequently, this method of collection may result in smaller sample sizes than would have been selected for self-enumeration or telephone interviews. Another problem with personal interviews is that it can be difficult to find people at home or at work, so the interviewer may be required to visit the residence or place of work several times before successfully contacting the respondent. Sometimes, the respondent is present, but the time is inconvenient, requiring the interviewer to reschedule the interview.

Other advantages of personal interviews include:
- interviewers can make direct observations (this is not possible with telephone interviews);
- interviewers generally do a better job of converting refusals in person;
- interviewers can instil confidence in respondents by showing them official identification.

Other disadvantages of personal interviews include:
- it is sometimes difficult to hire and retain suitably qualified interviewers in all surveyed areas;
- it is difficult to shift workloads to less busy interviewers;
- it is difficult to implement a quality control program for the interviewing process.

4.1.2.2 Telephone Interviews

Telephone interviews offer a reasonable response rate at a reasonable cost. In Canada, they have medium to high response rates, lower than personal interviews but higher than self-enumeration (the typical response rate at Statistics Canada is 70-85%). Some self-enumeration surveys use telephone interviews for follow-up in order to achieve a better response rate. Telephone interviews are usually cheaper than personal interviews since there is no travelling cost for interviewers and collection is usually faster than for personal interviews or self-enumeration. Telephone interviews can also be used to ask sensitive questions, although this method is not as anonymous as self-enumeration. This method of collection is safer than personal interviews since the interviewer does not need to travel to dangerous or isolated areas. Also, if a respondent is not at home or would like to reschedule the interview, less time is wasted contacting the respondent than for personal interviews. Finally, quality control of the interviewing process can be easily implemented since telephone interviews can be easily monitored.

One disadvantage of telephone surveys is that they are limited by the length of the interview and complexity of the questionnaire: respondents have less patience for long, complex interviews over the telephone than in person. But, since the questionnaire is administered by an interviewer, it can be more complex than for self-enumeration. Another disadvantage is that direct observations cannot be made over the telephone.

Other disadvantages of telephone interviews include:
- it may be difficult to construct a survey frame with good coverage of telephone numbers;
- sampling telephone numbers is often inefficient (i.e., may telephone many out-of-scope units);
- confidentiality may be a problem if another person can overhear the respondent's answers (for example, where there are shared telephone lines);
- telephone interviews are less personal than personal interviews, so it may be more difficult to convince people of the importance of the survey;
- telephone interviews may be costly if long-distance calls are made.

For more details on sampling telephone numbers including random digit dialling, see **Chapter 6 - Sample Designs**.

4.1.2.2.1 Telephone Sampling

The telephone interviewing process often incorporates the sample selection process: the sample is often selected by the interviewer during the first step of the interview. The following describes issues relating to telephone sampling that can determine whether or not telephone interviewing is the appropriate method of data collection for a particular survey.

Telephone sampling and telephone interviewing are often chosen for household surveys as a practical compromise between higher quality, higher cost area frame samples with personal interviewing and lower quality, lower cost self-enumeration mail-out mail-back surveys. The use of telephone sampling and interviewing avoids the high costs of maintaining area frames and of travel time for personal interviews, while still maintaining fairly high response rates. As is always the case for any sampling method it is important that the sampled population be representative of the target population, at least with respect to the characteristics of interest to the survey. This can be a problem with telephone surveys if the proportion of the target population without telephone service is not small, or if it differs significantly between sub-populations. (Some potential biases due to differences in rates of telephone service can be reduced in the same way that differential rates of non-response can be accounted for.)

An example of the potential biases of using a non-representative frame is the now classic case of the Literary Digest poll conducted during the 1936 presidential election in the USA. The poll predicted that the Republican candidate Alf Landon would defeat President Roosevelt:

<blockquote>
Landon   55%
Roosevelt   41%.
</blockquote>

<blockquote>
However, the actual results were quite different:
Landon   37%
Roosevelt   61%.
</blockquote>

The frame used for this mail-out mail-back poll was based primarily on addresses found in telephone directories and automobile registration lists. In 1936, Americans owning cars or telephones tended to be wealthy and to vote for the Republican party. A large portion of the voting electorate, however, owned neither a telephone nor a car, and these people tended to vote for the Democratic party. (Today, in Canada, the United States, and many European countries, virtually all households have telephone service, so the potential biases for many estimates from telephone surveys are much less than in this 1936 example.)

An important issue when selecting a telephone sample is the choice of sampling frame. For a telephone frame to be complete it should include all telephone numbers in use; for it to be efficient, it should

contain as few numbers not in use as possible. In general improving completeness of a telephone frame reduces its efficiency. It is important to try to achieve both efficiency and completeness. Using telephone directories (on-line or on paper) as the frame for selecting telephone samples can be quite efficient, but its lack of completeness can lead to biases. Unpublished telephone numbers are not in these directories by definition, and the directories are always several months to several years out of date, so people with new numbers do not appear either. To improve the completeness of coverage of a telephone sample, Random Digit Dialling (RDD) techniques are generally used. The following is an example of what can be done in Canada to achieve both efficiency and completeness.

The form that telephone numbers take varies from country to country, but in Canada the North American model is used, where a telephone number is a ten digit number consisting of a three digit area code, followed by a three digit prefix, followed by four more digits. There are currently 21 area codes used in Canada, so a simple frame would consist of appending the 10 million possible seven digit numbers to each of the 21 area codes, producing a frame of 210 million telephone numbers. This frame would be absolutely complete (until a new area code were introduced), but since there are only about 13 million telephone numbers in Canada that actually reach households, 94% of the numbers selected at random from this frame would not reach households. Hence using the frame would be very inefficient. It is possible to refine the frame. For North America it is possible to purchase a list of all area code and prefix combinations in use. There are currently 8,600 of these in Canada, with which a frame could be built by appending to each the 10,000 possible four digit numbers to yield a frame of 86 million numbers, of which only 85% would not reach households. The Mitofsky-Waksberg method can be used to further improve the operational efficiency of such a frame at the expense of complicating field procedures and possibly decreasing the statistical efficiency through clustering. Statistics Canada further refines the telephone sampling frame by using administrative data.

Define a hundreds bank as the 100 telephone numbers that share the same area code, prefix, and next two digits. Using administrative lists of published telephone numbers it is possible to identify all of the hundreds banks that contain at least one published household telephone number. There are about 260,000 such **working banks**, yielding a frame containing 26 million telephone numbers, of which only about half do not reach households. However, whereas the first two frames are complete at some point in time (and remain complete until new area codes or new area code and prefix combinations come into use), the frame based on working hundreds banks may be incomplete. If a hundreds bank contains no published household numbers, but does contain some unpublished household numbers, it will not appear on the frame when it should. In addition, new hundreds banks are used by the telephone companies far more frequently than new area codes and prefixes, and the new area codes and prefixes are published before they come into use. This last RDD method is known as truncation of 0-listed banks or elimination of non-working banks.

Even when the elimination of non-working banks is used to improve efficiency, for a household survey in Canada about half of the telephone numbers in an RDD sample will be out-of-scope numbers. So, before an interview can be conducted over the telephone, the interviewer must confirm that the telephone number is in-scope for the survey. For RDD surveys in Canada four to six minutes of interviewer's time is spent on out-of-scope numbers for each completed interview. When the questionnaire is short, this time can represent a significant part of the total interviewer time spent per interview. It nevertheless is small compared to the travel time necessary for personal interviews.

Random digit dialling sample design is less flexible than area frame designs when it comes to stratification. (Stratification divides the survey population into subpopulations, for example, provinces. There are three main reasons for stratification: to make the sampling strategy efficient; to ensure adequate sample sizes for specific subpopulations for which analysis is to be performed; and to protect against drawing a 'bad' sample.) While area frames allow flexibility in the choice of geographic strata, for RDD

surveys, the geography of stratification must be based on area code and prefix (or similar concepts for non-North American telephone systems). There generally is a geographical area associated with these, but it may not match any municipal boundaries or other boundaries of importance to the survey. To compensate, RDD sampling allows for selecting unclustered samples of households, yielding samples that tend to be more statistically efficient (lower design effect) than samples from area frames.

For more information on telephone sampling, see Dillman (1978), Groves et al. (1979), Groves et al (1988) and Lavrakis (1987). For a discussion of frame coverage problems, see **Chapter 3 - Introduction to Survey Design.** For a thorough discussion of sample designs, see **Chapter 6 - Sample Designs**. See **Chapter 7 - Estimation** for a discussion of nonresponse adjustments.

4.1.3   Choosing between Self-Enumeration and Interviewer-Assisted Methods

There are various issues that must be considered when selecting a method of data collection:
- collection information available on the survey frame;
- characteristics of the target population;
- nature of the questions being asked;
- available resources (e.g., interviewers);
- how easy the questionnaire is to complete;
- privacy considerations;
- data quality requirements.

Collection information that is available on the survey frame plays a key factor in determining which method of data collection is most appropriate. If the frame does not include mailing addresses, then self-enumeration questionnaires cannot be mailed out to respondents. If up-to-date telephone numbers are not available and Random Digit Dialling is considered to be inappropriate, then telephone interviews cannot be conducted.

The characteristics of the target population influence the data collection method. If the literacy rate of the population is low or language difficulties are an issue (e.g., immigrants), interviewer-assisted methods may be the only option. The geographic distribution of the population and sample is also important. If the population and sample are widely dispersed across the country, personal interviews could be too expensive and difficult to manage. (The distribution of the population and the cost of data collection are factors in determining which method of sampling is most appropriate. For more details, see **Chapter 6 - Sample Designs**.)

The nature of the survey questions influences data collection. If the subject matter is sensitive, then a method of collection that builds in anonymity such as self-enumeration or telephone interviews may be the most appropriate. If complex questions are asked, an interviewer may be needed to explain questions and concepts. If the interviewer needs to make observations or measurements (e.g., administering a literacy test to children) or show the respondent material (e.g., graphics or diagrams), then personal interviews might be required.

Available resources heavily influence the choice of data collection method. These resources include available budget, personnel, equipment and time. In order to use an interviewer-assisted method, sufficient budget must be available to pay for the training, hiring and travelling of interviewers. The statistical agency also needs to be able to find the required number of interviewers. If a computer-assisted method is selected, then expert computer programmers are required along with the necessary computer equipment.

Some methods of data collection are easier to administer than others. For example, centralised telephone interviews (i.e., where all the interviewers make their calls from one location) are easier to organise than geographically dispersed personal interviews. Also, the time frame within which the data must be collected is important – self-enumeration methods are typically slower than interviewer-assisted methods and manual paper-based methods are usually slower than computer-assisted ones.

Finally, data quality requirements should be considered when selecting a data collection method. Interviewers who are well trained in the concepts being used by the survey can reduce response errors and nonresponse. Precision requirements should be considered: larger samples generally yield more precise estimates (i.e., estimates with smaller sampling error), but the more expensive the data collection method, the smaller the sample the client can probably afford. Personal interviews are often the most expensive method and self-enumeration surveys the least expensive. The ability to measure quality and implement quality control procedures may also be important. It is easier to monitor the quality of telephone interviews, for example, than personal interviews.

The following table compares personal interviews, telephone interviews and self-enumeration data collection methods with respect to cost, time to complete data collection and response rates.

Table 1: Interviewer-Assisted versus Self-Enumeration Data Collection Methods

	Self-Enumeration	Interviewer-Assisted	
		Personal	**Telephone**
Cost	Low	High	Medium
Time	Longer	Average	Shorter
Response Rate	Low	High	Medium-high

For details on how to select a sample design, see **Chapter 6 - Sample Designs**. For factors that determine the sample size, see **Chapter 8 - Sample Size Determination**.

4.2   Computer-Assisted Data Collection

A major factor in survey design is whether collection involves computer methods or a traditional paper-based approach, where answers are recorded on a paper questionnaire. While so-called Paper and Pencil Interviewing (PAPI), is still sometimes used, computer-assisted data collection is becoming more prevalent.

For surveys that are only conducted once, paper-based methods are often cheaper and require less development time than computer-based methods. However, data capture – the transformation of responses into a machine-readable form – must be performed as a separate operation after collection. Data capture is a necessary survey step since all survey data must ultimately be entered into and stored in a computer.

Other disadvantages of paper-based collection include:
- manual data collection is time-consuming and optically scanning the questionnaire may not be an option;
- the questionnaire should not have complicated skip patterns or edits;
- printing questionnaires can be costly;
- mailing questionnaires can be costly;
- completed questionnaires must be stored and securely protected to ensure respondent confidentiality.

The main benefit of computer-assisted methods is that data collection and data capture are combined, resulting in an integrated, faster and more efficient collection and capture process. Computer-assisted interviewing (CAI) may be conducted using any data collection method:
-    self-enumeration (Computer-Assisted Self-Interviewing, CASI);
-    by telephone (Computer-Assisted Telephone Interviewing, CATI);
-    in person (Computer-Assisted Personal Interviewing, CAPI).

CASI is a relatively new and little used technology in which the questionnaire, complete with an editing program to identify missing, invalid or inconsistent entries, and help features, is sent to the respondent in electronic format. The respondent uses his or her own computer to complete the questionnaire. This allows a respondent who possesses the necessary computer equipment and software to capture and edit the data directly using his or her computer while being prompted by the system through the survey questions. The questionnaire on a diskette may be sent by the regular mail or by courier, or the electronic file may be forwarded by modem and returned over a secure line.

Currently, pilot projects at Statistics Canada are being conducted to collect data in structured standard formats via the Internet in a secure fashion. The advantages of using the Internet are the reduced costs for data collection and data capture and the increased timeliness. One disadvantage of using the Internet is that the questionnaire must be compatible with different versions of Internet software (e.g., Explorer, Netscape, Windows, UNIX, etc.). Another disadvantage is the relatively low number of high speed Internet users (although this number could grow rapidly over the next few years), making it an unlikely option for household surveys but more possible for business surveys.

In general, the advantage of CASI is its flexibility and convenience for the respondent who has the computer equipment and software, the main disadvantage is that not all respondents have the necessary computer equipment.

With CATI and CAPI, each interviewer is equipped with a computer. The interviewer reads a script appearing on the screen, then enters the responses directly into the computer. In Canada, CATI and CAPI are becoming increasingly prevalent as computer technology improves.

In general, CAI has many advantages over PAPI, mainly due to combined data collection and capture. It is easier to monitor and control the quality of the data since data collection, automated editing and data capture are more consistent and controlled than with paper-based methods. Also, automated editing means that edit failures can be resolved immediately, resulting in less follow-up and response burden. It is easier to implement quality control of the interviewing process and to generate management reports on the status of the interviews (e.g., response rate, number of interviews completed, number outstanding, length of time per interview, etc.). The questionnaire can be more complex in terms of skip patterns and edits. Responses are often obtained much more rapidly than for paper-based surveys (especially ones that are mailed out and mailed back).

One disadvantage of computer-assisted collection is that the person filling out the questionnaire – the respondent or interviewer – must be trained and comfortable with the software application. (However, once comfortable with the application, the interviewer can spend more time on interpersonal skills.) Also, computer-assisted surveys require extensive and costly development work by computer programming experts (this can be decreased somewhat if a survey is able to adapt another survey's computer application). The questionnaire must be programmed so that each question appears on the computer screen in its proper sequence. The application must be tested thoroughly to ensure that the screens are presented in the correct order and that they guide the interviewer or respondent through pre-determined paths. Edits, online help and additional functions that help interviewers or respondents must also be programmed and tested. Also, for interviewer-assisted surveys, another disadvantage is the cost of

purchasing the equipment since each interviewer needs a computer (although this cost could be shared across surveys). And while there is the advantage of not having to securely store completed paper questionnaires to protect respondents' confidential data, computers must be protected from theft.

Developing and testing computer-assisted methods, particularly for a new survey, may be a long and costly process. However, for surveys with a large sample size, computer-based collection may greatly reduce data capture and editing costs. For repeated surveys, computer-based collection may be less expensive than paper-based collection in the long run because of the savings in printing and since the cost of development can be spread out over several collection cycles.

Other advantages of computer-based collection are:
- it is environmentally friendly (questionnaires are not printed out);
- dependent interviewing can be easily performed for repeated surveys to reduce response error (i.e., information provided by a respondent in a previous cycle of the survey can be used at subsequent cycles).

Other disadvantages of computer-based collection are:
- transmission between computers (e.g., from the interviewer's computer to head office) must be over a secure line in order to protect the confidentiality of respondent data;
- it is vulnerable to technical difficulties (battery life, file transfer problems, etc.) that are time-consuming to fix and could result in the loss or damage of data;
- it requires computer experts to develop the software and deal with technical problems.

Data capture is dealt with in more depth in **Chapter 9 - Data Collection Operations**. Data processing, including optical scanning for data capture, and editing are discussed in **Chapter 10 - Processing.**

4.3   Other Methods of Collection

Besides self-enumeration and interviewer-assisted methods, other data collection methods include: direct observation, electronic data reporting, administrative data, combined methods and supplementary or omnibus surveys.

4.3.1   Direct Observation

This method consists of observing or measuring directly the characteristics of interest in the field or in a laboratory. It may be the only possibility for certain concepts (e.g., some medical data) and is commonly used for pricing surveys. Remote sensing is a form of direct observation that interprets satellite images. It is used in some farm surveys to estimate types and areas of crops. This form of collection cannot be applied to most data, since most data cannot be observed or directly measured.

Direct measurement is usually precise and when observations only are made there is no response burden. However, when measurements of people are made, the study subjects may find these measurements irksome or burdensome: for example, a medical study that takes blood samples from patients. This can result in low participation rates.

One difficulty with direct measurement is that it can be expensive since all interviewers must be trained to observe or measure the data and this may require hiring specialists (e.g., nurses to take blood-pressure measurements). If specialists are required and only a few can be hired, this can severely restrict the sample size and design.

4.3.2   Electronic Data Reporting (EDR)

Some surveys allow respondents to provide their electronic data (e.g., on diskettes, computer tapes or cartridges) in their own format. EDR is a form of self-enumeration and can be very convenient for the respondent but is usually only offered when there is no other means of obtaining the data. For example, some businesses may only provide their data this way.

When the data are transferred from the respondent's computer to the statistical agency's using a dedicated line (modem to modem), this is referred to as Computer to Computer Data Transfer. EDR is often avoided since, if a standard format cannot be agreed upon with the respondent, extensive work is involved in editing and manipulating the data to suit the format required by the statistical agency.

4.3.3   Administrative Data

Some surveys can obtain the information they require from existing administrative data. ***Administrative data are those that have been collected for administrative purposes (e.g., to administer, regulate or tax activities of businesses or individuals) as opposed to statistical purposes (to study groups of individuals, businesses, farms, etc.)***.

Administrative records have a huge advantage in that they avoid a major portion of data collection costs and respondent burden. They can also result in timely survey results since the data already exist. However, the purpose of the administrative program may be quite different from that of the survey, therefore concepts and definitions must be carefully assessed (e.g., the target population and coverage of the target population). Also, there is a lack of control over the quality of the data (which is determined by the administrator, not the statistical agency). Follow-up of edit failures is usually impossible. There is also usually considerable processing work to be done to ensure that the administrative data are in the format required by the statistical agency. Finally, there may be privacy concerns regarding the use of the administrative data for statistical purposes.

For more details on the uses of administrative data, see **Appendix A - Administrative Data**.

4.3.4   Combining Methods

Often the most satisfactory collection strategy is to offer respondents a choice of data collection methods. The advantages of combining methods include improved response rates, fewer response errors and faster collection. One disadvantage of combining methods is that collection may be more complex and expensive. Another disadvantage is that it produces heterogeneous data that can complicate processing and analysis. For example, if a self-enumeration mail-out survey is conducted and nonrespondents are followed-up by telephone with a shorter questionnaire, then both versions of the questionnaire must be reconciled during processing. And bias may be introduced if data from the telephone interviews are of better quality than the self-enumeration questionnaires, which will complicate data analysis.

Another example of combining methods is a monthly survey where it may be cost-effective to contact the respondent in person for the first interview and by telephone for subsequent interviews. This is what is done for the Canadian Labour Force Survey. For the Canadian Census of Population, the initial data collection is a mail-out/mail-back survey. Follow-up is done with telephone and personal interviews; the

response to mailed self-enumeration surveys is improved when non-respondents are followed-up in two stages - first by telephone, then in person. Another alternative – becoming more and more popular – is to combine data collected by a questionnaire with administrative data, in order to reduce recall error, respondent burden and survey costs.

4.3.5   Supplementary and Omnibus Surveys

Sometimes, it is possible to share a collection vehicle with another survey, via an omnibus survey or a supplementary survey. In a supplementary survey, the new questionnaire is added as a supplement to an existing survey's questionnaire. Typically, the existing survey is a large-scale survey. Supplementary surveys are common in government agencies. An example at Statistics Canada is the Canadian Travel Survey, which collects information on trips and characteristics of Canadians who travel and is conducted as a supplement to the Labour Force Survey.

In an omnibus survey, questions for several different surveys are combined into a single questionnaire. This way, the omnibus survey's questionnaire is composed of several sections, each dealing with a different topic and each conducted for a different client. The costs of the survey are shared by the clients in proportion to the effort involved in the collection and processing of the different sections of the survey. It can therefore be an effective means of reducing the costs associated with developing and carrying out the survey. This type of survey is carried out on a regular basis by private research companies and statistical agencies and involves several partners with varying research needs. The major advantage of this approach is the, often substantial, reduction in costs, compared to conducting a separate survey for each topic.

One disadvantage of this approach is that the respondent is faced with a large questionnaire composed of a variety of, what may be, unrelated and sometimes sensitive topics. This can result in a burdensome questionnaire to which a respondent is less inclined to respond. Also, the lack of control over the order of the sections of the questionnaire can have an effect on the responses.

4.4   Summary

There are three main methods of data collection: self-enumeration, personal interviews and telephone interviews. Self-enumeration by mail is usually the cheapest form of data collection. Unfortunately, self-enumeration surveys often have the lowest response rates and can take the most time to conduct, particularly if the questionnaire is delivered and returned by mail.

Personal interviews usually yield the highest response rates but can also be the most expensive. They are often used for surveys with complex or extensive questions, when the sample requires a personal visit to locate or select respondents, when there is poor coverage of the target population with telephones or when the population has a low literacy rate.

Telephone interviews usually have medium response rates, are less expensive than personal interviews and are the quickest method of collection. They can be particularly advantageous when the population and sample are geographically dispersed, where personal interviews would be expensive and difficult to conduct. The main problem with telephone interviews is telephone sampling: lists of telephone numbers rapidly become out-of-date (resulting in frame undercoverage) and Random Digit Dialling is inefficient.

All of these data collection methods can be either paper-based or computer assisted. The main advantage of computer-assisted methods is that data collection and capture are combined. The main disadvantage of computer methods is the considerable time and cost required to develop the computer application.

Other methods of data collection include: direct observation, electronic data reporting, administrative data, combining methods and supplementary or omnibus surveys. Direct observation can be precise, but cannot be applied to all data and often requires the use of specialists. Electronic data reporting is convenient for respondents who can report their data electronically, but may require considerable work to convert the respondent's data into the required format. Administrative data can be used as an indirect data collection method for some surveys. This can eliminate response burden, greatly reduce the cost of the survey and improve the timeliness, however the statistical agency must carefully review the concepts used by the administrative source and the quality of the data. A combination of methods is often a good way to reduce costs, improve response rates and timeliness. Another way to reduce costs is to join forces with other surveys using a supplementary or omnibus survey.

Bibliography

Cox, B.G., D.A. Binder, B.N. Chinnappa, A. Christianson, M.J. Colledge and P.S. Kott, eds. 1995. *Business Survey Methods*. John Wiley and Sons, New York.

Couper, M.P., R.P. Baker, J. Bethlehem, C.Z.F. Clark, J. Martin, W.L. Nicholls II and J.M. O'Reilly, eds. 1998. *Computer Assisted Survey Information Collection*. John Wiley and Sons, New York.

Dielman, L. and M.P. Couper. 1995. Data Quality in a CAPI Survey: Keying Errors. *Journal of Official Statistics,* 11: 141-146.

Dillman, D.A. 1978. *Mail and Telephone Surveys: The Total Design Method.* John Wiley and Sons, New York.

Dillman, D.A. 2000. *Mail and Internet Surveys: The Tailored Design Method*. John Wiley and Sons, New York.

Dufour, J., R. Kaushal, C. Clark and J. Bench, eds. 1995. *Converting the Labour Force Survey to Computer-Assisted Interviewing*. Statistics Canada. HSMD-95-009E.

Groves, R.M. 1989. *Survey Errors and Survey Costs*. John Wiley and Sons, New York.

Groves, R.M., P.P. Biemer, L.E. Lyberg, J.T. Massey, W. L. Nicholls and J. Waksberg, eds. 1988. *Telephone Survey Methodology*. John Wiley and Sons, New York.

Groves, R.M. and R.L. Kahn. 1979. *Surveys by Telephone: A National Comparison with Personal Interviews*. Academic Press, New York.

Kasprzyk, D., G.J. Duncan, G. Kalton and M.P. Singh, eds. 1989. *Panel Surveys*. John Wiley and Sons, New York.

Lavrakis, P.J. 1987. *Telephone Survey Methods: Sampling, Selection and Supervision.* Applied Social Research Methods Series. 7. Sage Publications, California.

Table 2: Comparison of Data Collection Methods

Method	Advantages	Disadvantages
A. Paper-Based	- can contain printed reference material to reduce response error - does not require computers for data collection - can take less time to develop collection procedures than for computer-based methods - for one-time surveys or small surveys, collection may be cheaper than computer-based methods	- data capture is separate from collection - printing questionnaires can be expensive - questionnaires cannot have a complex flow/skip pattern - requires much manual work for data collection - questionnaire can have only a few simple, manual edits - dependent-interviewing difficult for repeated surveys
A.1 Self-Enumeration	- easy to administer - can reduce response error since respondent can consult personal records - usually the most inexpensive data collection method, therefore client can afford larger samples with better precision - questionnaire can be completed without the presence of an interviewer and therefore is good for sensitive questions - does not require large numbers of trained interviewers	- can increase response error since respondent is unlikely to read reference material - data may be of poorer quality than for interviewer-assisted methods - the questionnaire must be well-designed and respondent-friendly with clear instructions to encourage participation and reduce response errors - questionnaire cannot be too long or complex - should only be applied to simple, straight-forward survey topics or well-educated populations - response rates lower than for interviewer-assisted methods (many follow-ups may be required to improve the response rate) - need to follow-up edit failures - if questionnaires are mailed, must pay for postage - mail-out/mail-back questionnaires can be the slowest method of data collection

Method	Advantages	Disadvantages
A2. Interviewer-Assisted	- better response rates than self-enumeration since interviewer can stimulate interest and be sensitive to respondent's concerns - interviewer can improve data quality by explaining concepts, helping with problems: can reduce response errors and the number of partially completed questionnaires - interviewer can ensure that the correct unit is surveyed - can lower response burden since interviewer can immediately edit and follow-up edit failures - interviewer can explain methods used to ensure data security and confidentiality - allows for a more flexible collection period than self-enumeration (more interviewers can be hired to speed up collection) - can be applied to populations with poor literacy skills	- interviews can be expensive: cost of training interviewers, interviewers' salaries, lodging, transportation for personal interviews/office space for telephone interviews - need to have time to train interviewers - good management skills are required to co-ordinate all the interviews - can increase response error: poorly trained interviewers can increase response error; respondents may be reluctant to respond to sensitive questions (especially if the interviewer is hired locally) or may only provide socially correct answers - obtaining a survey frame with good coverage of all telephone numbers may be difficult - telephone sampling is inefficient
A2.1. Personal Interviews	- provides a very personalised interview (more personalised than telephone interviews) which usually results in higher response rates than for telephone interviews - interviewer can instil confidence in respondents by showing them official identification - interviewer can make direct observations - a more complex questionnaire is possible than for telephone interviews or self-enumeration	- usually the most expensive method of data collection, resulting in smaller sample sizes - difficult to implement quality control of interviews versus telephone interviews which are easy to monitor - can be difficult and time consuming to find people at home or at work - can be difficult to find and keep suitably qualified interviewers in all survey areas - cannot easily shift workload to less busy interviewers

Method	Advantages	Disadvantages
A2.2. Telephone Interviews	- response rates are usually higher than for self-enumeration - quality control of interviewing is easily implemented - cheaper than personal interviews (do not have to pay for travel and lodging costs) - fastest response time (versus personal interviews or self-enumeration) - can conduct interviews in difficult or inaccessible areas - more anonymous than personal interviews: can ask sensitive questions - less costly than personal interviews, permitting larger samples if needed	- response rates lower than for personal interviews - need to pay for office space for interviewers - may need to pay for long-distance telephone calls - questionnaire cannot be too long or complex - direct observations cannot be made - may be confidentiality problems if some telephone lines are shared - telephone sampling is inefficient: dialling a telephone number can lead to no contact, nonresponse or an out-of-scope unit - potential bias due to undercoverage when sampling from an administrative list of telephone numbers - RDD sampling has limited geographical stratification variables
B. Computer-Assisted Methods	- editing during collection can be automated, resulting in immediate resolution of edit failures and consequently less response burden due to follow-up - data collection, editing and capture are integrated, making them more timely (faster response time) and efficient and easier to monitor than paper-based methods - potentially better quality data - can have questionnaires with complex branching (skip patterns) - easy to produce management reports (e.g., on response rates) - may be cheaper than paper-based collection for repeated or large surveys - may be able to save in development costs by adapting software developed for a similar survey - better protection of confidentiality of completed questionnaires - environmentally friendly (less paper wasted) - dependent interviewing is possible for repeated surveys	- developing the computer application can take a long time and be expensive - need to test the computer application thoroughly - require computer experts to develop/adapt computer application - vulnerable to technical difficulties - interviewers or respondents must know how to use the computer application - infrastructure requirements (e.g., to equip interviewers with laptop computers) - need to be able to securely transmit data from one computer to another (e.g., from the field to Head Office)

Method	Advantages	Disadvantages
B1. Computer Assisted Self Interviews (CASI)	- flexible and convenient for the respondents with computers	- respondents must be comfortable using computers and/or the application and have the necessary computer software and hardware
B2. Computer Assisted Interviews (CAI)	- can automate the management of interviews (e.g., automate scheduling of interviews) - easier to manage interviews than for paper-based collection - can increase data quality: interviewers who are comfortable with the computer application can spend more time on interpersonal skills	- cost of computer equipment for interviewers - additional training of interviewers on computer application - security issues (e.g., computer can be stolen)
C. Other Methods of Data Collection		
C1. Direct Observation	- when all data are observed, there is no response burden - data collected are usually more precise than for interview or self-enumeration methods	- can be very costly if specialists are required to take measurements, resulting in small samples - cannot be applied to most surveys - if measurements are taken, participants may find this burdensome, resulting in a low participation rate
C2. Electronic Data Reporting (EDR)	- convenient for the respondents with computers	- format of respondent data may vary, resulting in costly and time-consuming processing
C2.1. Internet	- reduced costs for collection and capture - increased timeliness	- small number of Internet users
C3. Administrative Data	- data readily available, often resulting in cheap and timely survey results - low response burden	- purpose of administrative program may be different than survey: need to assess usefulness of administrative source with respect to survey's concepts and definitions (e.g., target population and coverage problems, reference periods, etc.) - statistical agency has little control over data quality - difficult or impossible to follow-up edit failures - administrative data may require time-consuming and costly processing (e.g., record layout may need to be changed) - there may be privacy concerns regarding the use of administrative data
C4. Combining Methods	- improved response rate - reduced response error - faster collection	- collection can be more complex and expensive - introduces a heterogeneity in the data that can complicate processing

Method	Advantages	Disadvantages
C5. Supplementary and Omnibus Surveys	- costs shared across several surveys	- need to find appropriate surveys to work with / may not want to be associated with some surveys - may be burdensome for the respondent, resulting in lower response rates - lack of control over the order of the sections of the questionnaire can have an effect on the responses

Chapter 5 - Questionnaire Design

5.0 Introduction

A questionnaire (or form) is a group or sequence of questions designed to obtain information on a subject from a respondent. Questionnaires include forms used for sample surveys and censuses as well as administrative forms. Questionnaires play a central role in the data collection process. They have a major impact on data quality since the questionnaire is the process whereby data are collected. They also influence the image that the statistical agency projects to the public.

The questions posed must conform to the survey's Statement of Objectives and provide information that is useful for data analysis. All information requirements must be met, but each question should have an explicit rationale for being on the questionnaire. It must be known why each question is being asked and how the information is to be used. The question wording must be clear. The questions must be sequenced logically for the respondent. The questions must be designed so that they are easily understood and can be accurately answered by respondents. Finally, the questionnaire should be tested before implementation using cognitive testing, focus groups, informal testing and other methods described in this chapter.

A well-designed questionnaire should:
- collect data efficiently with a minimum number of errors and inconsistencies;
- be respondent friendly and interviewer friendly (if interviewer-assisted);
- lead to an overall reduction in the cost and time associated with data collection.

The purpose of this chapter is to provide an overview of the steps of questionnaire design, including the development and testing of questionnaires. The main types of questions – open versus closed – are described as well as their advantages and disadvantages. Guidelines for developing questions are also covered. Finally, response error and processing issues related to questionnaire design are addressed.

5.1 The Questionnaire Design Process

The questionnaire design process starts with the formulation of survey objectives and information requirements (**Chapter 2 - Formulation of the Statement of Objectives**) and continues with the following steps:
- consult with data users and respondents;
- review previous questionnaires;
- draft the questionnaire;
- review and revise questionnaire;
- test and revise questionnaire;
- finalise questionnaire.

5.1.1 Consult with Data Users and Respondents

The process of consulting with data users, which began during with the formulation of the survey's objectives during the planning phase, continues during the design and development of the questionnaire. This extended consultation is particularly important for major, if not all surveys conducted by a statistical agency. By clearly understanding how the data are to be used, the statistical agency should be able to develop a well-designed questionnaire that meets the users' needs.

Not only data users, but respondents, experts in the field of study and those who have conducted similar surveys in the past should be consulted before the questionnaire is drafted. They should be able to provide insight into the type of information that respondents can provide and help clarify the concepts to be studied. Meeting with respondents can help identify issues and concerns that are important to them and may affect decisions regarding the content of the questionnaire. It can also be helpful in identifying the wording and language that respondents use to describe the survey concepts – this can provide useful insights into how questions and response categories should be worded. These discussions can take the form of in-depth consultations or *focus groups* (see Section 5.1.5.3).

5.1.2   Review Previous Questionnaires

Other surveys are a good source of information when developing a survey. Examining questions that were used by other surveys on the same or a similar topic can be a useful starting point when considering how to draft a question (namely, the question wording). In some situations, the same questions should be used, for instance when trying to compare results from different surveys. Also, documentation on the data quality from such surveys should be examined to assess the effectiveness of the questionnaire (e.g., problems with question wording, response burden, refusal rates, etc.).

5.1.3   Draft the Questionnaire

The next step is to develop a draft of the whole questionnaire. Because the questionnaire is affected by the whole survey design, along with the survey's objectives the following factors must be considered:

i.   Method of data collection

The length of the questionnaire and the manner in which questions are posed depends on the data collection methodology. For self-enumeration surveys, questionnaires should be less complex and shorter than for interviewer-assisted methods and preferably be 'stand-alone' meaning all relevant information (e.g., instructions, contact information, examples) is included on the questionnaire. With interviewer-assisted methods, the wording of a question is often different than for self-enumeration questionnaires. That is, the question should sound natural when asked out loud. With self-enumeration and personal interviews more response categories are possible than with telephone interviews which should be kept short.

The appearance, organisation and data recording structure will also be very different depending on whether the questionnaire is for self-enumeration, for telephone or personal interview, paper and pencil, or computer-assisted.

ii.   Characteristics of respondents

The characteristics of respondents should be considered when drafting the questions. They may have an impact on the terminology or complexity of language used for the questions. Questions intended for a survey of the general public should be easily understandable by all respondents, while a survey aimed at professionals may use technical or professional language related to the work of the respondents.

iii.   Response burden

Every effort should be made to consider the burden of responding to the questionnaire, the time and effort required to provide answers and whether other individuals or records have to be consulted. The number of questions should be kept to a minimum. Each question must have a reason for being on the questionnaire. (The purpose of some questions may be to ensure that respondents understand a subsequent question, or for evaluation purposes.)

iv.   Complexity of the data to be collected

Careful wording of the questions is necessary when collecting complex data. Instructions should be included in questions covering complex topics. This will help the interviewer to explain questions and the respondent to accurately answer them.

v.   Confidentiality and sensitivity of the information

These issues may directly influence how the questions are drafted. The questionnaire instrument should include introductory statements regarding how the confidentiality of respondent data is to be protected. It should also explain how the data are to be used, who has access to the data, how long the data will be kept, etc. When asking questions about sensitive issues (a question that respondents may not feel comfortable answering), it may be necessary to use techniques that soften the impact of asking the question. This increases the likelihood of a response (for more, see section 5.3.8).

vi.   Translation

The questionnaire should be translated into all languages that are commonly spoken by the target population. Care must be taken when translating questions from another language to take account of not only the language, but also different customs and culture.

vii.   Comparability of results with other surveys

When survey results are to be compared with other surveys, the questions must be drafted in the same manner. Each version of the question must cover the issue in the same way and have the same meaning in the context of the question. To ensure the comparability of the results with other surveys, the same question wording should be used after the quality of the earlier results is confirmed. Also, some questions may be sensitive to questions immediately preceding them.

viii.   Consistency

The wording of the question must have the same meaning for all respondents as that intended by the statistical agency. If the questionnaire is to be translated into different languages it is particularly important to test all language versions.

ix.   Other factors

Other factors to consider when drafting questions include:
-    the availability of the data being sought;
-    the respondent's willingness to provide the data;
-    the likelihood of nonresponse;
-    administrative requirements;

- the type of questions;
- the wording of each question;
- the layout of the questionnaire ;
- sources of measurement or response error;
- processing of the questionnaire.

Administrative requirements of the survey organisation include such things as data sharing agreements, a statement informing respondents of the confidentiality of their responses, bilingual versions of the questionnaire, etc.

Questions can be either open or closed (closed questions provide response categories). Types of questions are discussed in detail in section 5.2. Guidelines for wording survey questions are covered in section 5.3. Sources of response error are discussed in section 5.4. The layout of the questionnaire and processing considerations are presented in sections 5.5 and 5.6.

5.1.4   Review and Revise the Questionnaire

It is essential that the questionnaire be reviewed internally before it is tested. This review should identify any obvious problems with the questionnaire such as mistakes in spelling or grammar or awkward wording. It is also useful at this stage to have the questionnaire reviewed by people who are not directly involved with the project. Reviewers could include experts in the field of study, people who have experience designing questionnaires, interviewers or members of the population to be surveyed. They can often provide helpful comments and suggestions leading to revisions in the questions and response categories.

5.1.5   Test and Revise the Questionnaire

It is important to test all versions (i.e., all language versions) of the questionnaire on 'typical' respondents long before data collection begins (i.e., typical for the target population, which may mean respondents of a certain age, sex and level of education). It may also be important to test the questionnaire on specific subpopulations that may have problems with particular questions.

Responding to a question is a complex process. Respondents must first understand the question. They must then search their memories or records to retrieve the requested information. After retrieving the information, they must think about the correct answer to the question and how much of that answer they are willing to reveal. Only then do they communicate an answer to the question. Each of these processes may be a source of error.

Testing methods are intended to identify difficulties and errors with the questions. Testing can also identify whether the question order affects the interpretation of questions, whether instructions are clear and how respondents feel about the appearance of the questionnaire. The benefit of questionnaire testing includes the production of a respondent and interviewer friendly questionnaire which permits the collection of accurate data, with a format that facilitates data capture and coding thereby minimising errors and reducing the cost and time of data collection, capture and processing.

Methods used to test questionnaires (their content, layout, etc.) are typically based on small, subjective non-probability samples of respondents from the target population. The methods described in the following sections are:

- informal testing (pretesting);
- cognitive methods;
- focus groups;
- interviewer debriefings;
- behaviour coding of interviewer/respondent interactions;
- split sample tests;
- pilot tests.

5.1.5.1 Informal Testing (Pretesting)

Informal testing (sometimes referred to as pretesting) is easy and inexpensive and is a fundamental step in the development of a questionnaire. If no other testing of the questionnaire is done, as a minimum, informal testing should be performed. The size of the informal test sample can range from 20 to 100 or more respondents. If the main purpose is to discover wording or sequencing problems, very few interviews are needed. More interviews (50 to 100) are necessary to determine response categories for closed questions based on the responses to open questions in the informal test. The questionnaire should be administered in the same manner as planned for the main survey (e.g., interviewer-assisted in person or by telephone; paper or computer-assisted). However, self-enumeration questionnaires should be tested using an interviewer.

With informal testing, respondents are not debriefed; the respondent simply completes the questionnaire or interview, mirroring what would happen during the actual data collection. Informal testing only indicates where there is a problem. Without further investigation, it does not identify why or how it can be corrected. Also, informal testing may not identify all problems with the questionnaire.

Informal testing of questionnaires is used to:
- discover poor question wording or ordering;
- identify errors in questionnaire layout or instructions;
- identify problems with the computer software application, if computer-assisted;
- determine problems caused by the respondent's inability or unwillingness to answer the questions;
- suggest additional response categories that can be pre-coded on the questionnaire;
- provide a preliminary indication of the interview length and response rate (including item nonresponse).

5.1.5.2 Cognitive Methods

Cognitive methods are especially useful in testing questionnaires because they are designed to investigate the steps in the response process. Cognitive methods provide the means to examine a respondent's thought processes as he or she answers the survey questions. In this way, cognitive methods help assess the validity of questions and identify potential sources of response and nonresponse error.

Cognitive interviews provide the opportunity to evaluate the questionnaire from the respondent's point of view. They focus on issues such as comprehension and reactions to the form. This brings the respondent's perspective directly into the questionnaire design process, and leads to the design of respondent-friendly questionnaires that can be easily understood and accurately completed.

Cognitive interviews often take place in a 'laboratory' setting or room that has a one-way mirror for observation. Sample sizes are relatively small. As few as 12 to 15 to as many as 100 or more cognitive

interviews are used to test a preliminary version of a questionnaire. Because sample sizes are relatively small, an iterative approach is sometimes adopted whereby changes are made to the questionnaire following a few cognitive interviews before further testing takes place.

Cognitive testing methods include:

i.   The observation of respondents

The respondent is observed while completing the questionnaire. Observation provides information on respondent behaviour such as:
- areas of the questionnaire that are read;
- the sequence in which questions are answered;
- whether reference is made to instructions;
- the types of records consulted;
- whether another person is consulted;
- the time required to complete each section;
- corrections or changes made to responses.

ii.   Think aloud interviews

The respondent is asked to 'think aloud' while answering the questions, commenting on each question, and explaining how the final response was chosen. This type of think-aloud interview is called a concurrent think-aloud interview. If instead, the respondent explains his/her thought processes afterwards during a follow-up discussion, then the interview is called a retrospective think-aloud interview. Both of these methods are very useful in testing questionnaires and in identifying potential sources of error and improvements that can be made.

Specific techniques such as *probing questions, paraphrasing* and *confidence ratings* are used during cognitive interviews.

a.   Probing questions

Probing questions are used to focus on particular aspects of the response process (i.e., understanding, retrieving, thinking or responding). For example, the interviewer may ask how and why a respondent chose an answer, or how concepts, words and time reference periods were interpreted.

b.   Paraphrasing

The respondent is asked to repeat the instructions or the question in his or her own words, or to explain the meaning of terms and concepts. Paraphrasing helps determine whether a respondent has read and understood the instructions and questions as intended.

c.   Confidence ratings

The respondent rates the degree of confidence in the accuracy of his or her own answers. This technique indicates to what extent the respondent had difficulty in formulating an answer to a question and whether or not guessing was involved.

5.1.5.3 Focus Groups

A focus group is a discussion of a selected topic by participants who are chosen from the population of interest. Focus groups provide the opportunity to consult with members of the target population, data users, or interviewers so that their points of view can be brought into the questionnaire design process. In the early stages of questionnaire development, focus groups can be used to clarify survey objectives and data requirements, to identify salient research issues, definitions, and concepts. Focus groups are also useful in testing questionnaires. They are used to evaluate a respondent's understanding of the language and wording used in questions and instructions, and to evaluate alternative question wordings and formats.

A focus group is led by a moderator who is knowledgeable about group interviewing techniques and the purpose of the discussion. The size of each group is usually between 6 and 12 persons, with the optimum size being 7 to 9 persons. A focus group usually lasts for about two hours. Focus groups are audio-recorded (and sometimes video-recorded) and can be viewed by observers in an adjoining room behind a one-way mirror. The observation of focus groups by the questionnaire developers is recommended. Although observers do not take part in the focus group discussion, their observations can be helpful when communicated to the moderator at the end of the focus group session.

If a self-enumeration questionnaire is being tested, then the questionnaire can be completed immediately prior to the focus group discussion (time permitting) or completed in advance and brought to the focus group session by the respondent. If the questionnaire is interviewer-assisted, the interviewers can administer the questionnaire a few days before the focus group takes place.

A useful technique is to begin the focus group discussion by asking participants to provide their overall reaction to the questionnaire. Specific questions and issues concerning the questionnaire are then discussed. The focus group moderator reviews the whole questionnaire question-by-question or focuses on specific questions of interest. The moderator should be skilled at probing since some focus group participants may be reluctant to make negative comments even if they are pertinent. The moderator should also give each member the opportunity to speak, to avoid situations where one or two persons dominate the discussion. The focus group can be concluded by asking participants to recommend the most important improvement that they feel should be made to the questionnaire.

5.1.5.4 Interviewer Debriefings

Interviewer debriefings often take place after a focus group session or during informal tests. Interviewers discuss their experiences interviewing respondents and provide an understanding of how the questionnaire is performing. Their perspective can identify questionnaire improvements. Interviewer debriefings usually take place in a group setting that is very similar to a focus group. Alternatively, rating forms or debriefing questionnaires can be used to collect information about problems encountered with the questionnaire and suggestions for improvements.

5.1.5.5 Behaviour Coding of Interviewer/Respondent Interactions

While the questionnaire is being administered by an interviewer, behaviour coding can be conducted. This type of testing involves the systematic coding by a third party of the interaction between the interviewer and the respondent. The focus is on how the interviewer asks the questions and how the respondent reacts. The test interview is often audio-recorded and the interviewer-respondent relation is later analysed. Behaviour coding helps identify problems such as the interviewer failing to read the

question as worded or a respondent asking for clarifications. If behaviour coding indicates difficulties with a certain question, then corrective action may be warranted. Behaviour coding does not, however, usually provide information about the reasons for the problems nor solutions to them. A large sample size is often required to analyse the results of behaviour coding, especially if the questionnaire has many skip patterns that take respondents through various paths of the questionnaire.

5.1.5.6 Split Sample Tests

Split sample tests are conducted to determine the 'best' of two or more alternative versions of a questionnaire or question. Split sample testing is sometimes called 'split ballot' or 'split panel' experiments. It involves an experimental sample design that is incorporated into the data collection process. In a simple split sample design, half of the sample receives one version of the questionnaire while the other half receives the other version.

Besides comparing variations in questions, split sample tests can also compare different methods of data collection in order to determine which method is better. A probability sample design and adequate sample sizes are required to analyse differences between the samples.

5.1.5.7 Pilot Test

A pilot test is conducted in order to observe all stages of the survey process, including administration of the questionnaire. A pilot study is a 'dress rehearsal'; it duplicates the final survey design on a small scale from beginning to end, including data processing and analysis. It allows the statistical agency to see how well the questionnaire performs during all the steps in a survey (data collection, editing, imputation, processing, data analysis, etc.). Normally, the questionnaire is thoroughly tested using the methods mentioned previously before a pilot test takes place.

5.1.6   Finalise the Questionnaire

Questionnaire design is an iterative process: throughout questionnaire development and testing, changes are continually being made. Objectives and information requirements are formulated and re-evaluated, data users and respondents are consulted, proposed questions are drafted and tested, questions are reviewed and revised until a final questionnaire is developed. The final stage of the process comes when the decision is made that no further changes will be made to the questionnaire. At this point, the questionnaire is finalised and printed or programmed, depending on the data capture method being used.

5.2   Types of Questions: Open versus Closed

There are two types of questions: open and closed. ***Open questions are those where response categories are not provided to the respondent***. The respondent provides an exact numerical figure or answers the question in his or her own words which is either written down, in the case of self-enumeration, or recorded verbatim by the interviewer. Open questions should be followed by sufficient space to record the response.

An example of an open question is:

What is the most important problem facing Canada?

_____

_____

_____

Closed questions are those where response categories are listed with the question. Closed questions are answered by checking a box or circling the proper response from those provided. The possible responses listed for a question are called response categories.

An example of a closed question is:

Which of the following is the most important problem facing Canada? (Please check one only)
❍ *Unemployment*
❍ *Economy/Recession*
❍ *Federal Deficit*
❍ *Taxes*
❍ *National Unity*
❍ *Crime/Violence*
❍ *Environment*
❍ *Other*

Open questions allow the respondent to express an answer without being influenced by the response categories that would be provided by a closed question. However, this allows the question to be interpreted different ways. An open question therefore generally expands the scope of the question while the closed version gives the respondent clues about how the question is to be interpreted. Closed questions also restrict the respondent to a predetermined set of responses.

There are several applications of open questions. One advantage of open questions is that they allow the respondent the opportunity for self-expression or elaboration. This is important when examining an issue that is not well understood or is very broad. Consequently, open questions are often used during questionnaire development and testing. For example, they are used in focus groups to obtain comments and opinions on the question presented and to generate discussion. Open questions also allow the statistical agency to obtain the respondent's own 'natural' wording. This is important when examining question wording and response categories for a closed question.

Another advantage of open questions is that they can be used to obtain exact numerical data, for example a respondent's exact age. Business surveys often ask for exact amounts for reported revenues and expenses. Exact numerical data are necessary for certain types of data analysis (e.g., to calculate an average or median).

Another use of open questions is to provide follow-up to closed questions. For example, a closed question may ask:

Do you have any suggestions to improve our service to our customers?
❍ *No*
❍ *Yes*

If the respondent answers 'Yes,' then a follow-up open question might be:

If yes, what are your suggestions?

_____

_____

_____

Open questions such as 'Do you have any additional comments?' are often used at the end of sections of questions or at the end of the questionnaire. This ensures that the respondent has the opportunity to include everything that he or she feels is relevant to the issues being addressed by the questionnaire. Some respondents may want to include additional information to clarify an answer. It is important to plan for this type of information on the questionnaire.

There are disadvantages to open questions with write-in (as opposed to numeric) responses. They are burdensome since the respondent must determine the intent of the question and formulate an answer without the aid of response categories. And for self-enumeration surveys, recording the answer is time-consuming. For interviewer-assisted surveys, data collection, capture and coding is burdensome. It is often difficult for the interviewer to capture the respondent's answer verbatim and after collection, in order to facilitate processing and data analysis, all of the different responses are usually categorised and assigned a numerical code. Open questions, therefore, usually lead to more costly, time-consuming and error-prone processing than closed questions.

In the case of numerical data, open questions are more difficult for respondents to answer than closed questions and more difficult and prone to error during data capture.

Examples of open questions requiring write-in responses are:

> *What products or services does your business provide?*

> *What do you think you will be doing 5 years from now?*

> *Please comment further on any questions or issues covered in this questionnaire*

Examples of open questions requiring numeric responses are:

> *What is your best estimate of the total income before taxes and deductions of all household members from all sources in the past 12 months?*

> *How many years has the current owner operated this establishment?*

> *In a typical month, how often do members of your household use the Internet at home?*

There are numerous advantages to closed questions, the most important ones being that they are less burdensome to respondents and data collection and capture is cheaper and easier. They are quicker and easier to answer since respondents simply choose the appropriate response categories rather than formulate a response and state it in their own words. The respondent is more likely to answer the question as intended because the response categories indicate the focus of the questions. It is easier to analyse data that has been collected using closed questions, since the answers are more consistent and already grouped. Also, if a question is being used for several surveys, using the same response categories facilitates comparisons across surveys.

There are several disadvantages to closed questions. When drafting the questions, effort is sometimes required to develop the response categories (i.e., coding is done before collection, but it can still be difficult). As with all coding, the response categories must be mutually exclusive and exhaustive. If the response categories are not clearly formulated, the respondent could have more problems than if an open question were used. Another concern with closed questions is that because response categories are listed, the respondent may feel obliged to choose one of the response categories whether or not her or she has formulated an answer or even has the knowledge required to answer the question. For questions where an opinion is asked, this can force the respondent to choose a category that does not correspond to his or her opinion, or to express an opinion when in fact he or she has none. (To avoid this situation, a 'Do not know' and/or 'Not applicable' category is sometimes included. For interviewer-assisted questionnaires, it is common practice to include a 'Refused' response category.) Another potential problem is that response categories can oversimplify an issue by restricting a respondent's possible answer.

There are several kinds of closed questions: the most frequently used are two choice, multiple choice and checklist, ranking and rating questions. They are described below.

For more information on coding open and closed questions, see **Chapter 10 - Processing**.

5.2.1   Two-Choice Questions

The two-choice question is the simplest version of a closed question. Often it is a yes/no question and is used to split the respondents into two distinct groups. Two-choice questions are also used as screening questions to prevent respondents from being asked a series of questions that do not apply to them. The direction 'Go to question X' then appears directly after one of the response categories so that the respondents can skip some questions. This results in what is referred to as skip patterns in a questionnaire.

For example:

> *Did you smoke cigarettes yesterday?*
> ❍ *Yes*
> ❍ *No -------------Go to Question 14*

5.2.2   Multiple Choice and Checklist Questions

The *multiple choice question* asks the respondent to select *one response* from a list of choices, whereas the *checklist question* asks the respondent to pick *one or more responses* from the list. It may not be evident to the respondent whether the question is multiple choice or checklist. Therefore, instructions should be included. Note that an 'Other (specify)' category is normally provided to ensure that the list is exhaustive.

Example of a multiple choice question:

> *What type of dwelling is this? (Check one only)*

❍ *Single house*
❍ *Double (side-by-side)*
❍ *Garden home, town house or row house*
❍ *Duplex (one-above-another)*
❍ *Low-rise apartment (less than 5 stories)*
❍ *High-rise apartment (5 stories or more)*
❍ *Other (please specify)_____*

Example of a checklist question:

During your vacation, in what types of accommodation did you stay? (Check as many as apply)
❍ *Hotel (including tourist home)*
❍ *Motel*
❍ *Camping or trailer park*
❍ *Home of friends or relatives*
❍ *Commercial cottage or cabin*
❍ *Other (hostels, universities, etc.)*

The response categories for multiple choice and checklist questions require careful drafting. The list of response categories should be mutually exclusive and exhaustive. Consider the following example:

How old are you in years?
❍ *20-30*
❍ *30-40*
❍ *40-50*
❍ *50 or more*

The categories in this example are not mutually exclusive; they overlap. A respondent who is 30, 40 or 50 years old has a choice of two response categories. Data analysis would be difficult since it is impossible to know which category such a respondent would choose. Another problem with the response categories is that the list is not exhaustive. If persons under 20 are part of the target population, how would they answer this question? A better choice of response categories would be:

How old are you in years?
❍ *under 20*
❍ *20-29*
❍ *30-39*
❍ *40-49*
❍ *50 or more*

5.2.3   Ranking Questions

Another type of closed question is the ranking question, where the respondent is asked to order the response categories. For example:

Here is a list of some of the ways that people go about finding jobs. Please rank them in order of effectiveness by placing the number '1' beside the method you think would be most helpful, a '2' beside the method you think would be second most helpful, and so on.

    ____   *Mailing out résumés*
    ____   *Newspaper or magazine ads*
    ____   *Government Employment Centres*
    ____   *Checking with friends*
    ____   *A private placement service*
    ____   *Direct contact with employers*
    ____   *Other (please specify)* _____

Respondents often find it burdensome to rank categories, especially if the items to be ranked are very different from each other, or if the interview is conducted over the telephone. Another problem with ranking questions is that the sizes of the rank intervals are unknown and unlikely to be equal: the interval between 1 and 2 cannot be interpreted to be the same as that between 2 and 3. This complicates data analysis. For example, if three items are listed to be ranked, a respondent will rank them 1, 2 and 3, but it may be that the respondent considers the first two to be very close and the last item to be a distant third. Such information cannot be gleaned from the simple ranking. Another problem is that a respondent may assign two or more items the same ranking. In the above example, a respondent might rank both 'Newspaper or magazine ads' and 'Government Employment Centres' as 1. Another problem with ranking questions is that respondents may not be able to rank all the choices on the list. It may be reasonable to expect respondents to only rank a few (e.g., five or less).

The following is an example of a ranking question where the respondent is asked to select the most important factors and then rank only the ones that are important.

> *Please rank the 5 most important factors that influence your company's choice of a transportation carrier. This information will help us to focus our attention and resources on areas that are critical to meeting your service needs.*
>
> *Please rank their importance by placing the number '1' beside the factor that you think is the most important, a '2' beside the factor that you think is the second most important, and so on.*
> ___   *Damage-free transportation*
> ___   *Price*
> ___   *Marketing and sales representatives*
> ___   *Customer service representatives*
> ___   *Prompt resolution of service problems*
> ___   *Freight claims handling*
> ___   *Service consistency*
> ___   *Service frequency*
> ___   *Transit time*
> ___   *Timely notification of service delays*
> ___   *Invoicing accuracy*
> ___   *Other (please specify)*

5.2.4   Rating Questions

With rating questions, respondents are asked to rate their answer. For example:

How satisfied are you with our customer service?
❍ *Very satisfied*
❍ *Satisfied*
❍ *Dissatisfied*
❍ *Very dissatisfied*

There are several considerations when formulating a rating question. First, how many categories should the rating scale have? It could have just two – agree, disagree – or as many as 10, ranging from 1(not at all important) to 10 (extremely important).

Second, there is the issue of whether or not the rating scale should have a neutral alternative – for example, neither satisfied nor dissatisfied. In the absence of a neutral alternative, the respondent is forced to make a choice. On the other hand, when a neutral response category is offered, respondents tend to choose it. One option is to include the neutral alternative in an interviewer-assisted questionnaire but not offer it to the respondent. This way it is selected only if the respondent spontaneously expresses it.

The above example does not offer a neutral alternative; the one below does.

How satisfied are you with our customer service?
❍ *Very satisfied*
❍ *Satisfied*
❍ *Neither satisfied nor dissatisfied*
❍ *Dissatisfied*
❍ *Very dissatisfied*

The third consideration when formulating a rating question is whether to include a category such as 'Do not know/no opinion' or 'Not applicable'. This depends on the question being asked. For example, when asking about a particular service that the respondent may have never used, it is necessary to include a 'not applicable' category.

For each of these issues (the number of categories on rating scale, the use of a neutral alternative, the use of 'not applicable'), the solution depends on the survey objectives, the item to be rated, the method of data collection and the statistical agency's own preferences.

The ranking question presented earlier in section 5.2.3 about the choice of transportation carriers can be reformatted as a rating question as follows:

Listed below are a number of factors that influence a company's choice of a transportation carrier. Some may be more or less important to your company than others. According to your company's priorities, please rate the importance of each factor from 1 to 10 where 1 means 'Not at all important' and 10 means 'Extremely important'.

___   *Damage-free transportation*
___   *Price*
___   *Marketing and sales representatives*
___   *Customer service representatives*
___   *Prompt resolution of service problems*
___   *Service consistency*
___   *Service frequency*
___   *Transit time*
___   *Timely notification of service delays*
___   *Invoicing accuracy*

While the rating question version would take longer to ask in an interview, it is much easier for the respondent to rate each response category than to rank the response categories. This is particularly true for telephone interviews.

5.3   Guidelines for Wording Survey Questions

Questions should be formed so that they are clear and meaningful to survey respondents. Survey data will be of higher quality if respondents can easily understand the meaning of the words used. Respondents will also be more willing and able to provide information if they clearly understand what is being asked of them. Furthermore, it is essential that respondents understand a survey question in the way intended by the questionnaire designer.

The wording of a question can distort survey results and provide inaccurate data if respondents:
-    do not understand what the words in a question mean;
-    interpret the words differently than intended;
-    are unfamiliar with the concept(s) conveyed by the wording of a question.

To avoid these problems, the following sections describe some general guidelines to keep in mind.

5.3.1   Keep it Simple

The best way to communicate clearly with respondents is to use simple, everyday words and to make sure that all terms are appropriate for the population being surveyed. The following question does not use simple, everyday language.

> *Are you aware of the impending amalgamation of surrounding constituencies into the New Metro area?*

Many survey respondents may not be aware of, or understand, the meaning of the terms: *impending amalgamation, constituencies,* or *New Metro area*.

Always consider the language skills of respondents when developing questions. Try to choose words that are easy for everybody to understand. When surveying more educated populations such as lawyers, teachers or other professionals, it is possible to use more complex language. The important thing is that the language used should correspond to what is commonly understood by the target population.

In general, avoid using technical words or specialised jargon with which respondents are unfamiliar. However, if such terms are needed, respondents should be given additional clarification or definitions. New or complex concepts must be defined so that all respondents have the same understanding of the question. Definitions can be included in the question, in a set of instructions for respondents that appears elsewhere on the questionnaire or in a separate instruction booklet (although a separate booklet is less likely to be read).

The following question does not use simple, common words.

> *Have you ever received a pneumococcus vaccination?*

It is likely that most people in the general population would not know the medical term, *pneumococcus,* and thus would have a hard time answering the question. As a result, many people would probably not be able to provide an accurate response. Better wording would be:

> *Have you ever received a flu vaccination?*

5.3.2   Define Acronyms and Abbreviations

Acronyms and abbreviations are often found in technical and scientific writing, as well as in legal and business writing. They are best used in contexts where readers are familiar with them. In surveys of the general population, they should not be used unless they are commonly used. Questions are more likely to be clearly understood if they contain the complete form of the word, term or organisation they refer to, rather than the abbreviation. Any acronyms or abbreviations that must be used should always be defined first.

The following question uses an acronym that may confuse respondents.

> *Do you know the location of the nearest PFRA office?*

Many respondents will not know that PFRA is the acronym for Prairie Farm Rehabilitation Administration.

5.3.3   Ensure that Questions are Applicable

It is important to make an effort to minimise the burden on respondents. One important way to do this is to ensure that respondents are only asked questions that are relevant to them. This reduces the length of interviews, cuts down on the time respondents are required to participate, and lowers the cost of the survey.

For example, the following question would not apply to all respondents – only to those who are employed.

> *What is your present occupation?*

This question should follow a screening question designed to find out if a respondent is employed, and it should only be asked of those who indicate that they are. Although the question seems harmless, it could prove annoying to those who are not employed.

Questionnaire designers should also ensure that respondents have enough knowledge to answer the questions asked. If not, they may choose not to respond, or they may give a false answer. For example, few people in the general population have enough specialised knowledge to provide an informed answer to the following question.

> *Do you think that incineration at $1600^{o}C$ for 30 minutes is an adequate way to dispose of polychlorinated biphenyls?*

5.3.4   Be Specific

The wording of survey questions must be as specific as possible to ensure that respondents understand exactly what is required of them. Here, a similar process as that used to define concepts, presented in **Chapter 2 - Formulation of Survey Objectives**, is used. The questionnaire designer must ask: Who? What? Where? and When? For each question, it should be clearly specified:
- Who the question applies to;
- What information should be included in or excluded from the response;
- What units the answer should be provided in (e.g., kg or lbs);
- What time period the question refers to (When?).

At first glance, the following question may seem simple and straightforward.

> *What is your income?*

Upon reflection, however, the question is not that easy to answer. First, it is not evident who the word *your* refers to. Does it refer to the respondent's personal income, his or her family income, or his or her household income? This should be made clear. Second, what is the *time period* that the respondent should provide the requested income information for? Last week, last month, or last year? Finally, what should the respondent count as income? Salary and wages only? Salary and wages including gratuities? Salary and wages, as well as income from other sources? Or something else?

The following two examples show better ways to ask the question (assuming that 'household' has been defined for the respondent).

> *What was your household's total income, from all sources before taxes and deductions, for last year?*

> *Last year, what was your total household income before deductions? Include income that you received from wages, salaries, and all other sources.*

The following question illustrates the problem that can occur when the wording of a question is not specific enough. Prior to being asked this question in a survey, respondents were shown a bottle of orange beverage (*A Civil Action 47LL* (1945), U.S. D.C. N.J., U.S. vs 88 Cases – Bireley's Orange Beverage).

> *How much orange juice do you think it contains?*
> Here are examples of the many different responses that could be given:

❍ *one orange and a little water and sugar*	❍ *one-fourth orange juice*
❍ *25% orange and 75% carbonated water*	❍ *very little, if any, orange juice*
❍ *juice of one half dozen oranges*	❍ *do not know*
❍ *3 ounces of orange juice*	❍ *not very much*
❍ *full strength*	❍ *3 to 4 ounces of orange juice*
❍ *a quarter cup of orange juice*	❍ *a pint*
❍ *none*	❍ *most of it*
❍ *not much*	❍ *about a glass and a half.*

More precise ways to word the orange juice question follow:

> *This bottle holds 300 ml of a drink. How many millilitres of that would you say is orange juice?*
> *___ ml*

> *What percentage of this drink would you say is orange juice? ___ %*

> *What part of this drink—a quarter, a half, three-quarters, or what—would you say is orange juice? ___*

Each of these questions requests an answer in specific units: millilitres, a percentage, or a fraction. By asking the questions in one of these ways, the statistical agency is more likely to be given responses in the units mentioned in the question.

5.3.5   Avoid Double-Barrelled Questions

A question that actually asks two questions in one is called a double-barrelled question. These questions generally deal with more than one concept. For example:

> *Do you plan to leave your car at home and take the bus to work during the coming year?*

This question may be very difficult for some respondents to answer since their personal situation may not fit into a simple yes or no. For example, a respondent may plan to:
-   take the car sometimes and take the bus sometimes;
-   always leave the car at home and always bicycle to work;
-   take the car sometimes and bicycle to work sometimes;
-   always leave the car at home and always travel to work by some other means;
-   take the car sometimes and travel to work by some other means sometimes;
-   some other combination.

The question really asks two questions: *Do you plan to leave your car at home during the coming year?* and *Do you plan to take the bus to work during the coming year?* The best solution may be to split the question into these two questions.

Questionnaire designers should review all questions containing the words *and* and *or* to see whether they are likely to confuse respondents. It is a good idea to examine the objective of such questions to determine if a single question is appropriate or whether it would be better to:
-   split the question into two or more questions;
-   highlight key words in the question;
-   provide clarifying instructions;
-   provide examples;
-   ask only what is relevant to the survey's objectives.

That being said, it is important to recognise that not all questions containing the words *and* and *or* are necessarily double-barrelled. For example:

> *What is the language you first learned and still understand?*

The objective of this question is to determine, among the languages the respondent understands, which was the first one learned. The answer required is the language that satisfies both conditions in the question. Although this may be evident to the questionnaire designer, some respondents may not be sure

how to respond. To help respondents understand what is required, it is a good idea to provide instructions with examples, and to emphasise the word *and* in the question, for example:

> *What is the language you first learned **and** still understand?*
> *(Respondent instructions: This question is asked to determine the language that satisfies the two conditions, language **you first learned** and **still understand**. For example, a person may have first learned Chinese but no longer understands it because he/she emigrated to Canada at a very young age. Hence, the response Chinese would be incorrect since it does not satisfy the two conditions of the question. Subsequently, the next language learned was English and the person still understands it. In this case, the correct response to the question is English, which is the language first learned and still understood.)*

5.3.6 Avoid Leading Questions

A leading or loaded question is one that suggests or leads the respondent to a certain answer. In other words, the way the question is phrased has an influence on the response. Leading questions can distort survey responses and affect survey results.

Leading question:

> *Please tell me whether you agree with, disagree with, or have no opinion on the following statement: 'Tourism is beneficial to Northumberland County and therefore should be promoted.'*

Neutral question:

> *Please tell me whether you agree with, disagree with, or have no opinion on the following statement: 'Tourism to Northumberland County should be promoted.'*

Survey questions should ensure that all possible alternatives are clear to the respondent. If not, it can result in a leading question that adversely affects the survey results. The following question leads to only one response alternative (Payne, 1951).

> *Do you think most manufacturing companies that lay off workers during slack periods could arrange things to avoid layoffs, giving steady work right through the year?*
> ❍ *Yes*
> ❍ *No*
> ❍ *No option*

Results
> *63%   Yes, companies could avoid layoffs*
> *22%   No, companies could not avoid layoffs*
> *15%   No opinion*

In this question, the only alternative offered respondents is whether they think companies *can arrange things to avoid layoffs*. Often, when only one alternative is presented, there is a tendency for respondents to agree with that alternative. In this example, 63% of respondents said they thought that *companies could avoid layoffs*—the only option provided in the question. An alternate wording for the same question follows.

Do you think most manufacturing companies that lay off workers during slack periods could arrange things to avoid layoffs, and provide employees with steady work throughout the year, or do you think that layoffs are unavoidable?
❍ *Yes, companies could avoid layoffs*
❍ *No, layoffs are unavoidable*
❍ *No opinion*

Results

      35%   Yes, companies could avoid layoffs
      41%   No, layoffs are unavoidable
      24%   No opinion

This question includes two clear alternatives: *companies could avoid layoffs* and *layoffs are unavoidable.* When this question was asked, the results were more evenly distributed between *yes, no* and *no opinion* than for the previous question.

In theory, providing possible alternative responses in the question makes it more likely that people will reflect on the answer before responding and thus provide a more reliable answer.

5.3.7   Avoid using Double Negatives

Sentence structures that contain double negatives should be avoided because respondents will not know whether they agree or disagree. For example,

      Would you be for or against not allowing the sale of alcohol in convenience stores?

To answer the question, the respondent would have to figure out that being *for* not allowing the sale of alcohol in convenience stores would be to be *against* allowing it. Similarly, to be *against* not allowing the sale of alcohol in convenience stores would be the same as being *for* allowing it.

This question is difficult because it contains a double negative: *against* and *not* are both negative words. Questions containing double negatives are often confusing to respondents who, without realising it, may give an answer that contradicts their beliefs. It is far better to rephrase the question so that it contains no more than one negative word. A clearer version of this question follows:

      Would you be for or against allowing the sale of alcohol in convenience stores?

5.3.8   Soften the Impact of Sensitive Questions

Questions that respondents consider sensitive, personal or threatening may lead to *social desirability bias*. Respondents tend to choose the response that is most favourable to their self-esteem, or that accords with social norms, rather than express a real belief or reveal the truth. This can result in the under-reporting of behaviours or characteristics being measured.

For example, the following questions may result in social desirability bias:

      Was there ever a time when you were not able to provide for your family?

Have you ever driven a motor vehicle after having had too much to drink?

What is your income?

How much do you weigh?

In the past month, how often have you participated in chat groups on the Internet?

Have you ever thought about committing suicide?

As mentioned in **Chapter 4 - Data Collection Methods**, some methods of data collection (namely, self-enumeration questionnaires and telephone surveys) are more anonymous than others, so respondents are less threatened by sensitive questions. If the questionnaire is administered by an interviewer, sensitive questions, in particular, should not be asked of a respondent when others are present.

Careful wording can also help reduce the impact of sensitive questions on survey responses. There are several techniques for asking a sensitive question in a less threatening way. One approach is to introduce the question by suggesting that the sensitive behaviour is not uncommon. Terms such as *many people* or *most people* can be used to introduce the question. When using this technique, care must be taken not to introduce bias (i.e., the question should not induce the respondent to report behaviour that never occurred). Another technique is to use warm-up questions; lead into the sensitive question with a number of related, less sensitive questions. A third technique is to use a closed question with a range of response categories. For example, for personal information such as age or income, or the frequency of undesirable behaviour, the respondent may be more willing to answer the question if a range of responses is provided. For example:

> *What was your total personal income before deductions last year? (Include income that you received from wages, salaries, and all other sources.)*
> ❍ *Less than $20,000*
> ❍ *$20,000 to $39,999*
> ❍ *$40,000 to $59,999*
> ❍ *$60,000 to $79,999*
> ❍ *$80,000 to $99,999*
> ❍ *$100,000 or more*

5.3.9   Ensure that Questions Read Well

Survey questions should be as concise as possible and use everyday language that the survey population has no trouble understanding. Respondents should be addressed in the second person (*you*) for a friendly, personal tone and basic rules of grammar should be followed.

The most important test is how the questions sound when read out loud. They should sound natural and conversational, and be easy for the listener to follow. The following question does not follow this guideline.

> *How would you rate the usefulness of the provision of information on the psychological and sociological aspects of transition such as access to the computerised interactive vocational counselling program provided by the departmental regional office to retiring employees where available and as determined by the regional personnel officer?*

This question is too long, uses complex language and constructions and sounds stiff and bureaucratic – all of which makes it difficult to understand and answer.

5.4 Response Error

In **Chapter 3 - Introduction to Survey Design** one of the sources of nonsampling error discussed was measurement error, which is the ***difference between the recorded response to a question and the 'true' value***. In the questionnaire design literature, this error is more commonly referred to as response error. Since the questionnaire is the means by which data are collected, it can be a major source of response errors. It is therefore crucial that the questionnaire be designed and tested to minimise such errors.

5.4.1 Sources of Response Error

Response errors can occur anywhere in the question-answer-recording process. The errors can be attributed to the questionnaire, the respondent, the interviewer, the method of data collection or the measuring tool (in the case of a direct measurement survey).

Sources of response error due to the questionnaire have already been mentioned in previous sections. For example, closed questions can force the respondent to choose a response whether or not he or she has an opinion or even the knowledge to answer the question, and social desirability bias can be a problem with sensitive questions. Any poorly worded question can be misinterpreted. In general response errors caused by the questionnaire may be due to:
-    the type of question (open or closed);
-    the wording of the question;
-    the length of the questionnaire (leading to respondent fatigue);
-    the layout of the questionnaire (e.g., complicated skip patterns can cause errors, particularly for paper questionnaires, see section 5.5);
-    the processing of the questionnaire (see section 5.6).

The respondent may also have difficulty recalling past behaviours or events. This source of response error is called *memory error*. One type of memory error is *recall error* whereby the respondent does not recall all the events that occurred within the reference period. This results in the under-reporting of behaviours or events. The reverse situation is also possible. The respondent may report activities that occurred outside the reference period as having occurred during the reference period. This source of error is called *telescoping error* and it usually results in the over-reporting of behaviours or events. This is because respondents tend to report behaviours or events as having occurred more recently that they actually did. This is called *forward telescoping*. Respondents may occasionally report that behaviours or events occurred longer ago than they actually did. This is called *backward telescoping*. Generally speaking, the longer the reference period, the greater is the recall loss (and hence the potential for recall error). However, shorter reference periods tend to increase telescoping errors.

Repeated surveys can experience what is referred to as the *seam problem*, which occurs when an abnormally large number of changes are reported at the seam of two reference periods compared to the number changes within a reference period. It can be corrected using dependent interviewing.
Some examples of questions that require the respondent to recall past events or behaviours are:

> *In the last 12 months, how many times did you visit a medical doctor?*

During the last month, which magazines have you read?

During the last week, which TV programs did you watch?

Interviewers can also be a source of response error. Each interviewer must ask the questions in the same manner each time an interview is conducted. If there are several interviewers and one interviewer modifies the wording of a question, then the meaning of the question can be changed. Interviewers may also incorrectly record the response – carelessly or deliberately (believing that the respondent should have answered differently) or through misinterpretation of the response. In direct measurement surveys, the characteristic (e.g., blood pressure) could be incorrectly measured being measured by the interviewer. Interviewers, by their reaction to answers, can also influence respondent behaviour. For example, if the interviewer expresses surprise at how much a respondent spends on clothing, the respondent may report less for subsequent expenditure questions.

5.4.2   Techniques to Reduce Response Error

The sources of response errors can be identified and techniques employed to reduce the impact of these types of errors.

The length of the question may have an impact on response errors. Questionnaires often cover a variety of topics. For questionnaires administered by an interviewer, it is difficult for the respondent to anticipate the next question. A technique that aids the respondent to focus on a new topic is the use of longer questions which are still specific, simple and clear. A longer version of a question gives the respondent more time to formulate an answer. Research suggests that the longer question may stimulate the respondent to talk more, and that this additional talk may aid the respondent's recall. Also, it may give the respondent more time to think and to provide a more complete answer.

Short question:

What health problems have you had in the past year?

Long question:

The next question asks about health problems during the past year. This is something that we ask everyone in the survey. What health problems have you had in the past year?

In order to reduce response errors introduced by interviewers, they should be well trained and quality control procedures such as re-interviewing techniques should be implemented in order to identify problems and provide retraining to the interviewers as needed.

To reduce response errors introduced by the questionnaire, every effort should be made to produce a well-designed questionnaire as outlined in this chapter.

If problems with memory are detected in a questionnaire, any of the following techniques can be used:

i.   The reference period can be shortened if it is determined that the respondent has difficulty remembering all the events that occurred within the reference period.

This can occur for events that occur frequently. For example, if there is a question about the number of times the respondent visited the doctor in the last year it may be difficult to recall every occurrence if the respondent visited the doctor often. With a shorter reference period, it is possible that the answers will be more accurate than with the longer period. However, the reference period should not be so short that an insufficient number of events are reported. During the evaluation of the questionnaire, the optimal length for the reference period could be determined.

ii.   Use of a calendar, or milestones like holidays can also help to minimise memory error.

iii.   A technique to reduce telescoping errors is bounded recall.

Respondents are interviewed at the beginning and at the end of the reference period. The events identified at the time of the first interview can be discounted if they are reported again during the second interview.

iv.   Dependent interviewing can also be performed for repeated surveys to reduce response error.

With dependent interviewing information provided by a respondent in a previous cycle of the survey is made available at subsequent cycles. This can help respondents place events in the requested time frame and prevent them from reporting previously reported events.

v.   If it is difficult for the respondent to report an event accurately, it may be possible to make use of records.

For example, if the respondent is asked to report income for the past year, the respondent could confirm the answer by referring to their income tax forms. There may be other situations where the respondent keeps records. Some people keep records of household expenses, such as monthly telephone bills or records of fuel purchases. The use of records to reduce memory errors is more likely to be applied to the self-enumeration questionnaire.

vi.   Another technique that is useful for self-enumeration questionnaires is the diary.

When it is important to collect detailed information over an extended period of time, the respondent can use a diary to record the events as they occur. Diaries tend to be used for surveys on household expenditures, food consumption, time use, television viewing and radio listening.

In the case of interviewer-assisted questionnaires, other techniques can be used to aid the respondent in accurately answering the questions. If the respondent is asked to report food consumption over a 24-hour period it may be difficult for the respondent to indicate portion sizes. The interviewer could have visual aids available that would indicate various portion sizes and the respondent could select the appropriate one.

Other survey design issues such as the timing of data collection can also improve recall, for example scheduling an income survey in April.

5.5   Questionnaire Layout

In addition to question type and wording, the order of the questions, transitional statements, instructions and the format of the questionnaire also play an important role in creating a quality questionnaire.

5.5.1   Sequencing of Questions

The order of the questions should be designed to encourage the respondent to complete and maintain interest in the questionnaire or interview. The sequence of questions should be logical to the respondent and facilitate recall. The questions should flow smoothly from one question to the next. Questions on a subject should be grouped together.

i.   Introduction

The introduction to the survey – read by or to the respondent – is very important because it sets the tone for the whole questionnaire. The introduction of the questionnaire should:
-    provide the title or subject of the survey;
-    identify the sponsor of the survey;
-    explain the purpose of the survey;
-    request the respondent's co-operation;
-    explain why it is important to complete the questionnaire;
-    ensure that the value of providing information is made clear to the respondents;
-    explain how the survey data will be used;
-    explain how the respondent can access the survey results;
-    indicate that the answers will be kept confidential and indicate any agreements to share data with other statistical agencies, government departments, clients, etc.;
-    for mail surveys, provide the return address and the date for return.

ii.   Opening questions

The opening questions play an important role in encouraging the respondent to participate in the survey. The first question should relate directly to the purpose of the survey and apply to all respondents, otherwise the respondent will question the relevance of the survey. The first questions should also be easy to answer; starting with an open question that requires a detailed answer may lead to nonresponse if the questionnaire is perceived to be too burdensome to complete.

iii.   Placement of sensitive questions

Careful consideration should be given to the placement of sensitive questions. If introduced too early, the respondent may be reluctant to answer them, while if asked at the end of a long questionnaire, respondent fatigue may play a role in the quality of the answers. Therefore, sensitive questions should be introduced at a point where the respondent is most likely to feel comfortable answering them and where they are most meaningful in the context of other questions. For example, sensitive questions about health should be introduced in the section with other health-related questions.

iv.   Placement of demographic and classification questions

This information is often used for grouping purposes for data analysis and to allow comparisons across surveys. The reason for asking these types of questions should be explained, for example, 'The next few questions will help to relate information on your health to that of other people with similar backgrounds.' In the case of household surveys and other social surveys, the demographic information is occasionally located at the end of the questionnaire.

5.5.2   Transitional Statements

Transitional statements are used in questionnaires to introduce sections of related questions. Their use is important in interviewer-assisted questionnaires because it indicates to the respondent that a new topic is going to be discussed. For example:

> *Part A - We first would like to collect some background information about your farm operation.*
>
> *Part B - We would now like you to provide information about your production acreage in the last year.*
>
> *Part C - The next questions are about your farm business income statements during the last year.*

5.5.3   Instructions

Whether self-enumeration or interviewer-assisted, a questionnaire should include clear, short and easy-to-find instructions. These instructions may be placed directly above the questions concerned, at the beginning of the questionnaire, in a separate guide that accompanies the questions, on a fold-out page, etc.

In the following example the instructions are included in bold as a part of the second question.

> *For whom did you work?*
>
> *What kind of business, industry or service was this? Give a full description.* **For example, paper box manufacturing, road construction, retail shoe store, etc.**

If the instructions are located elsewhere in the questionnaire, the respondent or interviewer must be told where to find the instructions. For example, the question could refer the respondent to instructions in a reference guide. Sometimes instructions are included at the beginning of the questionnaire or at the beginning of a section of the questionnaire. For example:

> *Note: The following questions refer to your job or business last week. If you did not have a job or business last week, answer for your job of the longest duration since January 1. If you had more than one job last week, answer for the job at which you worked the most hours.*

In the above example, the directions are included before the questions are asked and may be presented in a different typeface than that used for the questions.

Definitions should be provided at the beginning of the questionnaire if they are relevant to questions throughout the questionnaire, otherwise they can be provided in the specific questions as required. The use of boldface print emphasises important items such as reference or reporting periods so that the respondent is more likely to think in terms of the reference period of the question. If it is necessary to specify particular items as inclusions or exclusions, it is best to include them directly in the questions and not as separate instructions. For example:

> *How many rooms are there in this dwelling?*

- Include the kitchen, bedrooms, finished rooms in the attic or basement, etc.

Last year, did any of the operators of this agricultural operation suffer a farm-related injury that required medical attention from a health professional (doctor, nurse, etc.) or resulted in lost work time?
- Include only injuries to operators of this agricultural operation.
- Do not include chronic health conditions.

What is the total area of field crops to be harvested this year, even if they were sown or planted in an earlier year?
- Include all field crops whether the land area is owned, rented or leased from others.
- Include all land to be seeded even if it is not yet seeded.
- Report the areas only once, even if more than one crop will be harvested this year.

How many weeks per year do you usually work at this position? Please include paid vacation and other paid leave.

For paper questionnaires, skip instructions should be clearly indicated. Well-placed and bold arrows should be used to direct the respondent or interviewer to the next appropriate question. Skip instructions should be clearly linked to the relevant response box (e.g., by lines connecting directly to the response box or circle). Finally, the use of skip instructions should be minimised on self-enumeration questionnaires.

5.5.4   Format Considerations

There are many considerations when organising the printed word on paper or a computer screen. Consistency of typeface and font should be maintained for questions, instructions, headings and transitional statements. The use of different typeface and font for questions and instructions allows the respondent or interviewer to easily identify the questions. Titles and section headings are usually in a larger font than the questions and response categories. The questions should be numbered consecutively throughout the entire questionnaire. Numbers, titles or letters can indicate sections. Data entry codes that appear on the questionnaire should not interfere with the questions or the numbering of the questions.

It is a good idea to provide titles or headings for each section of the questionnaire. For example:

INFORMATION FOR RESPONDENTS

SECTION 1: General Information
SECTION 2: Statement of Income
SECTION 3: Capital Expenditures
SECTION 4: Labour Force
SECTION 5: Comments

All aspects of the questionnaire relating to how the questionnaire looks must be considered. For self-enumeration questionnaires, the front cover is extremely important since it must attract the attention of the respondent. Decisions have to be made regarding the type and size of paper used for the questionnaire.

Colour can be used in several ways on questionnaires. Different versions of the questionnaire (e.g., for different languages) can be printed on different coloured paper. As well, for questionnaires printed on

coloured paper, the response boxes are white or a lighter shade of the same colour. This aids the respondent or interviewer in finding the correct placement of the answer for each question.

The convention of using response boxes for open questions and response circles for closed questions is another way to aid the respondent or interviewer. It is easier to identify where the answer should be entered when using this convention. The circle for closed answer categories should be consistently placed either before or after the answer. Graphics can be used to enhance the questionnaire. If appropriate, the graphics can be used to indicate section topics but should not interfere with the completion of the questionnaire.

For computer-assisted interview applications, Statistics Canada's has developed standards in order to present a common interface to all interviewers and reduce development, testing and training costs. These standards apply to such things as:
- the use of colour and/or black and white;
- fonts;
- function keys;
- navigation keys;
- standard question screens;
- Microsoft Windows interface.

Details of these standards can be found in *Screen Display and Functionality Standards for Social Survey Full BLAISE Applications* (2001).

5.6   Processing Considerations in Questionnaire Design

Processing transforms survey responses obtained during collection into a form that is suitable for tabulation and data analysis. It includes all data handling activities after collection and prior to estimation. In order to streamline processing, some activities – namely, data capture, editing and coding – can be done during data collection with a computer-assisted application.

Processing tasks should be considered during the design and development of the questionnaire. The coding scheme should be developed at the same time as the questions are drafted. The codes associated with closed questions should appear on the paper questionnaire. As well, consideration should be given to data capture when deciding on the layout of a paper questionnaire.

The ease with which data capture of paper questionnaires can be accomplished is affected by the layout of the questionnaire. The consistent placement of numeric codes next to response categories and the alignment of questions in columns facilitates data capture. All the processing steps involving the questionnaire (data capture, coding, etc.) should be tested to ensure that the questionnaire works effectively with these operations.

When drafting questions the impact on data capture should be considered. Each questionnaire should include a unique identification number. This facilitates the verification of data capture. Sometimes it is necessary to go back to the original questionnaire to determine if the information has been captured accurately. For paper questionnaires, the data should be captured as soon as possible after receiving them. This allows for the implementation of systems used to verify that the information on the file is the same as the information on the questionnaire.

For more details on processing, see **Chapter 10 - Processing**.

5.7 Summary

This chapter addressed how to design and develop a questionnaire. The first step is the formulation of survey objectives. Next, data users and respondents are consulted and questionnaires for similar surveys are reviewed. A draft version of the questionnaire is composed which should be tested and revised thoroughly before finalising the questionnaire. Testing can include: informal testing, cognitive testing, focus groups, interviewer debriefings, behaviour coding, split sample tests and a pilot test.

Questions can be of two types: open or closed. Closed questions may be two-choice questions, multiple choice, ranking or rating questions. Open questions allow for self-expression but can be burdensome and time-consuming as well as difficult to analyse. Closed questions are usually less burdensome for the respondent and data collection and capture is cheaper and easier. However a poor choice of response categories can cause response error.

When wording a survey question, the following guidelines should be followed:
- keep it simple;
- define acronyms and abbreviations;
- ensure questions are applicable;
- be specific;
- avoid double-barrelled questions;
- avoid leading questions;
- avoid using double negatives;
- soften the impact of sensitive questions;
- ensure that questions read well.

The questionnaire should be designed to minimise possible response errors. The layout of the questionnaire is also important. The introduction and sequencing of questions can help or hinder respondent participation. Transitional statements introducing new topics should be used and instructions for the respondent or interviewer should be clear, short and easy-to-find. The general format of the questionnaire should be assessed for their impact on the respondent and interviewer: the font, section headings, colour of the questionnaire, format of response categories, etc. Finally, how the questionnaire is to be processed should be considered: it should be designed to facilitate data collection and capture.

Bibliography

Advertising Research Foundation. 1985. *Focus Groups: Issues and Approaches.* Advertising Research Foundation, Inc., New York, New York. 10022.

American Statistical Association. 1993. How to Conduct Pretesting. *The Section on Survey Research Methods.* American Statistical Association.

Babyak, C., A. Gower, L. Gendron, J. Mulvihill and R.A. Zaroski. 2000. Testing of Questionnaires for Statistics Canada's Unified Enterprise Survey. *Proceedings of the International Conference on Establishment Surveys II*. American Statistical Association.

Biemer, P.P., R.M. Groves, L.E. Lyberg, N.A. Mathiowetz and S. Sudman, eds. 1991. *Measurement Errors in Surveys*. John Wiley and Sons, New York.

Bishop, G.F. 1987. Experiments with the Middle Response Alternative in Survey Questions. *Public Opinion Quarterly,* 51: 220-232.

Bureau of the Census. *Pretesting Policy and Options: Demographic Surveys at the Census Bureau*. U.S. Department of Commerce, Washington, D.C.

Carlson, Lynda T., J.L. Preston and D.K. French. 1993. Using Focus Groups to Identify User Needs and Data Availability. *Proceedings of the International Conference on Establishment Surveys.* American Statistical Association. 300-308.

Converse, J.M. and S. Presser. 1986. *Survey Questions: Handcrafting the Standardized Questionnaire.* Sage University Paper Series on Quantitative Applications in the Social Sciences. 07-063. Sage Publications, Thousand Oaks, California.

Couper, M.P. 2001. Web Surveys. *Public Opinion Quarterly,* 64(4): 464-494.

Desvousges, W.H. and J.H. Frey. 1989. Integrating Focus Groups and Surveys: Examples from Environmental Risk Studies. *Journal of Official Statistics,* 5(4): 349-363.

Dillman, D.A. 1978. *Mail and Telephone Surveys: The Total Design Method.* John Wiley and Sons, New York.

Dillman, D.A., M.D. Sinclair and J.R. Clark. 1993. Effects of Questionnaire Length, Respondent-friendly Design, and a Difficult Question on Response Rates for Occupant-addressed Census Mail Surveys. *Public Opinion Quarterly,* 57(3): 289-304.

Esposito, J.L., P.C. Campanelli, J.M. Rothgeb and A.E. Polivka. 1991. Determining Which Questions are Best: Methodologies for Evaluating Survey Questions. *Proceedings of the Section on Survey Research Methods*, American Statistical Association. 46-57.

Fowler, F.J., Jr. 1995. *Improving Survey Questions: Design and Evaluation.* Applied Social Research Methods Series. 38. Sage Publications, Thousand Oaks, California.

Fowler, F.J., Jr. and T.W. Mangione. 1990. *Standardized Survey Interviewing.* Applied Social Research Methods Series. 18, Sage Publications, Thousand Oaks, California.

Gower, A.R. 1994. Questionnaire Design for Business Surveys. *Survey Methodology,* 20(2): 125-136.

Gower, A.R. 1997. Asking Questions Using Combinations of Sequential, Matrix, Single Sheet and Book Formats in a Test of the Canadian Census Questionnaire. *Proceedings of Statistics Canada Symposium 97: New Directions in Surveys and Censuses.* Statistics Canada. 219-224.

Gower, A.R. and G. Haarsma. 1997. A Comparison of Two Methods in a Test of the Canadian Census Questionnaire: Think-aloud Interviews vs. Focus Groups. *Proceedings of the Minimum Standards in Questionnaire Testing Workshop.* Statistics Sweden. 35-37.

Gower, A.R., B. Bélanger and M.-J. Williams. 1998. Using Focus Groups with Respondents and Interviewers to Evaluate the Questionnaire and Interviewing Procedures after the Survey Has Taken Place. *Proceedings of the 1998 Joint Statistical Meetings, Section on Survey Research Methods.* American Statistical Association. 404-409.

Gower, A.R., K. McClure, A. Paletta and M.-J. Williams. 1999. When to Use Focus Groups versus Cognitive Interviews in the Development and Testing of Questionnaires: The Statistics Canada Experience. *Proceedings: Quality Issues in Question Testing (QUEST 99).* Office for National Statistics, England. 51-66.

Jabine, T., E. Loftus, M. Straf, J. Tanur, and R. Tourangeau, eds. *Cognitive Aspects of Survey Methodology: Building a Bridge Between Disciplines.* National Academy of Science, Washington, DC.

Kalton, G. and H. Schuman. 1982. The Effect of the Question on Survey Responses: A Review. *Journal of the Royal Statistical Society,* 145(1): 42-73.

Krueger, R.A. 1997. *Analyzing and Reporting Focus Group Results.* Focus Group Kit. 6. Sage Publications, Thousand Oaks, California.

Krueger, R.A. 1997. *Developing Questions for Focus Groups.* Focus Group Kit. 3. Sage Publications, Thousand Oaks, California.

Morgan, D.L. 1997. *Planning Focus Groups.* Focus Group Kit. 2. Sage Publications, Thousand Oaks, California.

Morgan, D.L. 1997. *The Focus Group Guidebook.* Focus Group Kit. 1. Sage Publications, Thousand Oaks, California.

Oppenheim, A.N. 1992. *Questionnaire Design, Interviewing and Attitude Measurement.* Pinter Publishers, London.

Payne, S.L. 1951. *The Art of Asking Questions*, Princeton University Press, Princeton, New Jersey

Platek, R., F.K. Pierre-Pierre and P. Stevens. 1985. *Development and Design of Survey Questionnaires.* Statistics Canada. 12-519E.

Presser, S. and J. Blair. 1994. Survey Pretesting: Do Different Methods Produce Different Results? *Sociological Methodology,* 24: 73-104.

Statistics Canada. 1994. Policy on the Development, Testing and Evaluation of Questionnaires. *Policy Manual.* 2.8.

Statistics Canada. 1996a. Policy on Informing Survey Respondents. *Policy Manual.* 1.1.

Statistics Canada. 2001. *Screen Display and Functionality Standards for Social Survey Full BLAISE Applications.*

Statistics Canada. 2001. *Standard Question Blocks for Social Survey Full BLAISE Applications.*

Tourangeau, R., L.J. Rips and K. Rasinski. 2000. *The Psychology of Survey Response*, Cambridge University Press, Cambridge, U.K.

Chapter 6 - Sample Designs

6.0   Introduction

Chapter 3 - Introduction to Survey Design stated that during the planning phase the statistical agency must decide whether to conduct a census or sample survey. If the decision is a sample survey, then the agency needs to plan how to select the sample. ***Sampling is a means of selecting a subset of units from a population for the purpose of collecting information for those units to draw inferences about the population as a whole***.

There are two types of sampling: non-probability and probability sampling. The one chosen depends primarily on whether reliable inferences are to be made about the population. Non-probability sampling, discussed in section 6.1, uses a subjective method of selecting units from a population. It provides a fast, easy and inexpensive way of selecting a sample. However, in order to make inferences about the population from the sample, the data analyst must assume that the sample is representative of the population. This is often a risky assumption to make in the case of non-probability sampling.

Probability sampling, discussed in section 6.2, involves the selection of units from a population based on the principle of randomisation or chance. Probability sampling is more complex, time consuming and usually more costly than non-probability sampling. However, because units from the population are randomly selected and each unit's inclusion probability can be calculated, reliable estimates can be produced along with estimates of the sampling error, and inferences can be made about the population.

There are several different ways in which a probability sample can be selected. The design chosen depends on a number of factors such as: the available survey frame, how different the population units are from each other (i.e., their variability) and how costly it is to survey members of the population. For a given population, a balance of sampling error with cost and timeliness is achieved through the choice of design and sample size.

The purpose of this chapter is to present different probability sample designs and factors to consider when determining which one is appropriate for a specific survey. For details on factors affecting sample size, see **Chapter 8 - Sample Size Determination and Allocation**.

6.1   Non-Probability Sampling

Non-probability sampling is a method of selecting units from a population using a subjective (i.e., non-random) method. Since non-probability sampling does not require a complete survey frame, it is a fast, easy and inexpensive way of obtaining data. The problem with non-probability sampling is that it is unclear whether or not it is possible to generalise the results from the sample to the population. The reason for this is that the selection of units from the population for a non-probability sample can result in large biases.

For example, a common design is for the interviewer to subjectively decide who should be sampled. Since the interviewer is most likely to select the most accessible or friendly members of the population, a large portion of the population has no chance of ever being selected, and this portion of the population is likely to differ in a systematic manner from those selected members. Not only can this bias the results of the

survey, it can falsely reduce the apparent variability of the population due to a tendency to select 'typical' units and eliminate extreme values. By contrast, probability sampling avoids such bias by randomly selecting units (see section 6.2).

Due to selection bias and (usually) the absence of a frame, an individual's inclusion probability cannot be calculated for non-probability samples, so there is no way of producing reliable estimates or estimates of their sampling error. In order to make inferences about the population, it is necessary to assume that the sample is representative of the population. This usually requires assuming that the characteristics of the population follow some model or are evenly or randomly distributed over the population. This is often dangerous due to the difficulty of assessing whether or not these assumptions hold.

Non-probability sampling is often used by market researchers as an inexpensive and quick alternative to probability sampling, but it is not a valid substitute for probability sampling for the reasons delineated above. So, why bother with non-probability sampling? Non-probability sampling can be applied to studies that are used as:
- an idea generating tool;
- a preliminary step towards the development of a probability sample survey;
- a follow-up step to help understand the results of a probability sample survey.

For example, non-probability sampling can provide valuable information in the early stages of an investigation. It can be used for exploratory or diagnostic studies to gain insights into people's attitudes, beliefs, motivations and behaviours. Sometimes non-probability sampling is the only viable option – for example, sampling volunteers may be the only way of obtaining data for medical experiments.

Non-probability sampling is often used to select individuals for focus groups and in-depth interviews. For example, at Statistics Canada, non-probability sampling is used to test Census of Population questions, to ensure that the questions asked and concepts used are clear to respondents. In addition, if the content of a question is deemed to be controversial, subpopulations may be selected and tested. If, through the use of focus groups, these questions can be made acceptable to these people, they may be acceptable for all members of the population. (For more on focus groups, see **Chapter 5 - Questionnaire Design**.)

Another example of the use of non-probability sampling is for preliminary studies. If a new survey is being designed to cover a field about which very little is known, pilot surveys often use non-probability designs. For example, consider the relatively new industry of web page designer. Suppose nothing is known about the number of people working in the industry, how much they earn, or other details of the profession. A pilot survey could be designed, with questionnaires sent to a few persons known to design Web pages. Feedback from the questionnaire may provide an idea about their earnings, and may indicate that many web designers work out of their homes, are only listed under their personal phone numbers and advertise exclusively on the Internet.

The **advantages** of non-probability sampling are that:

i.   It is quick and convenient.

As a general rule, non-probability samples can be quickly drawn and surveyed: it is very easy to simply walk outside and ask questions of the first hundred people encountered on the street.

ii.   It is relatively inexpensive.

It usually only takes a few hours of an interviewer's time to conduct such a survey. As well, non-probability samples are generally not spread out geographically, therefore travelling expenses for interviewers are low.

iii.   It does not require a survey frame.

iv.   It can be useful for exploratory studies and survey development.

The **disadvantages** of non-probability sampling are that:

i.   In order to make inferences about the population it requires strong assumptions about the representativeness of the sample. Due to the selection bias present in all non-probability samples, these are often dangerous assumptions to make. When inferences are to be made, probability sampling should be performed instead.

ii.   It is impossible to determine the probability that a unit in the population is selected for the sample, so reliable estimates and estimates of sampling error cannot be computed.

The following sections describe five different types of non-probability sampling schemes: haphazard sampling, volunteer sampling, judgement sampling, quota sampling and modified probability sampling. Network or snowball sampling, which is less commonly used, is presented in section 6.3.

6.1.1   Haphazard Sampling

Units are selected in an aimless, arbitrary manner with little or no planning involved. Haphazard sampling assumes that the population is homogeneous: if the population units are all alike, then any unit may be chosen for the sample. An example of haphazard sampling is the 'man in the street' interview where the interviewer selects any person who happens to walk by. Unfortunately, unless the population is truly homogeneous, selection is subject to the biases of the interviewer and whoever happened to walk by at the time of sampling.

6.1.2   Volunteer Sampling

With this method, the respondents are volunteers. Generally, volunteers must be screened so as to get a set of characteristics suitable for the purposes of the survey (e.g., individuals with a particular disease). This method can be subject to large selection biases, but is sometimes necessary. For example, for ethical reasons, volunteers with particular medical conditions may have to be solicited for some medical experiments.

Another example of volunteer sampling is callers to a radio or television show, when an issue is discussed and listeners are invited to call in to express their opinions. Only the people who care strongly enough about the subject one way or another tend to respond. The silent majority does not typically respond, resulting in a large selection bias. Volunteer sampling is often used to select individuals for focus groups or in-depth interviews (i.e., for qualitative testing, where no attempt is made to generalise to the whole population).

6.1.3   Judgement Sampling

With this method, sampling is done based on previous ideas of population composition and behaviour. An expert with knowledge of the population decides which units in the population should be sampled. In other words, the expert purposely selects what is considered to be a representative sample.

Judgement sampling is subject to the researcher's biases and is perhaps even more biased than haphazard sampling.

Since any preconceptions the researcher has are reflected in the sample, large biases can be introduced if these preconceptions are inaccurate. However, it can be useful in exploratory studies, for example in selecting members for focus groups or in-depth interviews to test specific aspects of a questionnaire.

6.1.4   Quota Sampling

This is one of the most common forms of non-probability sampling. Sampling is done until a specific number of units (quotas) for various subpopulations has been selected. Quota sampling is a means for satisfying sample size objectives for the subpopulations.

The quotas may be based on population proportions. For example, if there are 100 men and 100 women in the population and a sample of 20 are to be drawn, 10 men and 10 women may be interviewed. Quota sampling can be considered preferable to other forms of non-probability sampling (e.g., judgement sampling) because it forces the inclusion of members of different subpopulations.

Quota sampling is somewhat similar to stratified sampling in that similar units are grouped together (see section 6.2.6 for stratified sampling). However, it differs in how the units are selected. In probability sampling, the units are selected randomly while in quota sampling a non-random method is used – it is usually left up to the interviewer to decide who is sampled. Contacted units that are unwilling to participate are simply replaced by units that are, in effect ignoring nonresponse bias.

Market researchers often use quota sampling (particularly for telephone surveys) instead of stratified sampling to survey individuals with particular socio-economic profiles. This is because compared with stratified sampling, quota sampling is relatively inexpensive and easy to administer and has the desirable property of satisfying population proportions. However, it disguises potentially significant selection bias.

As with all other non-probability sample designs, in order to make inferences about the population, it is necessary to assume that persons selected are similar to those not selected. Such strong assumptions are rarely valid.

6.1.5   Modified Probability Sampling

Modified probability sampling is a combination of probability and non-probability sampling. The first stages are usually based on probability sampling (see the following section). The last stage is a non-probability sample, usually a quota sample. For example, geographical areas may be selected using a probability design, and then within each region, a quota sample of individuals may be drawn.

6.2   Probability Sampling

Probability sampling is a method of sampling that allows inferences to be made about the population based on observations from a sample. In order to be able to make inferences, the sample should not be subject to selection bias. Probability sampling avoids this bias by randomly selecting units from the population (using a computer or table of random numbers). It is important to note that random does not mean arbitrary. In particular, the interviewers do not arbitrarily choose respondents since then sampling would be subject to their personal biases. Random means that selection is unbiased – it is based on chance. With probability sampling, it is never left up to the discretion of the interviewer to subjectively decide who should be sampled.

There are two main criteria for probability sampling: one is that the units be randomly selected, the second is that all units in the survey population have a non-zero inclusion probability in the sample and that these probabilities can be calculated. It is not necessary for all units to have the same inclusion probability, indeed, in most complex surveys, the inclusion probability varies from unit to unit.

There are many different types of probability sample designs. The most basic is simple random sampling and the designs increase in complexity to encompass systematic sampling, probability-proportional-to-size sampling, cluster sampling, stratified sampling, multi-stage sampling, multi-phase sampling and replicated sampling. Each of these sampling techniques is useful in different situations. If the objective of the survey is simply to provide overall population estimates and stratification would be inappropriate or impossible, simple random sampling may be the best. If the cost of survey collection is high and the resources are available, cluster sampling is often used. If subpopulation estimates are also desired (such as estimates by province, age group, or size of business), stratified sampling is usually performed.

Most of the more complex designs use auxiliary information on the survey frame to improve sampling. If the frame has been created from a previous census or from administrative data, there may be a wealth of supplementary information that can be used for sampling. For example, for a farm survey, the statistical agency may have the size of every farm in hectares from the last agricultural census. For a survey of people, information (e.g., age, sex, ethnic origin, etc.) may be available for everyone from the last population census. For a business survey, the statistical agency may have administrative information such as the industry (e.g., retail, wholesale, manufacturing), the type of business (e.g., food store), the number of employees, etc. In order for the auxiliary information to improve sampling, there must be a correlation between the auxiliary data and the survey variables.

The main **advantage** of probability sampling is that since each unit is randomly selected and each unit's inclusion probability can be calculated reliable estimates and an estimate of the sampling error of each estimate can be produced. Therefore, inferences can be made about the population. In fact, with a probability design, a relatively small sample can often be used to draw inferences about a large population.

The main **disadvantages** of probability sampling are that it is more difficult, takes longer and is usually more expensive than non-probability sampling. In general, the expense of creating and maintaining a good quality frame is substantial. And because probability samples tend to be more spread out geographically across the population than non-probability samples, sample sizes are generally much larger and data collection is often more costly and difficult to manage. However, for a statistical agency, the ability to make inferences from a probability sample usually far outweighs these disadvantages.

For the qualities of a good frame, see **Chapter 3 - Introduction to Survey Design**. For more information on the uses of administrative data, see **Appendix A - Administrative Data.**

6.2.1   Statistical Efficiency

Simple Random Sampling (SRS) is used as a benchmark for evaluating the efficiency of other sampling strategies. In order to understand the concept of efficient sampling, some definitions are presented here.

A parameter is a population characteristic that the client or data user is interested in estimating, for example the population average, proportion or total***. An estimator is a formula by which an estimate of the parameter is calculated from the sample and an estimate is the value of the estimator using the data from the realised sample***. ***The sampling strategy is the combination of the sample design and estimator used.***

For example, the parameter of interest might be the population average, $\overline{Y}$, which is calculated as follows:

$$\overline{Y} = \sum_{i \in U} \frac{y_i}{N}$$

where y_i is the value of the variable y for the ith unit, U is the set of units in the population and there are N units in the population.

For an SRS with 100% response rate, the usual – but not the only – estimator for the population average is:

$$\hat{\overline{Y}} = \sum_{i \in S_r} \frac{y_i}{n}$$

where S_r is the set of respondents in the sample and there are n units in the sample. The value of $\sum_{i \in S_r} \frac{y_i}{n}$ for a particular sample is called the estimate.

Estimates calculated from different samples differ from one another. The ***sampling distribution of an estimator is the distribution of all the different values that the estimator can have for all possible samples from the same design from the population***. This distribution thus depends on the sampling strategy.

Estimators have certain desirable properties. One is that the estimator be unbiased or approximately unbiased. ***An estimator is unbiased if the average estimate over all possible samples is equal to the true value of the parameter***. Another desirable property of an estimator is that the sampling distribution be concentrated as closely as possible about the average (i.e., that the sampling error be small). The sampling error of an estimator is measured by its sampling variance, which is calculated as the average squared deviation about its mean calculated across all possible samples generated from the sample design. An estimator with small sampling variance is said to be *precise*. Precision increases as the sampling variance decreases. Note that an estimator can be precise but biased. *Accuracy* is a measure of both the bias and precision of the estimator: an accurate estimator has good precision and is nearly unbiased.

One sampling strategy is more efficient than another if the sampling variance of the estimator for the sampling strategy is smaller than that of another sampling strategy. So as not to confuse this type of efficiency with other types – for example, cost efficiency – this will be referred to as statistical efficiency. Statistical efficiency is an important consideration when comparing different possible designs since if one design can provide improved or equivalent precision using a smaller sample size, this can provide considerable cost savings. The following sample designs compare their efficiency relative to SRS. Formally, this is measured by calculating the design effect, presented in section 7.3.3 of **Chapter 7 - Estimation**.

For more details on estimation, factors affecting precision and estimating precision, see **Chapter 7 - Estimation**.

6.2.2   Simple Random Sampling (SRS)

The starting point for all probability sampling designs is simple random sampling (SRS). SRS is a one-step selection method that ensures that every possible sample of size *n* has an equal chance of being selected. As a consequence, each unit in the sample has the same inclusion probability. This probability, π, is equal to *n/N*, where *N* is the number of units in the population.

Sampling may be done with or without replacement. Sampling with replacement allows for a unit to be selected more than once. Sampling without replacement means that once a unit has been selected, it cannot be selected again. Simple random sampling with replacement (SRSWR) and simple random sampling without replacement (SRSWOR) are practically identical if the sample size is a very small fraction of the population size. This is because the possibility of the same unit appearing more than once in the sample is small. Generally, sampling without replacement yields more precise results and is operationally more convenient. For the purpose of this chapter, sampling is assumed to be without replacement unless otherwise specified.

Consider a population of five people and suppose that a sample of three is selected (SRSWOR). Label the people in the population 1, 2, 3, 4 and 5 and denote the population as the set {1, 2, 3, 4, 5}. There are ten possible samples of three people: {1, 2, 3}, {1, 2, 4}, {1, 2, 5}, {1, 3, 4}, {1, 3, 5}, {1, 4, 5}, {2, 3, 4}, {2, 3, 5}, {2, 4, 5} and {3, 4, 5}. Each of these samples has an equal chance of being selected and each individual is selected in 6 out of the 10 possible samples, thus each individual has an inclusion probability of $\pi = n / N = 3 / 5$.

To select a simple random sample, the statistical agency usually has constructed a complete frame (either a list or area frame) before sampling. On a list frame, the units are generally numbered 1 to *N*, although the method of assigning a unique number to each unit is not important. Next, *n* units from the list are chosen at random using a random number table or a computer-generated random number and the corresponding units make up the sample.

As a means of illustrating the technique of SRSWOR, consider a survey of students from a school. Assume that a suitable list of students is available or can be created from existing sources. This list serves as the survey or sampling frame. Now, suppose that the population list contains *N*=1530 students of which a sample of size *n*=90 is required. The next step is to decide how to select the 90 students.

Sample selection can be done using a table of random numbers (see Table 1). The first step involves selecting a four-digit number (four since this is the number of digits in 1530). Sampling begins by selecting a number anywhere in the table and then proceeding in any direction. The first 90 four-digit numbers that do not exceed 1530 are selected.

Suppose row 01 and column 85 - 89 are selected as the starting point. Proceeding down this column, the random numbers selected are 189, 256, 984, 744, 1441, 617, etc. Selection continues until 90 different numbers are obtained. The result is a sample that consists of students with the corresponding numbers in the listing of the population. (Since the method under discussion is SRSWOR, any number that appears more than once is ignored). Although a random number table was used above to illustrate the manual selection of a simple random sample, practically speaking, a computer program would randomly select units.

SRS has a number of **advantages** over other probability sampling techniques, including:

i.   It is the simplest sampling technique.

ii.   It requires no additional (auxiliary) information on the frame in order to draw the sample.

The only information that is required is a complete list of the survey population and contact information.

iii.   It needs no technical development.

The theory behind SRS is well established, so that standard formulas exist to determine the sample size, population estimates and variance estimates and these formulas are easy to use.

The **disadvantages** of SRS are:

i.   It makes no use of auxiliary information even if such information exists on the survey frame. This can result in estimates being less statistically efficient than if another sample design had been used.

ii.   It can be expensive if personal interviews are used, since the sample may be widely spread out geographically.

iii.   It is possible to draw a 'bad' SRS sample. Since all samples of size n have an equal chance of being included in the sample, it is possible to draw a sample that is not well dispersed and that poorly represents the population.

Table 1: Excerpt of a Table of Random Numbers

	50-54	55-59	60-64	65-69	70-74	75-79	80-84	85-89	90-94	95-99
00	59311	58030	52098	87024	14194	82848	04190	96574	90464	29065
01	98567	76364	77204	27062	53402	96621	43918	01896	83991	51141
02	10363	97518	51400	98342	24830	61891	27101	37855	06235	33516
03	86852	19558	64432	99612	53537	59798	32803	67708	15297	28612
04	11258	24591	36863	31721	81305	94335	34936	02566	80972	08188
05	95068	84628	35911	33020	70659	80428	39936	31855	34334	64865
06	54463	47437	73804	36239	18739	72824	83671	39892	60518	37092
07	16874	62677	57412	31389	56869	62233	80827	73917	82402	84420
08	92484	63157	76593	03205	84869	72389	96363	52887	01087	66591
09	15669	56689	35682	53256	62300	81872	35213	09840	34471	74441
10	99116	75486	84989	23476	52967	67104	39495	39100	17217	74073
11	15696	10703	65178	90637	63110	17622	53988	71087	84148	11670
12	97720	15369	51269	69620	03388	13699	33423	67453	43269	56720
13	11666	13841	71681	98000	35979	39719	81899	07449	47985	46967
14	71628	73130	78783	75691	41632	09847	61547	18707	85489	69944
15	40501	51089	99943	91843	41995	88931	73631	69361	05375	15417
16	22518	55576	98215	82068	10798	82611	36584	67466	69377	40054
17	75112	30485	62173	02132	14878	92879	22281	16783	86352	00077
18	08327	02671	98191	84342	90813	49268	95441	15496	20168	09271
19	60251	45548	02146	05597	48228	81366	34598	72856	66762	17002
20	57430	82270	10421	00540	43648	75888	66049	21511	47676	33444
21	73528	39559	34434	88596	54086	71693	43132	14414	79949	85193
22	25991	65959	70769	64721	86413	33475	42740	06175	82758	66248
23	78388	16638	09134	59980	63806	48472	39318	35434	24057	74739
24	12477	09965	96657	57994	59439	76330	24596	77515	09577	91871
...	...	...	...	...	...	...	...	...	...	...
45	12900	71775	29845	60774	94924	21810	38636	33717	67598	82521
46	75086	23537	49639	33595	31484	97588	28617	17979	78749	35234
47	99445	51434	29181	09993	38190	42553	68922	52125	91077	40197
48	26075	31671	45386	36583	93459	48599	52022	41330	60650	91321
49	13636	93596	23377	51133	95126	61496	42474	45141	46660	42338

Simple Random Sample (illustrated, *n=12*)
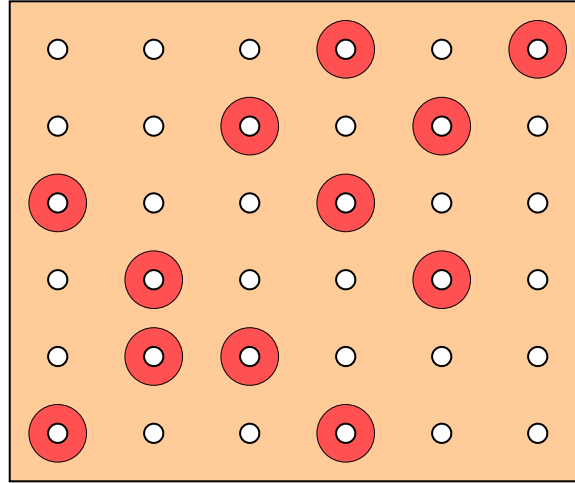
6.2.3   Systematic Sampling (SYS)

In systematic sampling (SYS), units are selected from the population at regular intervals. Systematic sampling is sometimes used when the statistical agency would like to use SRS but no list is available, or when the list is roughly random in order in which case SYS is even simpler to conduct than SRS. A Sampling interval and a random start are required.   When a list frame is used and the population size, *N*, is a multiple of the sample size, *n*, every k^{th} unit is selected where the interval *k* is equal to *N/n*. The random start, *r*, is a single random number between 1 and *k*, inclusively. The units selected are then*: r, r+k, r+2k, ..., r+(n-1)k*. Like SRS, each unit has an inclusion probability, π, equal to *n/N* but, unlike SRS, not every combination of *n* units has an equal chance of being selected: SYS can only select samples in which the units are separated by *k*. Thus, under this method, only *k* possible samples can be drawn from the population.

To illustrate SYS, suppose a population contains *N=54* units and a sample of size *n=9* units is to be drawn. The sampling interval would be *k=N/n=54/9=6*. Next, a random number between 1 and *k=6*, say 2, is chosen. The population units selected for the sample are then numbered: 2, 8, 14, 20, 26, 32, 38, 44 and 50. With a sampling interval of 6 and a population of size 54, there are only 6 possible SYS samples, while for a simple random sample of size 6, there are over 25 million possible samples.

One advantage of systematic sampling is that it can be used when no list of the population units is available in advance. In this case, a conceptual frame can be constructed by sampling every k^{th} person until the end of the population is reached.

One problem with SYS is that the sample size, *n*, is not known until after the sample has been selected. Another problem arises when the sampling interval, *k*, matches some periodicity in the population. For example, suppose that a survey of traffic flow is to be conducted in an area and only one day of the week can be sampled, in other words *k* is every 7th day. The survey's estimated traffic flow will be dramatically different if the sampled days are all Sundays as opposed to all Tuesdays. Of course, if the sampling period is every 5th day, then every day of the week could be surveyed. Unfortunately, in most cases, periodicity is not known in advance.

If N cannot be evenly divided by n, the sampling interval for SYS is not a whole number. In this case, k could be set equal to the nearest whole number, but then the sample size would vary from sample to sample. For example, suppose that $N=55$ and $n=9$, then $k=55/9=6.1$. If k is assumed to be 6, and if $r=2$, the sample contains those units numbered: 2, 8, 14, 20, 26, 32, 38, 44 and 50. If the random start is $r=1$ and every sixth unit is selected, then the sample consists of units: 1, 7, 13, 19, 25, 31, 37, 43, 49 and 55. In this case, the sample is of size 10, not 9. Another approach is to set each of the values $r, r+k, r+2k, ..., r+(n-1)k$ to the nearest whole number. With this approach, the realised sample size is fixed. For example, suppose again that $N=55$ and $n=9$, so that $k=55/9=6.1$. If $r=1$, the sample consists of units 1, 7, 13, 19, 25, 31, 38, 44 and 50.

Alternatively, if N cannot be evenly divided by n then, to avoid a variable sample size, *circular systematic sampling* could be performed. With this method, the population units are thought to exist on a circle and modular counting is used. The value of k is set equal to the whole number nearest to N/n, but now the random start, r, can be between 1 and N, rather than 1 and k (i.e., the first unit can be anywhere on the list). The selected units, as before, are: $r, r+k, r+2k, ..., r+(n-1)k$. If the jth unit is such that $r+(j-1)k > N$, then the selected unit is $r+(j-1)k - N$. That is, when the end of the list is reached, sampling continues at the beginning of the list. The advantage of the circular method is that each unit has an equal chance of being in the sample. For example, using the previous example, suppose that $N=55$ and $n=9$ and $k=6$. A random start, r, between 1 and 55 is selected, say $r=42$. Then the selected population units are: 42, 48, 54, 5, 11, 17, 23, 29 and 35.

SYS has a number of **advantages** depending on the circumstances and objective of the survey:

i. It is a proxy for SRS when there is no frame.

ii. It does not require auxiliary frame information, like SRS.

iii. It can result in a sample that is better dispersed than SRS (depending on the sampling interval and how the list is sorted).

iv. It has a well-established theory, just like SRS, and so estimates can be easily calculated.

v. It is simpler than SRS since only one random number is required.

The **disadvantages** of SYS are:

i. It can result in a 'bad' sample if the sampling interval matches some periodicity in the population.

ii. Like SRS, it does not use any auxiliary information that might be available on the frame, and thus it can result in an inefficient sampling strategy.
iii. The final sample size is not known in advance when a conceptual frame is used.

iv. It does not have an unbiased estimator of the sampling variance. In order to do variance estimation, the systematic sample is often treated as if it were a simple random sample. This is only appropriate when the list is sorted randomly. (For more information on variance estimation for a systematic sample, see Cochran (1977) or Lohr (1999).)

v. It can lead to a variable sample size if the population size, N, cannot be evenly divided by the desired sample size, n (but this can be avoided using circular SYS).

Systematic Sample (illustrated, *n*=12, *N*=36, *k*=3)
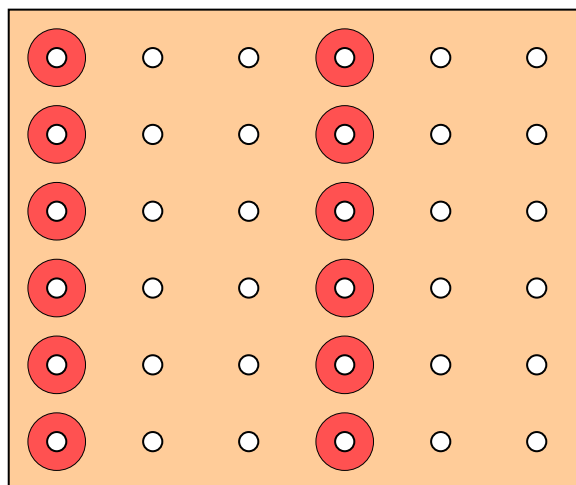
SRS and circular SYS are both equal probability sample designs, since every possible sample has exactly the same chance of being selected. Not all sampling techniques result in equal probabilities. The sample designs described in the following sections can result in unequal probabilities. It is important to remember that in probability sampling, the criterion is not that all units have the same inclusion probability but that all units have a known non-zero inclusion probability. Often, sampling with unequal probabilities can improve the statistical efficiency of the sampling strategy.

6.2.4   Probability-Proportional-to-Size (PPS) Sampling

Probability-proportional-to-size (PPS) sampling is one technique that uses auxiliary data and yields unequal probabilities of inclusion. If population units vary in size and these sizes are known, such information can be used during sampling to increase the statistical efficiency.

PPS can yield dramatic increases in precision if the size measures are accurate and the variables of interest are correlated with the size of the unit. For less accurate size measures, it is better to create size groupings and perform stratified sampling (Section 6.2.6).

A good example of a PPS size variable is area. Farm surveys often use PPS, where the size measure is the size of the farm in hectares. Admittedly, the size of a farm can grow (or shrink) if the farmer buys or sells land, but for the most part, farm size is constant from year to year. In addition, typical questions for farm surveys, such as income, crop production, livestock holdings and expenses are often correlated with land holdings. Other size measures for business surveys include the number of employees, annual sales and the number of locations, although these variables are more likely to change from year to year.

In PPS sampling, the size of the unit determines the inclusion probability. Using farms as an example, this means that a farm with an area of 200 hectares has twice the probability of being selected as a farm with 100 hectares.

To illustrate, assume that there is a population of six farms and that the client is interested in estimating the total expenses of this farming population by sampling one farm. (A sample of size one is used for the purpose of illustration; in practice, a statistical agency rarely selects only one unit.). Suppose that there is a stable size measure for each farm (the size of the farm in hectares) and, to illustrate the efficiency gains over SRS, assume that each farm's expenses are known. (Obviously, in real life, if the expenses were known, there would be no need to conduct the survey.)

Consider the following list of farms:

Table 2: Population Values

Sampling Unit: Farm	Auxiliary Frame Information: Size of Farm in Hectares	Survey Variable of Interest: Expenses ($)
1	50	26,000
2	1,000	470,000
3	125	63,800
4	300	145,000
5	500	230,000
6	25	12,500
Total	**2,000**	**947,300**

For this population of six farms, the true total expenses are $947,300. A simple random sample could be selected, where each sample contains one unit and each unit has an inclusion probability of 1/6. Six different SRS samples of size n=1 are possible. Consider the results from SRS (see table 3). To do so, some estimation concepts (explained in detail in **Chapter 7 - Estimation**) must be introduced. For a sample of size one, the total expenses for the population is estimated by multiplying the sampled unit's expenses by the unit's weight. This weight is the average number of units in the survey population that the sampled unit represents and is the inverse of the inclusion probability.

For the PPS sample, the sampling variability is much lower. The estimates from the six possible samples now only range from a low of $920,000 to a high of $1.04 million – much better than SRS (see table 4). (The PPS inclusion probability is calculated as the size of the farm divided by the total size of all farms).

In this example, it was assumed that there is a relationship between expenses and the size of the farm, an assumption that obviously is valid here, or PPS would not have been as successful as it was. Indeed, if the variables of interest and the size variable were not correlated, PPS might not have been any better than SRS, and could have been worse.

The main **advantage** of PPS sampling is that it can improve the statistical efficiency of the sampling strategy by using auxiliary information. This can result in a dramatic reduction in the sampling variance compared with SRS or even stratified sampling (Section 6.2.6).

Table 3: Possible SRS Samples of Size *n*=1

Sample (Farm Selected)	Inclusion Probability (π)	Design Weight ($1/\pi$)	Expenses ($)	Population Estimate of Total Expenses ($)
Sample 1 (Farm 1)	1/6	6	26,000	156,000
Sample 2 (Farm 2)	1/6	6	470,000	2,820,000
Sample 3 (Farm 3)	1/6	6	63,800	382,800
Sample 4 (Farm 4)	1/6	6	145,000	870,000
Sample 5 (Farm 5)	1/6	6	230,000	1,380,000
Sample 6 (Farm 6)	1/6	6	12,500	75,000
Average Sample Estimate				**947,300**

Notice the large sampling variability in the SRS estimates, ranging from $75,000 to $2.8 million. PPS can give estimates with much smaller sampling variability.

Table 4: Possible PPS Samples of Size *n*=1

Sample (Farm Selected)	Size of Farm	Inclusion Probability (π)	Design Weight ($1/\pi$)	Expenses ($)	Population Estimate of Total Expenses ($)
Sample 1 (Farm 1)	50	50/2,000	2,000/50	26,000	1,040,000
Sample 2 (Farm 2)	1,000	1,000/2,000	2,000/1000	470,000	940,000
Sample 3 (Farm 3)	125	125/2,000	2,000/125	63,800	1,020,800
Sample 4 (Farm 4)	300	300/2,000	2,000/300	145,000	966,667
Sample 5 (Farm 5)	500	500/2,000	2,000/500	230,000	920,000
Sample 6 (Farm 6)	25	25/2,000	2,000/25	12,500	1,000,000
Average Sample Estimate					**947,300**

The **disadvantages** of PPS sampling are:

i.   It requires a survey frame that contains good quality, up-to-date auxiliary information for all units on the frame that can be used as size measures.

ii.   It is inappropriate if the size measures are not accurate or stable. In such circumstances, it is better to create size groupings and perform stratified sampling.

iii.   It is not always applicable, since not every population has a stable size measure that is correlated with the main survey variables.

iv.   It can result in a sampling strategy that is less statistically efficient than SRS for survey variables that are not correlated with the size variables.

v.   Estimation of the sampling variance of an estimate is more complex.

vi.   Frame creation is more costly and complex than SRS or SYS, since the size of each unit in the population needs to be measured and stored.

6.2.4.1 Methods of PPS Sampling

How is a PPS sample drawn? There are many PPS sampling schemes, however, three commonly used techniques are the random method, the systematic method and the randomised systematic method. (The following assumes that the size measures are integer values.)

i.   The random method for PPS sampling

-        for each unit in the population, cumulate the size measures for units up to and including itself;

-        determine the range corresponding to each unit in the population, that is, from (but not including) the cumulative sum for the previous unit to the cumulative sum for the current unit;

-        select a random number between 0 (if dealing with non-integer size measures) or 1 (for integer size measures) and the total cumulative size and select the unit whose range contains the random number;

-        repeat previous step until *n* units have been selected.

To illustrate using the farm example:

Table 5: PPS Sampling using the Random Method

Farm	Size	Cumulative Size	Range
1	50	50	1-50
2	1000	1050	51-1050
3	125	1175	1051-1175
4	300	1475	1176-1475
5	500	1975	1476-1975
6	25	2000	1976-2000

For a sample containing three units, three random numbers between 1 and 2000 are selected. Suppose these numbers are: 1697, 624 and 1109. Then the farms selected are: farm 5, farm 2 and farm 3.

In the case of the random method for PPS sampling without replacement, if more than one unit is selected, complications arise both in attempting to keep probabilities directly proportional to size and in estimating the sampling variances of survey estimates. This becomes even more complicated when more than two or three units are selected with PPS without replacement, and in fact, is the subject of considerable research. Much of this research is contained in the writings of Horvitz and Thompson (1952), Yates and Grundy (1953), Rao, Hartley and Cochran (1962), Fellegi (1963), and Brewer and Hanif (1983).

ii.   The systematic method

-        for each unit in the population, cumulate the size measures for units up to and including itself;

-        determine the range corresponding to each unit in the population, that is, from (but not including) the cumulative sum for the previous unit to the cumulative sum for the current unit;

-        determine the sampling interval, $k=$(total cumulative size)/n;

-        determine a random start, *r*, between 0 (if dealing with non-integer size measures) or 1 (for integer size measures) and *k;*

-        select those units whose range contains the random numbers *r, r+k, r+2k, ... r+(n-1)k.*

iii.   The randomised systematic method

In this scheme, the list is randomised prior to the application of systematic sampling. Just as with systematic sampling, if the list is used in its original order, some possible samples may be eliminated. By randomising the list, the number of potential samples that can be drawn is increased.

Note that these methods do pose certain problems. For example, for the systematic and randomised systematic methods, if the size of any unit is greater than the interval, it may be selected more than once. This problem can only be overcome by placing such large units into separate strata and sampling them independently (Section 6.2.6). A second problem is the difficulty of estimating sampling variances.

6.2.5   Cluster Sampling

Cluster sampling is the process of randomly selecting complete groups (clusters) of population units from the survey frame. It is usually a less statistically efficient sampling strategy than SRS and is performed for several reasons. The first reason is that sampling clusters can greatly reduce the cost of collection, particularly if the population is spread out and personal interviews are conducted. The second reason is that it is not always practical to sample individual units from the population. Sometimes, sampling groups of the population units is much easier (e.g., entire households). Finally, it allows the production of estimates for the clusters themselves (e.g., average revenue per household).

Cluster sampling is a two-step process. First, the population is grouped into clusters (this may consist of natural clustering, e.g., households, schools). The second step is to select a sample of clusters and interview all units within the selected clusters.

The survey frame may dictate the method of sampling. Until now, the focus has been on sampling individual units of the population from a list frame. If the units of the population are naturally grouped together, it is often easier to create a frame of these groups and sample them than try to create a list frame of all individual units in the population. For example, the client may be interested in sampling teachers but only have available a list of schools. In the case of household or farm surveys, many countries do not have complete and up-to-date lists of the people, households or farms for any large geographic area, but they do have maps of the areas. In this case an area frame could be created, with the geographical areas divided into regions (clusters), the regions sampled and everyone within the region interviewed. Different sample designs can be used to select the clusters, such as SRS, SYS or PPS. A common design uses PPS where sampling is proportional to the size of the cluster.

There are a number of considerations to bear in mind for cluster sampling. In order for estimates to be statistically efficient, the units within a cluster should be as different as possible. Otherwise, if the units within a cluster are similar, they all provide similar information and interviewing one unit would be sufficient.

Unfortunately, units within a cluster frequently have similar characteristics and therefore are more homogeneous than units randomly selected from the general population. This results in a sampling procedure that is less efficient than SRS. For example, suppose that for a city of 100,000, two samples are

drawn. For the first sample, cluster sampling is used and one city block, containing 400 residents, is selected at random. For the second sample, SRS is used to select 400 people from the list of 100,000 residents. The 400 residents in the SRS sample are likely to be far more diverse in terms of income, age, occupation, and educational background (to name only a few variables) than the 400 people in the cluster sample who all live on the same city block.

The statistical efficiency of cluster sampling depends on how homogeneous the units within the clusters are, how many population units are in each cluster and the number of clusters sampled. When neighbouring units are similar, it is more statistically efficient to select many small clusters rather than a few, larger clusters. However, when personal interviews are conducted, the more dispersed the sample is, the more expensive the survey. The statistical agency must strike a balance between the optimal number and size of clusters, and the cost.

There can be logistical difficulties with cluster sampling. If the survey frame is an area frame based on a map and the sampling unit is a cluster of dwellings, it can be difficult to determine if a dwelling is in a cluster or not. Some basic rules should be created to determine which units are in a cluster. For example, having a rule saying *dwellings belong to the cluster in which their main entrance (front door) lies* would eliminate most problems (usually, the entire dwelling is either in or out of the boundary of the cluster). If a dwelling seems to be evenly divided between clusters, toss a coin to avoid bias. In the Canadian Labour Force Survey, clusters are determined by drawing a line down the middle of the street. This makes it easy to determine whether a dwelling is in the sample or not. (For more information on these practical considerations, see **Chapter 9 - Data Collection Operations**).

The **advantages** of cluster sampling are:

i. It can greatly reduce the cost of collection by having a less dispersed sample than SRS. This is particularly important when the population is spread out and personal interviews are conducted, since savings can be achieved by reducing the travel time of interviewers, especially for rural populations.

ii. It is easier to apply than SRS or SYS to populations that are naturally clustered (e.g., households, schools) and for certain conceptual populations, such as people crossing a border during a specific time interval. For such populations, it may be difficult, expensive or impossible to construct a list of all individual units of the population, required by SRS.

iii. It allows the production of estimates for the clusters themselves. For example, estimates of the average number of teachers per school (where schools are clusters).

iv. It can be more statistically efficient than SRS if the units within the clusters are heterogeneous (different) with respect to the study variables and the clusters are homogeneous (similar). But in practice this is usually not the case.

The **disadvantages** of cluster sampling are:

i. It can be less statistically efficient than SRS if the units within the clusters are homogeneous with respect to the study variables. This is frequently the case, since units within a cluster tend to have similar characteristics. However, to offset this loss in statistical efficiency, the number of clusters selected can be increased.

ii.   Its final sample size is not usually known in advance, since it is not usually known how many units are within a cluster until after the survey has been conducted.

iii.   Its survey organisation can be more complex than for other methods.

iv.   Its variance estimation will be more complex than for SRS if clusters are sampled without replacement.

Cluster Sample (illustrated, 4 clusters are sampled)
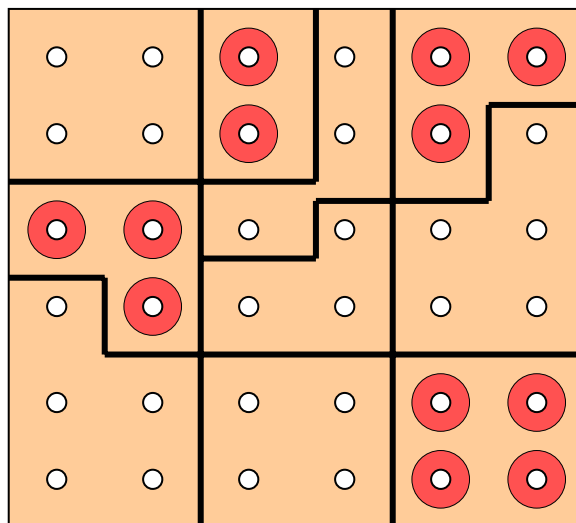
6.2.6   Stratified Sampling (STR)

With stratified sampling, the population is divided into homogeneous, mutually exclusive groups called strata, and then independent samples are selected from each stratum. Any of the sample designs mentioned in this chapter can be used to sample within strata, from the simpler methods such as SRS or SYS to the more complex methods such as PPS, cluster, multi-stage or multi-phase sampling (discussed later in this chapter). For example, with cluster sampling, it is very common to first stratify, then draw the cluster sample. This is called stratified cluster sampling.

A population can be stratified by any variables that are available for all units on the frame prior to the survey being conducted. For instance, this information may simply be the address of the unit, allowing stratification by province, or there may be income data on the frame, allowing stratification by income group. Commonly used stratification variables include: age, sex, geography (e.g., province), income, revenues, household size, size of business, type of business, number of employees, etc.

There are three main reasons for stratification. The first is to make the sampling strategy more efficient than SRS or SYS. The second is to ensure adequate sample sizes for specific domains of interest for which analysis is to be performed. The third is to protect against drawing a 'bad' sample.

First, for a given sample size and estimator, stratification may lead to lower sampling error or, conversely, for a given sampling error, to a smaller sample size. Note that, while both cluster sampling and stratification group units in the population, with stratified sampling, samples are drawn within each stratum, while for cluster sampling, samples of clusters are drawn and everyone in the cluster surveyed. And while stratification generally increases the precision of estimation with respect to SRS, clustering generally decreases it (since neighbouring units are usually similar).

In order to improve the statistical efficiency of a sampling strategy with respect to SRS, there must be strong homogeneity within a stratum (i.e., units within a stratum should be similar with respect to the variable of interest) and the strata themselves must be as different as possible (with respect to the same variable of interest). Generally, this is achieved if the stratification variables are correlated with the survey variable of interest. The reason why stratification can increase the precision of the estimates relative to SRS is explained by Cochran (1977):

> If each stratum is homogeneous, in that the measurements vary little from one unit to another, a precise estimate of any stratum mean can be obtained from a small sample in that stratum. These estimates can be combined in a precise estimate for the whole population.

Stratification is particularly important in the case of *skewed populations* (i.e., when the distribution of values of a variable is not symmetric, but leans to the right or the left). For example, business and farm surveys often have highly skewed populations – the few large business establishments and farms often have large values for variables of interest (e.g., revenues, expenditures, number of employees). In such cases, a few population units can exert a large influence on estimates – if they happen to be selected in the sample, they can greatly increase the estimate, and if they are not selected, the estimate will be much lower. In other words, these units can increase the sampling variability of the estimate. Therefore, such units should be placed in a stratum by themselves to ensure that they do not represent other, potentially much smaller, units in the population.

To stratify businesses, a size variable based on the number of employees, for example, is often used. If the size variable has three values – small, medium and large – the statistical efficiency is improved if the large businesses have similar sales, the medium businesses have similar sales, and the small businesses have similar sales and if large and medium businesses and the medium and small business have quite different sales. Similarly, for a sample design using area frames, the proper representation of large cities can be ensured by placing them in a separate stratum, and sampling each stratum separately.

In the previous example, it was reasonable to stratify by the number of employees, since this is a measure of the size of the company and is likely to be highly related to sales. However, if a survey is interested in the age of its employees, it makes no sense to stratify by the number of employees since there is no correlation. Also, stratification that is statistically efficient for one survey variable may not work well for others. Usually the stratification variables are chosen based on their correlation with the most important survey variables. This means that for those, less important, survey variables that are uncorrelated to the stratification variables, estimates for a stratified sample can be less efficient than SRS.

The second reason for stratification is to ensure adequate sample sizes for known ***domains of interest***. When designing a survey, often the overall goal is to estimate a total. How many people were unemployed last month? What were the total retail sales last month?

In addition to overall totals, the client often requires estimates for subgroups of the population, called domains. For example, the client may wish to know how many men were unemployed and compare this with the number of women who were unemployed. Similarly, the client may want to know the sales last month for clothing stores, or for all retail stores in a certain province. Creating estimates for subgroups is called domain estimation. If domain estimates are required, the ability to calculate them with a large enough sample in each domain should be incorporated into the sample design. If the information is available on the frame, the easiest way to do this is to ensure that strata exactly correspond to the domains of interest.

The third reason for stratifying is to protect against drawing a 'bad' sample. In the case of SRS, the selection of the sample is left entirely to chance. Stratified sampling attempts to restrict the possible samples to those that are less extreme by ensuring that at least certain parts of the population are represented in the sample. For example, to ensure that both men and women are included in the sample, the survey frame should be stratified by sex (assuming this auxiliary variable is available on the frame).

In addition to these reasons, stratification is often used for operational or administrative convenience. It can enable the statistical agency to control the distribution of fieldwork among its regional offices. For example, if data collection is conducted by province, then stratification by province is appropriate, in which case the provincial regional office can be given their portion of the sample.

Once the population has been divided into strata, the statistical agency needs to determine how many units should be sampled from each stratum. This step is referred to as allocation of the sample and is covered in **Chapter 8 - Sample Size Determination and Allocation.**

Inclusion probabilities usually vary from stratum to stratum; it depends on how the sample is allocated to each stratum. To calculate the inclusion probabilities for most sample designs, the size of the sample and the size of the population in each stratum must be considered. To illustrate, consider a population with N=1000 units stratified into two groups: one stratum has N_1=250 units and the other has N_2=750 units. Suppose that SRS is used to select n_1=50 units from the first stratum and n_2=50 units from the second the probability, π_2, that a unit in the second stratum is selected is $\pi_2 = 50/750 = 1/15$. Units thus have different probabilities of inclusion – a unit in the first stratum is more likely to be selected than one in the second.

The **advantages** of stratified sampling are:

i.   It can increase the precision of overall population estimates, resulting in a more efficient sampling strategy. A smaller sample can save a considerable amount on the survey, particularly data collection.

ii.   It can guarantee that important subgroups, when defined as strata, are well represented in the sample, resulting in statistically efficient domain estimators.

iii.   It can be operationally or administratively convenient.

iv.   It can protect against selecting a 'bad' sample.

v.   It allows different sampling frames and procedures to be applied to different strata (e.g., SRS in one stratum, PPS in another).

The **disadvantages** of stratified sampling are:

i.   It requires that the sampling frame contain high quality auxiliary information for all units on the frame, not just those in the sample, that can be used for stratification.

ii.   Frame creation is more costly and complex than for SRS or SYS, since the frame requires good auxiliary information.

iii.   It can result in a sampling strategy that is less statistically efficient than SRS for survey variables that are not correlated to the stratification variables.

iv.   Estimation is slightly more complex than for SRS or SYS.

Stratified Sample (illustrated, 4 strata, 3 units selected per stratum)
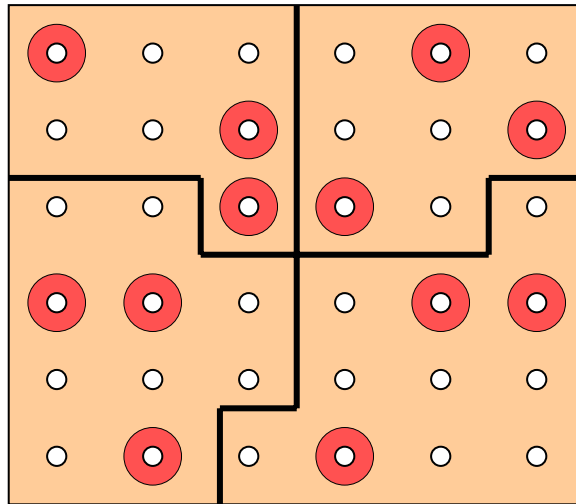
6.2.7   Multi-Stage Sampling

Thus far, the discussion has centred around one stage sample designs. Multi-stage sampling is the process of selecting a sample in two or more successive stages. The units selected at the first stage are called primary sampling units (PSU's), units selected at the second stage are called second stage units (SSU's), etc. The units at each stage are different in structure and are hierarchical (for example, people live in dwellings, dwellings make up a city block, city blocks make up a city, etc.). In two-stage sampling, the SSU's are often the individual units of the population.

A common multi-stage sample design involves two-stage cluster sampling using an area frame at the first stage to select regions (the PSU's) and then a systematic sample of dwellings (the SSU's) within a region at the second stage. With the one-stage cluster sampling presented earlier, every unit within a sampled cluster is included in the sample. In two-stage sampling, only some of the units within each selected PSU are subsampled.

Multi-stage sampling is commonly used with area frames to overcome the inefficiencies of one-stage cluster sampling, which in fact is rarely used. If the neighbouring units within a cluster are similar, then it is more statistically efficient to sample a few SSU's from many PSU's than to sample many SSU's from fewer PSU's.

Multi-stage samples can have any number of stages, but since the complexity of the design (and estimation) increases with the number of stages, designs are often restricted to two or three stages. It should be noted that the frame for the first stage is generally quite stable. For example, an area frame covering large geographical areas does not change rapidly over time. Second (and subsequent) stage frames required to sample units at subsequent stages are usually less stable. Often, these frames are list frames created in the field during collection. For example, for the geographic areas sampled at stage one, a list frame could be created for all those dwellings within the sampled areas. Note that, listing only sampled areas requires much less effort than trying to list the whole population. (See **Chapter 9 - Data Collection Operations** for details on listing).

Each stage of a multi-stage sample can be conducted using any sampling technique. Consequently, one of the chief advantages of a multi-stage sample is its flexibility. For example, within one PSU drawn at the first stage, an SRS sample may be drawn. For another PSU, there may be a measure of size that is correlated with the key survey variables, so PPS may be used within this PSU.

The Canadian Labour Force Survey (LFS) sample is an example of a multi-stage stratified sample. The country is divided into over 1,100 strata. Each stratum consists of a group of enumeration areas (EA's). EA's are geographic areas defined by the Census of Population so that the area that they cover can be canvassed by one census representative (they are created by keeping in mind the size of territory and the density of the population). The first stage of sampling is a stratified sample of clusters (EA's or groups of EA's) from within these strata. At the second stage, the clusters are mapped, all dwellings in them are listed, and the census representative selects a systematic sample of dwellings from each list. All persons within a selected dwelling are then interviewed for the survey.

Finally, note that although the examples provided thus far use an area frame at the first stage this is by no means a requirement for multi-stage sampling. An example of a multi-stage sample using a different kind of frame is a travel survey conducted at an airport. The primary sampling unit could be time – days in a month, while the second stage unit could be actual travellers. For a more complex travel survey, the second stage unit could be arriving passenger planes, while the third stage unit could be actual seats on the plane.

The **advantages** of multi-stage sampling are:

i.   It can result in a more statistically efficient sampling strategy than a one-stage cluster design when clusters are homogeneous with respect to the variables of interest (i.e., a sample size reduction).

ii.   It can greatly reduce the travel time and cost of personal interviews as a result of the sample being less dispersed than for other forms of sampling, such as SRS.

iii.   It is not necessary to have a list frame for the entire population. All that is needed is a good frame at each stage of sample selection.

The **disadvantages** of multi-stage sampling are:

i.   It is usually not as statistically efficient as SRS (although it can be more efficient than a one-stage cluster strategy).

ii.   The final sample size is not always known in advance, since it is not usually known how many units are within a cluster until after the survey has been conducted. (The sample size can be controlled, however, if a fixed number of units are selected per cluster.)

iii.   Its survey organisation is more complex than for one-stage cluster sampling.

iv.   Its formulas for calculating estimates and sampling variance can be complex.

Multi-Stage Sample (illustrated, 2 stage cluster design, 6 PSU's selected with 1 to 3 SSU's selected within each PSU)
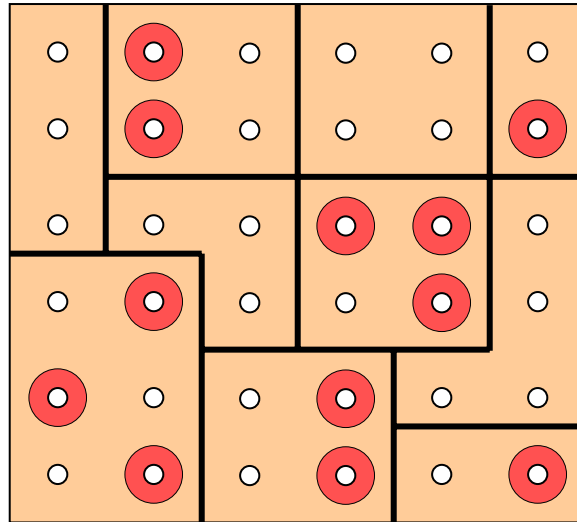
6.2.8   Multi-Phase Sampling

Despite the similarities in name, multi-phase sampling is quite different from multi-stage sampling. Although multi-phase sampling also involves taking two or more samples, all samples are drawn from the same frame and the units have the same structure at each phase. A multi-phase sample collects basic information from a large sample of units and then, for a subsample of these units, collects more detailed information. The most common form of multi-phase sampling is two-phase sampling (or double sampling), but three or more phases are also possible. However, as with multi-stage sampling, the more phases, the more complex the sample design and estimation.

Multi-phase sampling is useful when the frame lacks auxiliary information that could be used to stratify the population or to screen out part of the population. For example, suppose information is needed about cattle farmers, but the survey frame only lists farms, with no auxiliary information. A simple survey could be conducted whose only question is: 'Is part or all of your farm devoted to cattle farming?' With only one question, this survey should have a low cost per interview (especially if done by telephone) and consequently the agency should be able to draw a large sample.

Once the first sample has been drawn, a second, smaller sample can be drawn from amongst the cattle farmers and more detailed questions asked of these farmers. Using this method, the statistical agency avoids the expense of surveying units that are not in scope (i.e., who are not cattle farmers).

Multi-phase sampling can also be used to collect more detailed information from a subsample when there is insufficient budget to collect information from the whole sample, or when doing so would create excessive response burden. The Canadian Quarterly Retail Commodity Survey (QRCS) is one example. The first phase of the survey is the Monthly Wholesale Retail Trade Survey (MWRTS). Each month, MWRTS asks wholesale and retail establishments for two variables – their monthly sales and inventories. QRCS subsamples the retail establishments and asks them to report their sales by retail commodity, for example, clothing, electronics, foodstuffs, etc.

Similarly, multi-phase sampling can be used when there are very different costs of collection for different questions on a survey. Consider a health survey that asks some basic questions about diet, smoking, exercise and alcohol consumption. In addition, suppose the survey requires that respondents be subject to some direct measurements, such as running on a treadmill and having their blood pressure and cholesterol levels measured. It is relatively inexpensive to ask a few questions, but the medical tests require the time of a trained health practitioner and the use of an equipped laboratory, so are relatively expensive. This survey could be done as a two-phase sample, with the basic questions being asked at the first phase and only the smaller, second phase sample receiving the direct measurements.

In addition to stratification or screening information, data collected at the first phase can be used to improve the efficiency of estimation (e.g., for regression estimation). For more on estimation, see **Chapter 7 - Estimation**.

The **advantages** of multi-phase sampling are:

i.   It can greatly increase the precision of estimates (compared with SRS).

ii.   It can be used to obtain auxiliary information that is not on the sampling frame (in particular, stratification information for second phase sampling).

iii.   It can be used when the cost of collection for some of the survey variables is particularly expensive or burdensome for the respondent.

The **disadvantages** of multi-phase sampling are:

i.   It takes longer to get results than from a one-phase survey, if results from the first phase are required to conduct the second phase.

ii.   It can be more expensive than a one-phase survey since it requires interviewing a sampled unit more than once.

iii.   If the population is mobile or if the characteristics of interest change frequently, time delays between phases may pose problems.

iv.   Its survey organisation can be complex.

v.   Its formulas for the calculation of estimates and sampling variance can be quite complex.

Multi-phase sample (illustrated, 12 units selected at the first phase, 4 at the second)
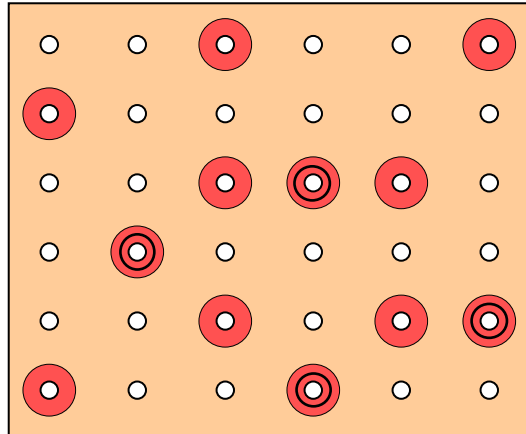
6.2.9 Replicated Sampling

Replicated sampling involves the selection of a number of independent samples from a population rather than a single sample. Instead of one overall sample, a number of smaller samples, of roughly equal size, called replicates, are independently selected, each based upon the same sample design. Replicated sampling might be used in situations where preliminary results are needed quickly. Such preliminary results might be based upon the processing and analysis of a single replicate.

The main reason for replicated sampling is to facilitate the calculation of the sampling variance of survey estimates (sampling variance is a measure of sampling error). While it is generally possible to calculate the sampling variance based on probability samples, such calculations can be exceedingly difficult depending on the complexity of the sample design. The problem is that some mathematical expressions for sampling variance are difficult to derive and tedious and costly to program. In particular, in the case of systematic sampling, variance estimates cannot be calculated directly unless assumptions are made about the arrangement of units in the list.

Measures of sampling error are determined by examining the extent to which sample estimates, based upon all possible samples of the same size and design, differ from one another. Replicated sampling simulates this concept. Instead of drawing all possible samples (which is not practical), a reasonable number of smaller samples are selected using identical methods. For example, instead of selecting one sample of size 10,000, ten independent samples of size 1,000 could be drawn. The estimates from each of these ten samples can be compared and estimates of sampling variance derived. The reliability of the sampling variance estimates increases with the number of replicates selected. (See section 7.3.4 of **Chapter 7 - Estimation,** for an example of replicated sampling for variance estimation.)

There are a number of other procedures that use replication to estimate the sampling variance for complex sample designs. These include balanced repeated replication, jackknife and bootstrap. These techniques, which all extend the basic idea of replicated sampling, differ from one another in terms of the accuracy with which they measure the sampling variance of different types of survey estimates and their operational complexity and the situations to which they best apply.

There are drawbacks to this approach. One disadvantage of this scheme is that estimates of sampling variance, in general, tend to be less precise than if they were based directly on the statistical expressions that incorporate sample design features such as multi-stage, stratification, etc.

Replicated Sampling (illustrated, 2 samples drawn of size 6)
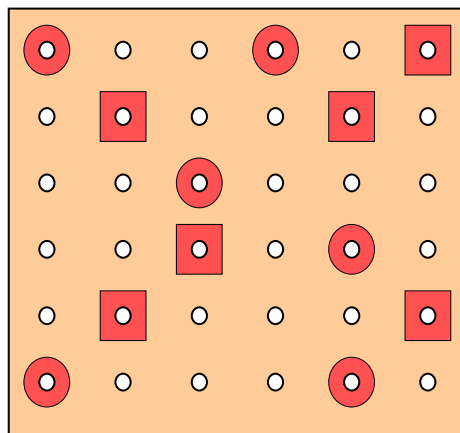
6.3 Special Topics in Sample Design

Sometimes, sample designs are modified to meet the special needs of a particular survey. This may be necessary because the target population is particularly difficult to locate, because the characteristic of interest is very rare in the population, because of the analytical needs of the survey or because of the method of data collection. **Chapter 4 - Data Collection Methods** presented telephone sampling designs, including Random Digit Dialling (RDD). The following sections describe other special applications of sample designs to fit particular survey needs.

6.3.1 Repeated Surveys

Surveys that are conducted once differ in several ways from repeated surveys. The aim of a repeated survey is often to study trends or changes in the characteristics of interest over a period of time.

Decisions made in the sample design of repeated surveys should take into account the possibility of deterioration in the statistical efficiency of the sampling strategy over time. A statistical agency may elect, for example, to use stratification variables that are more stable, avoiding those that may be more statistically efficient in the short run, but which change rapidly over time.

Another feature of a repeated survey is that, in general, a great deal of information is available which is useful for future design purposes. The adequacy of various features of the sample design such as the appropriateness of stratification variables and boundaries, the method of sample allocation and the size of units at various stages of a multi-stage design may be studied over time with a view to increasing statistical efficiency. Often, information required to efficiently design a one-time survey is very limited.

In the design of a repeated survey, provisions must be made to accommodate such events as births, deaths and changes in size measure. The sampling and estimation methods used in repeated surveys should incorporate these changes in a statistically efficient way with as little disruption as possible to the ongoing survey operations.

One particular type of repeated survey is a panel or *longitudinal survey*, where data are collected from the same sample units on several occasions. Such surveys usually measure changes in the characteristics of a given population with greater precision than do a series of independent samples of comparable size.

If a survey is to be repeated there are **advantages** to using a longitudinal sample, rather than doing a series of ad hoc independent samples. Some of the advantages are:

i. It reduces the sampling variance for estimates of change (i.e., $\hat{Y}_2 - \hat{Y}_1$, where $\hat{Y}_1$ is an estimate of the total at time 1 and $\hat{Y}_2$ is an estimate of the total at time 2). For example, this might be a measure of the change in the number of unemployed persons from one month to the next.

ii. It can be used to obtain information on the behaviour of respondents over time.

iii. It may reduce response errors (since respondents acquire a better understanding of the questionnaire).

iv. It may result in a cost reduction over time (development of survey, programming of computer systems, staff training, etc., are done over a long period of time).

Some of the **disadvantages** of using a longitudinal sample instead of several independent samples are:

i. Its estimation, treatment of nonresponse, etc., is more complex.

ii. It requires that the budget for the survey be guaranteed for the life of the panel. This entails a cost commitment over a long period of time.

iii. It is harder to maintain representativeness across time periods because of changes that occur in the population over time such as the addition of new units and the withdrawal of others.

iv. It may increase response error (for example, respondents' knowledge of the questionnaire may lead some to answer questions incorrectly in order to speed up the interview).

v. It can lead to higher nonresponse over time (due to respondent fatigue – the same person is surveyed repeatedly over time; difficulty tracing, etc.)

vi. Its organisation is more complex than for a one-time survey.

vii. It can result in survey-induced behaviour. For example, a respondent who is repeatedly asked about visits to the doctor may start visiting a doctor as a result of the survey.

viii. It can be difficult to define some concepts (e.g., household composition can change over time, so how is a longitudinal household defined?).

ix. If the initial sample drawn is a 'bad' sample, the statistical agency must continue with that sample.

One design that is intermediate between independent samples on successive occasions and a longitudinal sample takes the form of a rotating sample design in which part of the sample is replaced at each survey occasion.

For example, the Canadian Labour Force Survey (LFS) employs a rotation design in which households are included in the sample for six consecutive months, and every month, one sixth of the sample is replaced by a new group of households. The LFS sample is divided into six panels (or groups). Each panel in the survey is surveyed once a month for six months. At the end of its six months, the panel is removed from the survey (rotated out) and a new one is rotated in. This puts a limit on respondent burden (the average LFS interview is under 10 minutes) and gives a good sample overlap each month. An additional advantage is that the sample is refreshed each month. If the sample were never updated, then members of the sample would age over time, and families in new dwellings would never have a chance to enter the sample. As a result, the sample would no longer reflect the current population and would become biased over time.

This design offers the advantage of measuring monthly changes with greater precision, less cost and with less disruption to the field operations than would otherwise be the case if independent samples were used. It also reduces the problem of respondent burden associated with panel studies. (Nonetheless, to reflect changes in the size and structure of the population and data requirements, the LFS undergoes periodic redesigns, usually in the wake of the decennial census.)

In addition to the LFS, such designs are often used in business surveys. Note that rotating sample designs, in addition to the basic sample design, also require a methodology for how to rotate the sample. This can be complex and goes beyond the scope of this manual. For more details on rotating samples and longitudinal surveys in general, see Kalton, 1992.

6.3.2   Entry/Exit Surveys

Entry/exit surveys apply to populations crossing a border, for example people entering (or leaving) a country or users of a toll road. The problem with such populations is creating an up-to-date list frame with contact information so that the units can be interviewed or sent questionnaires. For example, suppose the client wishes to interview foreign visitors to Canada and that it is possible to obtain a list from customs of all visitors who entered the country on a particular date. One problem is how to find these people to interview them? By the time the frame is created, the travellers may have returned home, making an interview impractical. If they are still in Canada, it is unlikely that there is an address for them.

It is for these reasons that a conceptual frame and systematic sampling, or two-stage cluster sampling with systematic sampling within sampled clusters, is often used to survey such populations. The conceptual frame might be a list of the population units enumerated within a certain time interval at particular locations. For the frame to have complete coverage, these locations must be areas where the target population is concentrated. Often, entrance and exit areas are used. Exit areas are more popular since most surveys are interested in the activities the unit pursued before leaving the area.

An important consideration in the sample design – as with all sample designs – is field procedures. The operational and design challenge is to make optimal use of fieldworkers while maintaining a probability sample. An uneven flow of visitors creates a highly variable workload, making efficient staff allocation difficult. The most effective use of an interviewer's time is to interview the kth visitor after *completing* the current interview, but this would be a non-probability design. Systematic sampling where one person counts people and a small team of interviewers hand out questionnaires or conduct interviews is preferable. The team size will depend on the flow density and the length of the interview, if interviews are conducted.

Data collection can be done via self-enumeration, interviews or direct observation, when appropriate. For self-enumeration questionnaires, the response rate is better if the respondent completes the questionnaire on site, rather than mailing it back to the statistical agency. Interviews obviously require more field staff, but result in higher response rates. Direct observation is very accurate and desirable, but not always applicable.

The main **advantage** of an entry/exit survey is that the frame for the final stage can be created while in the field.

The **disadvantages** of an entry/exit survey are:

i.   It can be difficult to relate the survey population to a commonly understood population. This is because entry/exit surveys measure visitors, rather than people. For example, if a survey is conducted at a store, someone who visits the store more than once during the time period will be counted more than once.

ii.   It can be difficult to manage field operations due to variable flows in the population. For this reason, it is recommended that interviews be kept short.

iii.   It typically yields low response rates.

6.3.3   Snowball Sampling

Suppose the client wishes to find rare individuals in the population and already knows of the existence of some of these individuals and can contact them. One approach is to contact those individuals and simply ask them if they know anyone like themselves, contact those people, etc. The sample grows like a snowball rolling down a hill to hopefully include virtually everybody with that characteristic. Snowball sampling is useful for small or specialised populations such as blind, deaf, or other persons who may not belong to an organised group or such as musicians, painters, or poets, not readily identified on a survey list frame. However, snowball sampling is a method of nonprobability sampling: some individuals or sub-groups may have no chance of being sampled. In order to make inferences, strong modelling assumptions (which are usually not met) are required.

Network sampling and adaptive cluster sampling are similar sample designs that are used to target rare or specialised populations.

6.4   Summary

This chapter covered the basics of sampling. The two main types of sampling are probability sampling and non-probability sampling. Non-probability sampling is of limited use for surveys conducted by statistical agencies, since the biased selection of units does not readily permit inferences to be made about the survey population. However, it is fast and easy and can be useful for exploratory studies or during the development phase of a survey (e.g., to test the questionnaire).

Probability sampling should be used when inferences about the population are to be made based on the survey results. In a probability sample, every unit on the frame has a non-zero probability of being selected and the units are selected randomly. As a result, selection is unbiased and it is possible to calculate the probabilities of inclusion, calculate the sampling variance of estimates and make inferences

about the population. The main disadvantages of probability sampling is that it requires more time, is more costly than non-probability sampling and requires a high quality sampling frame.

The simplest probability sample designs are simple random sampling and systematic sampling, which result in equal probabilities of inclusion. More complex designs that can result in unequal probabilities of inclusion and most of which require auxiliary information include: stratified, probability-proportional-to-size, cluster, multi-stage and multi-phase sampling. Unequal probability designs are typically used to improve the statistical efficiency of the sampling strategy or to reduce the cost of sampling. Sometimes, their use is dictated by the sampling frame.

When deciding between the various possible designs, the first thing to determine is what designs are feasible given the survey frame, units on the survey frame, domains of interest, response burden, the method of data collection, budget, etc.?

Some things to consider are:
- Does the survey frame have auxiliary data that could be used to improve the efficiency of sampling? (Should the survey frame be stratified and/or should PPS be performed?)
- Does the survey frame lack auxiliary information that could be used to screen out units or that would be useful for stratification? Is data collection very expensive or burdensome? (Should two-phase sampling be performed?)
- Is the population naturally clustered or are the units on the survey frame clusters? Is the population spread out geographically and personal interviews to be conducted? (Should single-stage or multi-stage cluster sampling be performed?)

Finally, there are several special applications of sample designs that can be made depending on the specific needs of the survey.

For how to determine the size of sample required to satisfy a given level of precision, and how to compare the efficiency of different sample designs by comparing design effects, see **Chapter 8 - Sample Size Determination and Allocation**.

Bibliography

Bebbington, A.C. 1975. A Simple Method of Drawing a Sample without Replacement. *Applied Statistics,* 24(1).

Binder, D.A. 1998. Longitudinal Surveys: Why are These Surveys Different from all Other Surveys? *Survey Methodology,* 24(2): 101-108.

Brewer K.R.W. and M. Hanif. 1983. Sampling with Unequal Probabilities. Springer-Verlag, New York.

Cochran, W.G. 1977. *Sampling Techniques*. John Wiley and Sons, New York.

Conner, W.S. 1966. An Exact Formula for the Probability that Two Specified Sample Units Will Occur in a Sample Drawn with Unequal Probabilities and Without Replacement. *Journal of the American Statistical Association,* 61: 385-390.

Cox, B.G., D.A. Binder, B.N. Chinnappa, A. Christianson, M.J. Colledge and P.S. Kott, eds. 1995. *Business Survey Methods*. John Wiley and Sons, New York.

Droesbeke, J.-J., B. Fichet and P. Tassi, 1987. *Les Sondages*. Economica, Paris.

Fellegi, I.P. 1963. Sampling with Varying Probabilities Without Replacement Rotating and Non-Rotating Samples. *Journal of the American Statistical Association,* 58: 183-201.

Fink, A. 1995. *The Survey Kit*. Sage Publications, California.

Fowler, F.J. 1984. *Survey Research Methods*. 1. Sage Publications, California.

Gambino, J.G., M.P. Singh, J. Dufour, B. Kennedy and J. Lindeyer. 1998. *Methodology of the Canadian Labour Force Survey*. Statistics Canada. 71-526.

Gray, G.B. 1971. Joint Probabilities of Selection of Units in Systematic Samples. *Proceedings for the American Statistical Association*. 271-276.

Hidiroglou, M.A. 1994. Sampling and Estimation for Establishment Surveys: Stumbling Blocks and Progress. *Proceedings of the Section on Survey Research Methods*. American Statistical Association. 153-162.

Hidiroglou, M.A. and G.B. Gray. 1980. Construction of Joint Probabilities of Selection for Systematic P.P.S. Sampling. *Applied Statistics,* 29(1): 663-685.

Hidiroglou, M.A. and K.P. Srinath. 1993. Problems Associated with Designing Sub-Annual Business Surveys. *Journal of Economic Statistics,* 11: 397-405.

Horvitz, D.G. and D.J. Thompson. 1952. A Generalization of Sampling Without Replacement from a Finite Universe. *Journal of the American Statistical Association,* 47: 663-685.

Kalton, G. 1992. *Panel Surveys: Adding the Fourth Dimension*. Proceedings of Statistics Canada Symposium 1992: Design and Analysis of Longitudinal Surveys. 7-18.

Kalton, G., J. Kordos and R. Platek, eds. 1992. *Small Area Statistics and Survey Designs*. Central Statistical Office, Warsaw. 31-75.

Kasprzyk, D., G.J. Duncan, G. Kalton and M.P. Singh, eds. 1989. *Panel Surveys*. John Wiley and Sons, New York.

Kish, L. 1965. *Survey Sampling*. John Wiley and Sons, New York.

Lavallée, P. 1998. Course notes for *Theory and Application of Longitudinal Surveys*, Statistics Canada.

Levy, P. and S. Lemeshow. 1991. *Sampling of Populations*. John Wiley and Sons, New York.

Lohr, Sharon. 1999. *Sampling: Design and Analysis*. Duxbury Press, U.S.A.

McLeod, A.I. and D.R. Bellhouse. 1983. A Convenient Algorithm for Drawing a SRS. *Applied Statistics,* 32(2).

Moser C.A. and G. Kalton. 1971. *Survey Methods in Social Investigation*. Heinemann Educational Books Limited, London.

Rao, J.N.K, H.O. Hartley and W.G. Cochran. 1962. On a Simple Procedure of Unequal Probability Sampling Without Replacement. *Journal of the Royal Statistical Society,* B, 27: 482-490.

Särndal, C.E., B. Swensson and J. Wretman. 1992. *Model Assisted Survey Sampling*. Springer-Verlag, New York.

Satin, A. and W. Shastry. 1993. *Survey Sampling: A Non-Mathematical Guide – Second Edition*. Statistics Canada. 12-602E.

Stuart, A. 1968. *Basic Ideas of Scientific Sampling*. Charles Griffin and Company Limited, London.

Thompson, M. 1997. *Theory of Sample Surveys*. Chapman and Hill, United Kingdom.

Thompson, S.K. 1992. *Sampling*. John Wiley and Sons, New York.

Yates, F. and P.M. Grundy. 1953. Selection Without Replacement from Within Strata with Probability-proportional-to-size. *Journal of the Royal Statistical Society,* B, 15: 235-261.

Chapter 7 - Estimation

7.0 Introduction

Chapter 1 - Introduction to Surveys states that the client is typically motivated by a wish to study the characteristics of a population. ***Estimation is the means by which the statistical agency obtains values for the population of interest so that it can draw conclusions about that population based on information gathered from only a sample of the population***.

The principle behind estimation in a probability survey is that each sample unit represents not only itself, but also several units of the survey population. It is common to call the average number of units in the population that a unit in the sample represents the *design weight* of the unit. Determining this weight is an important part of the estimation process. While the design weights can be used for estimation, most surveys produce a set of estimation weights by adjusting the design weights. The two most common reasons for making adjustments are to account for nonresponse and to make use of auxiliary data.

Once the final estimation weights have been calculated, they are applied to the sample data in order to compute *estimates*. Summary measures of the population such as *totals*, *averages* and *proportions* are typically estimated for a wide range of characteristics collected from the sample units. These characteristics, often referred to as variables in statistical theory, may be qualitative – for example, sex or marital status – or quantitative – for example, age or income. Depending on the type of data, different formulas are appropriate for the estimation of summary measures.

An important part of estimation is estimating the magnitude of the sampling error in the estimate. This provides a measure of the quality of the survey's estimates for the specific sample design. Sampling error can only be estimated if probability sampling is used.

The purpose of this chapter is to illustrate how to calculate weights, generate estimates of summary measures and estimates of their sampling error for probability sample surveys.

7.1 Weighting

The first step in estimation is assigning a weight to each sampled unit or to each of the responding sampled units. The ***design weight*** can be thought of as ***the average number of units in the survey population that each sampled unit represents*** and is determined by the sample design. The design weight, w_d (where d stands for *design*) for a unit is the sample is the inverse of its inclusion probability, π. Note that for a multi-stage or multi-phase design, a unit's probability of selection is the combined probability of selection at each stage or phase. Thus, for a two-phase sample where a unit's probability of selection is π_1 at the first phase and π_2 at the second phase, a sample unit's design weight is:

$$w_d = \frac{1}{\pi_1} \times \frac{1}{\pi_2}$$

Survey sample data are generally provided in a file with one record for each sampled unit. Recall that with probability sampling, each unit has a known probability, π, of being sampled. If that inclusion probability is, for example, one in fifty, then each selected unit represents on average 50 units of the survey population and the design weight is w_d=50. If the weight is a whole number, one way to produce

estimates for the population would be to replicate each record so that there are 50 copies of each one and then to calculate any values of interest (such as averages, totals, ratios, etc.) from this file. Replication becomes more difficult when the weight is not an integer value. (For example, if two units out of five are selected using simple random sampling, then the design weight is w_d=2.5). In general, it is easier to include a weight variable to the record of each unit in the sample.

The discussion of weighting will begin with equal probability designs which is the simplest case of weighting.

7.1.1   Weighting for Equal Probability Sample Designs

Sample designs are called self-weighting when the design weights are the same for all units in the sample. This occurs when each unit has the same inclusion probability. For self-weighting designs, if no subsequent adjustments are made to the design weights (e.g., for nonresponse or auxiliary data), weights can be ignored in the production of *some* statistics, such as proportions and averages. The production of totals simply requires that the sample total be inflated by the design weight.

Which one-stage designs are self-weighting? Simple random samples (SRS) and systematic samples are self-weighting since each unit has an equal chance of being included in the sample. In the case of a stratified design, a self-weighting design is obtained, for example, when an SRS is selected in each stratum and the sample size in each stratum is proportional to the population size of the stratum. Thus, the sampling fraction is the same in each stratum and all units in the population have the same inclusion probability. (Allocating the sample across the strata in this manner is called N-proportional allocation and is discussed in more detail in **Chapter 8 - Sample Size Determination and Allocation**.)

Example 7.1: Stratified SRS with N-Proportional Allocation

Suppose a population of *N*=1,000 persons is divided into two strata on the survey frame. The first stratum is composed of N_1=400 men and the second one of N_2=600 women. A total sample of size *n*=250, across both strata, is selected and the sample is allocated proportionally to the size of each stratum. The sampling fraction in each stratum is thus equal to *n/N*=250/1,000=1/4.

Table 1: Stratified SRS with N-Proportional Allocation

Stratum	Population Size	Sample Size
Men	N_1=400	n_1=100
Women	N_2=600	n_2=150
Total	**N =1,000**	**n=250**

The inclusion probabilities in each stratum are:

Stratum 1, Men:

$$\pi_1 = \frac{n_1}{N_1}$$
$$= \frac{100}{400}$$
$$= \frac{1}{4}$$

Stratum 2, Women:

$$\pi_2 = \frac{n_2}{N_2}$$
$$= \frac{150}{600}$$
$$= \frac{1}{4}$$

Therefore, everyone has the same probability of being selected and the same design weight, $w_d = 1/\pi = 4$.

For a multi-stage design, self-weighting is achieved by selecting clusters with probability-proportional-to-size (PPS) at all stages except the final one. At the final stage, a fixed number of units within a cluster is selected (e.g., always pick $n=5$ at the final stage). PPS is often used in multi-stage designs since it can lead to a self-weighting sample while controlling the size of the sample.

An example of a self-weighting two-phase design would be one where an SRS or systematic sample or a stratified sample with N-proportional allocation is drawn at each phase.

For more information on sample designs, see **Chapter 6 - Sample Designs**.

7.1.2 Weighting for Unequal Probability Sample Designs

Although the simplicity of self-weighting designs is appealing, it is not always possible or desirable to select a self-weighting sample. For example, in the case of a stratified design for a national survey for smaller regions, N-proportional allocation may result in inadequate sample sizes and for larger regions, it may result in unnecessarily large samples.

The following example illustrates design weights for a stratified sample design where the sample size in each stratum is not proportional to the size of the population in the stratum. (For more details on disproportional allocation, see **Chapter 8 - Sample Size Determination and Allocation**.)

Example 7.2: Stratified SRS with Disproportional Allocation

For a survey on public transportation, the population of $N=1,100$ persons is divided in two geographical strata. Since it is felt that persons living in urban and rural areas might be very different with respect to the information collected from the survey, a stratified sample design is used. The urban stratum is of size $N_1=1,000$ while the rural stratum is of size $N_2=100$. A sample of $n=250$ persons is selected: $n_1=200$ in the urban stratum and $n_2=50$ in the rural stratum. What are the design weights of the sampled persons?

Table 2: Stratified SRS with Disproportional Allocation

Stratum	Population Size	Sample Size
Urban	$N_1=1,000$	$n_1=200$
Rural	$N_2=100$	$n_2=50$
Total	**$N=1,100$**	**$n=250$**

The inclusion probabilities in each stratum are:

Stratum 1, Urban:

$$\pi_1 = \frac{n_1}{N_1}$$
$$= \frac{200}{1,000}$$
$$= \frac{1}{5}$$

Stratum 2, Rural:

$$\pi_2 = \frac{n_2}{N_2}$$
$$= \frac{50}{100}$$
$$= \frac{1}{2}$$

On the sample file, each respondent in the urban stratum has a design weight of $w_{d,1}=5$ and each respondent in the rural stratum has a design weight of $w_{d,2}=2$.

For multi-stage or multi-phase sampling, the overall design weight is calculated my multiplying the probability of selection at each stage or phase and then taking the inverse. For example, suppose a two-stage cluster sample selects an SRS of $n_1=10$ out of $N_1=100$ clusters at the first stage and an SRS of $n_2=30$ units within each cluster at the second stage, where the number of units within each cluster is $N_2=60$.

The probability of selection at the first stage is:

$$\pi_1 = \frac{n_1}{N_1}$$
$$= \frac{10}{100}$$
$$= \frac{1}{10}$$

and the probability at the second stage is:

$$\pi_2 = \frac{n_2}{N_2}$$
$$= \frac{30}{60}$$
$$= \frac{1}{2}$$

So the design weight is:

$$w_d = \frac{1}{\pi_1} \times \frac{1}{\pi_2}$$
$$= 10 \times 2$$
$$= 20$$

7.1.3   Weight Adjustment for Nonresponse

All surveys suffer from nonresponse, which occurs when all or some of the information requested from sampled units is unavailable for some reason. As presented in **Chapter 3 - Introduction to Survey Design**, there are two main types of nonresponse, item and total nonresponse. *Item (or partial) nonresponse occurs when information is available for only some items*, such as when the respondent answers only part of the questionnaire. In this case, the most common approach is to impute the missing values. (Different approaches for imputing item or partial nonresponse are discussed in **Chapter 10 - Processing**.)

This section focuses on *total nonresponse – the case when all or almost all data for a sampled unit are missing*. This can occur when the sample unit refuses to participate, no contact is made, the unit cannot be located or the information obtained is unusable. The easiest way to deal with such nonresponse is to ignore it. In some exceptional circumstances, proportions or averages estimated without adjusting for total

nonresponse are the same as those produced using a nonresponse adjustment. However, not compensating for the nonresponding units leads to the underestimation of totals (for example, the size of a population, total income or total acreage of crops).

The most common way of dealing with total nonresponse is to adjust the design weights based on the assumption that the responding units represent both responding and nonresponding units. This is reasonable under the assumption that, for the characteristics measured in the survey, the nonrespondents are like the respondents. The design weights of the nonrespondents are then redistributed amongst the respondents. This is often done using a nonresponse adjustment factor that is multiplied by the design weight to produce a nonresponse adjusted weight, as illustrated in example 7.3 below.

It should be noted that data from a census may also have a nonresponse weight adjustment, where the initial design weights in this case would be equal to one, $w_d = 1$. For more details on nonresponse bias, see **Chapter 3 - Introduction to Survey Design** and **Chapter 5 - Questionnaire Design**.

7.1.3.1   Nonresponse Weight Adjustment Factors

The nonresponse adjustment factor is usually defined as the ratio of the sum of the weights in the original sample to the sum of the weights of the responding units. In a self-weighting design, this is equivalent to the ratio of the number of units in the original sample to the number of responding units and is illustrated below.

Example 7.3: Nonresponse Adjustment Factor for SRS, One Nonresponse Group

An SRS of $n = 25$ persons was selected from a population of $N=100$ persons. Denote the number of respondent units by n_r. Only $n_r = 20$ persons provided all the information required. What are the nonresponse adjusted weights of the sample units?

1. The first step is to calculate the inclusion probabilities for an SRS:

$$\pi = \frac{n}{N}$$
$$= \frac{25}{100}$$
$$= \frac{1}{4}$$

Therefore, the design weight for every sampled unit is $w_d = 4$.

2. The second step is to calculate the nonresponse adjustment factor.

Since only $n_r = 20$ persons out of the $n = 25$ selected provided the information required, the final sample size is 20. Assuming the responding units can be used to represent both responding and nonresponding units, the nonresponse adjustment factor is:

$$\frac{n}{n_r} = \frac{25}{20}$$
$$= 1.25$$

3. The last step is to compute the nonresponse adjusted weight.

The nonresponse adjusted design weight, w_{nr}, is the product of the design weight and the nonresponse adjustment factor:

$$w_{nr} = w_d \frac{n}{n_r}$$
$$= 4 \times 1.25$$
$$= 5$$

Therefore, each respondent represents 5 people in the survey population. *A final weight of 5* is assigned to each unit on the data file.

If the assumption that all non-respondents are like respondents for the characteristics measured in the survey is appropriate, the same nonresponse adjustment factor can be used for all respondent units (as above). However, there are usually subgroups with different response propensities and different characteristics, in which case, one adjustment for all respondents can bias the results. For example, single person households often have lower response rates and different characteristics than multi-person households. In such cases, separate nonresponse adjustments should be performed.

In the example below, a different nonresponse adjustment factor is applied to each of the two strata: urban and rural. The reason for this is that characteristics of interest differ between strata.

Example 7.2 (continued): Nonresponse Adjustment Factor for Stratified SRS (where Nonresponse Group = Stratum)

During data collection, only $n_{r,1} = 150$ persons in the urban stratum and $n_{r,2} = 40$ persons in the rural stratum provide the required information. What are the nonresponse adjusted weights of these respondents?

Table 3: Stratified SRS with Nonresponse

Stratum	Population Size	Sample Size	Number of Respondents
Urban	$N_1 = 1,000$	$n_1 = 200$	$n_{r,1} = 150$
Rural	$N_2 = 100$	$n_2 = 50$	$n_{r,2} = 40$

1. The design weight in each stratum is $w_{d,1} = 5$ for the urban stratum and $w_{d,2} = 2$ for the rural stratum.

2. A nonresponse adjustment factor is calculated for each stratum as follows:

Stratum 1, Urban:

$$\frac{n_1}{n_{r,1}} = \frac{200}{150}$$
$$= 1.33$$

Stratum 2, Rural:

$$\frac{n_2}{n_{r,2}} = \frac{50}{40}$$
$$= 1.25$$

3. The nonresponse adjusted weight for each stratum is the product of the design weight and the nonresponse adjustment factor.

Stratum 1, Urban:

$$w_{nr,1} = w_{d,1} \frac{n_1}{n_{r,1}}$$
$$= 5 \times 1.33$$
$$= 6.67$$

Stratum 2, Rural:

$$w_{nr,2} = w_{d,2} \frac{n_2}{n_{r,2}}$$
$$= 2 \times 1.25$$
$$= 2.5$$

On the sample file, each respondent in the urban stratum is given a final weight of 6.67 and each respondent in the rural stratum is given a final weight of 2.5.

When calculating the nonresponse adjustment factor, it is important to take into consideration the fact that some sampled units may turn out to be out-of-scope (i.e., not part of the target population). For example, in a survey of retail businesses, some of the frame information may be incorrect and a sampled unit may actually be a wholesaler. The nonresponse adjustment should only be calculated with respect to in-scope units. This is because out-of-scope units in the sample typically represent other out-of-scope units in the frame. Because out-of-scope units are not expected to answer the survey, their response rates can be assumed to be 100%. The above example assumes that all nonrespondents are in-scope; the resulting adjustment factors could be quite different depending on what are believed to be the true number of in-scope nonrespondents.

For all of these methods, it is best to group together similar records, as is done for nonresponse weight adjustments (see **Chapter 7 - Estimation**). These groupings are referred to as imputation classes.

The nonresponse adjustment should be performed separately for similar groups of respondents, where each group of respondents can represent the nonrespondents in that group. These groupings may be strata, or post-strata (see following section), or analysis can be performed to determine the groupings (e.g., chi-square tests or logistic regression). For more details on nonresponse adjustments, see Groves and Couper (1998).

For an explanation of chi-square tests and logistic regression, see **Chapter 11 - Analysis of Survey Data**.

7.1.4   Using Auxiliary Information to Adjust Weights

The design weight multiplied by the nonresponse adjustment factor can be used to produce final weights and survey estimates of the desired characteristics. However, sometimes information about the survey population is available from other sources, for example information from a previous census. This information can also be incorporated in the weighting process.

There are two main reasons for using auxiliary data at estimation. The first reason is that it is often important for the survey estimates to match known population totals or estimates from another, more reliable, survey. For example, many social surveys adjust their survey estimates in order to be consistent with estimates (age, sex distributions, etc.) of the most recent census of population. Auxiliary information may also be obtained from administrative data or from another survey that is considered to be more reliable because of its larger sample size or because its published estimates must be respected.

The second reason for using auxiliary data is to improve the precision of the estimates. Recall that an

estimator with small sampling variance – a measure of sampling error – is said to be precise. **Chapter 6 - Sample Designs** discussed the importance using auxiliary data when designing the sample in order to improve the statistical efficiency of the sampling strategy. At the design stage, however, auxiliary information must be available for all units on the frame. At estimation, auxiliary data can be used to improve the precision of the estimates as long as the values of the auxiliary variables are collected for the surveyed units and that population totals or estimates are available for these auxiliary variables from another reliable source.

For example, if a person's age is not available on the frame, then it cannot be used to stratify the population. However, if this information is collected by the survey, then the survey's estimates can be adjusted to match the Census' age distribution. If age is correlated to other variables collected by the survey (for example, health variables), its use as auxiliary data can improve the precision of the estimates. This will be illustrated in the following sections.

Auxiliary information may also be used to further correct for different nonresponse rates in different subgroups of the population. It may also help to adjust for coverage inadequacies that result in the survey population differing from the target population.

There are three basic requirements for the successful use of auxiliary data at the estimation stage:
- the auxiliary data must be well correlated with the survey variables;
- the external sources of information concerning the population must be accurate;
- the auxiliary information must be collected for all responding sample units if only population totals are known.

The gains in efficiency of estimates that use auxiliary data depend on how well the survey variables are correlated with the available auxiliary data. The accuracy of the auxiliary information is important. Not only do the data have to be reliable, it is important that the external data source pertain to the same target population and be based upon comparable concepts, definitions, reference periods, etc., as that of the survey.

The following sections describe how auxiliary data can be used for estimation. For more information on the use of auxiliary data, see **Appendix A - Administrative Data.**

7.1.4.1 Post-Stratification

Post-stratification is used to adjust the survey's weights using variables that are suitable for stratification but which could not be used at the design stage because the data were not available, or for which more up-to-date, reliable stratification information for the population became available after sample selection. Post-stratification is used when the auxiliary data are in the form of counts, for example, the number of men and women in the population. It is most effective at reducing sampling variance when the population averages of the variables of interest are as different as possible across the post-strata. It should be noted that whenever possible, it is preferable to stratify at the design stage rather than to post-stratify.

The following example shows how to use post-stratification to improve the estimate of the number of smokers in a company.

Example 7.4: Post-Stratification Weight Adjustment for SRS

Suppose that a survey is conducted to get information on smoking habits of the employees of a small company. An SRS of n=25 persons is selected from the list of N=78 employees. At the design stage, no

auxiliary information was available that could be used for stratification.

In addition to information on smoking habits, the age and sex of each respondent is collected. Of the original n=25 persons, n_r=15 respond with the following distribution:

Table 4: SRS with Nonresponse and Post-Stratification

	Post-Stratum 1, Men	Post-Stratum 2, Women	Number of Respondents
All Employees	3	12	15
Employees who Smoke	1	7	8

1. The inclusion probability for each sampled unit is:

$$\pi = \frac{n}{N}$$
$$= \frac{25}{78}$$
$$= 0.32$$

The design weight therefore is w_d=1/π=3.12.

2. The nonresponse adjustment factor, assuming that everyone in the survey has the same probability of responding to the survey (i.e., one nonresponse group) is:

$$\frac{n}{n_r} = \frac{25}{15}$$
$$= 1.67$$

3. The nonresponse adjusted weight is:

$$w_{nr} = w_d \frac{n}{n_r}$$
$$= 3.12 \times 1.67$$
$$= 5.2$$

So, all respondents have the same nonresponse adjusted weight, w_r=5.2. Using these weights, the following survey estimates are generated (for details on how to generate survey estimates, see section 7.2):

Table 5: Survey Estimates with Nonresponse Adjustment

	Men	Women	Total
Number of Employees	15.6	62.4	78.0
Number of Smokers	5.2	36.4	41.6
Proportion of Smokers	0.33	0.59	0.53

The nonresponse adjusted weights lead to an estimate of about 16 men and 62 women working in the company, with an estimated 33% of men and 59% of women in the company smoking. Suppose that after the survey has been conducted, the following auxiliary information becomes available: there are 42 men and 36 women working in the company. The estimates produced by the survey are quite different from

these true values.

The statistical agency would like the survey estimates to be consistent with the known number of men and women. The agency also suspects that smoking habits are related to a person's sex, so post-stratification could improve the precision of the smoking estimates. In fact, if this information had been available at the time of the sample design, the statistical agency would have stratified by sex. What can be done?

It is possible to stratify the sample after the fact and create what are referred to as post-stratified weights to be used at estimation. The post-stratified weight, w_{pst}, is the product of the nonresponse adjusted weight, w_{nr}, and the post-stratified adjustment factor.

The post-stratified adjustment factor is computed for each post-stratum. This factor corresponds to the ratio of the number of population units in the post-stratum, N, to the estimated number of population units in the post-stratum, $\hat{N}$, which is estimated using the design weights adjusted for nonresponse.

4. In this example, the post-stratification adjustment factor is:

Post-Stratum 1, Men:

$$\frac{N_{men}}{\hat{N}_{men}} = \frac{42}{15.6}$$

$$= 2.69$$

Post-Stratum 2, Women:

$$\frac{N_{women}}{\hat{N}_{women}} = \frac{36}{62.4}$$

$$= 0.58$$

(Note that the while this example is for SRS the same formula, $N / \hat{N}$, is used for more complex design weights.)

When applied to the nonresponse adjusted weight, it produces the final post-stratified weights:

Post-Stratum 1, Men:

$$w_{pst,men} = w_{nr} \times \frac{N_{men}}{\hat{N}_{men}}$$

$$= 5.2 \times 2.69$$

$$= 14$$

Post-Stratum 2, Women:

$$w_{pst,women} = w_{nr} \times \frac{N_{women}}{\hat{N}_{women}}$$

$$= 5.2 \times 0.58$$

$$= 3$$

Using the post-stratified weights, the survey estimates are now:

Table 6: Survey Estimates with Nonresponse and Post-Stratification Adjustment

	Men	Women	Total
Number of Persons	42	36	78
Number of Smokers	14	21	35
Proportion of Smokers	0.33	0.59	0.45

The estimates of the number of men and women are now consistent with the known totals of men and women in the company, and to the extent that sex is related to the number and proportion of smokers, considerable improvements in precision may be obtained. Note that the proportion of smokers within each post-stratum has not changed, but that the proportion of smokers in the total population, which involves more than one post-stratum, has changed.

7.1.4.2 Ratio Estimation

A method commonly used in surveys for incorporating auxiliary information to improve survey estimates is *ratio estimation*. When the data are in the form of counts, ratio estimation corresponds to post-stratification. In general, with ratio estimation the weights of the records in a classification group are adjusted by a multiplicative factor. This factor is the ratio of the estimate from the auxiliary data to the survey estimate for the same variable, for the classification group.

For example, if the objective of a survey is to estimate the acreage of wheat in specific regions, then knowledge of the total acreage in each region could be a useful auxiliary variable. If the acreage of wheat is highly correlated with the total land within the region, this auxiliary information could improve the estimates of acreage of wheat. Using ratio estimation, the adjustment factor for each region would be the total land area in the region divided by the sample estimate of the total land area in the region (i.e., the adjustment factor would be of the form $Y / \hat{Y}$). In Example 7.4, the ratios were the number of men divided by the estimated number of men and the same ratio for women, which, since these are counts, corresponds to post-stratification. Like the preceding methods, ratio estimation can be applied separately by stratum, if auxiliary information is available at that level and the sample size in each stratum is adequate.

7.1.4.3 More Complex Weight Adjustments: Calibration and Generalised Regression

Ratio estimation is based on the assumption that there is a simple multiplicative relationship between the survey characteristics and an auxiliary variable (i.e., 2.7 as many men implies 2.7 as many male smokers). However, this assumption may not hold true in all situations. First, using a single auxiliary variable may be insufficient to provide good estimates. Second, the relationship between the variable being estimated and the auxiliary variable may be more complex than a simple multiplicative one. In this case, *regression estimation* may be used. Regression estimation is a more complex approach that allows the analyst to consider more sophisticated models, including models with more than one auxiliary variable.

Another problem with ratio estimation is that it may be necessary to ensure that the weighted sample totals agree with known population totals for *more than one* characteristic. When the weighted sample totals must agree with reference totals for more than one characteristic, a method called *calibration* needs to be used. This situation would arise, for example, when poststrata are formed using more than one variable and only the marginal population totals for each variable are known. For example, if population counts were available by age group and by sex but the counts of men and women within each age group were unknown, in which case, the post-stratification method described previously could not be applied using both characteristics. (Ratio estimation and post-stratification are calibration using one variable.)

An extension of the ratio method, referred to as *raking ratio estimation* allows the statistical agency to compute adjusted weights so that the estimates are very close to marginal reference counts for each characteristic. A description of this method can be found in Deming and Stephan (1940), Arora and Brackstone (1977), Bankier (1978), Brackstone and Rao (1978), Binder (1988).

Generalised estimation procedures have also been developed to produce estimates that agree with reference totals for many characteristics simultaneously. In these general techniques, the process of ensuring that the reference totals are matched is referred to as *calibration* and the weight adjustments produced are called *calibration factors*.

As with post-stratification and ratio estimation, these techniques result in adjustments to the initial design weights. The final weights used to calculate estimates become the product of the initial weights adjusted for nonresponse and calibration factors. Generalised estimation procedures are beyond the scope of this document. The reader will find the theory of generalised regression estimation in Särndal, Swensson and Wretman (1992), Deville and Särndal (1992), and Hidiroglou and Särndal (1998). See also **Chapter 11 - Analysis of Survey Data** for an introduction to linear regression.

7.2 Production of Simple Estimates (Totals, Averages and Proportions)

The examples so far have illustrated how to calculate design weights and adjust them for nonresponse and auxiliary data. This section explains how to generate estimates using the final estimation weights.

We have already noted in **Chapter 6 - Sample Designs** that with probability sampling, the sampling distribution of the estimator can be determined. With non-probability sampling, since the probabilities of different samples being selected are unknown, the sampling distribution cannot be calculated. Being able to measure sampling error is an important part of survey estimation and therefore one of the main reasons for performing probability sampling.

7.2.1 Estimators for Different Types of Data

Simple descriptive statistics such as totals, averages and proportions are produced for virtually every survey. Usually, more complex statistics and analyses are also required. In most surveys, data are collected for a wide range of variables which may be qualitative (also referred to as categorical) or quantitative.

For some qualitative variables, such as sex or marital status, only a few categories are possible. For opinion questions, the respondents' answers are often collected using a scale of agreement such as *strongly agree, agree, neither agree nor disagree, disagree, strongly disagree.* Note that with categorical data, each unit fits into one and only one category.

If the unit of measurement indicates quantities such as metres or years, the data are called *quantitative data*. Quantitative data are typically answers to questions of the type *how much?* or *how many?* Some examples are age, number of children, number of hours worked, expenditure and income, and blood pressure.

Different types of estimators are appropriate for these different types of variables. Proportions and total counts are typically produced for qualitative variables while averages and totals are estimated for quantitative variables. In this section, the procedures for the production of estimates will be presented separately for qualitative and quantitative data.

Besides the type of data, another consideration during estimation is the nature of the population for which the estimates are to be made. Estimates can be produced for the whole survey population or for specific subgroups or *domains* of the population (e.g., provinces). When the original classification of sampling units has changed between the time of sample selection and estimation, the new classification should be used for domain estimation.

The answers to the following questions will help determine how the survey estimates are computed:
-    What type of statistic is needed? A total, an average, a proportion?

- What type of data is being used? Qualitative or quantitative?
- What are the final weights?
- What are the domains of interest?

The procedures for estimating totals, averages and proportions for the whole survey population and domains using weights are described below for qualitative and quantitative data.

The following estimators can be applied to any probability sample design – simple (e.g., SRS, SYS) or more complex. What is important is that each unit's final weight correctly account for the sample design.

i.   Estimating a population total

For qualitative and quantitative data, the estimate of the *total number of units in the survey population* is calculated by adding together the final adjusted weights of the responding units:

$$\hat{N} = \sum_{i \in S_r} w_i$$

where i is the ith responding unit in the sample and w_i is its final adjusted weight and S_r is the set of responding units.

For quantitative data, the estimate of a *total value* (such as total expenditure) is the product of the final weight, w_i, and the value, y_i, for each responding unit, summed over all responding units:

$$\hat{Y} = \sum_{i \in S_r} w_i y_i$$

ii.   Estimating a population average

For quantitative data, the estimate of an average value in the population is obtained by adding together the product of the sample value and the weight for each responding unit, and dividing this amount by the sum of the weights. In other words, the estimate of the average in the population is the estimate of the total value for quantitative data divided by the estimate of the total number of units in the population.

$$\hat{\bar{Y}} = \frac{\sum_{i \in S_r} w_i y_i}{\sum_{i \in S_r} w_i}$$

$$= \frac{\hat{Y}}{\hat{N}}$$

Note that for SRS or SYS with 100% response rate and no weight adjustments, the estimator reduces to:

$$\hat{\bar{Y}} = \frac{\sum_{i \in S_r} y_i}{n}$$

iii.   Estimating a population proportion

For qualitative data, the estimate of the proportion of units in the survey population having a given characteristic is obtained by adding together the weights for the units having that characteristic, and dividing this total by the sum of the weights for all respondents. In other words, the estimate of the proportion in the population is the estimate of the total number of units possessing the given characteristic divided by the estimate of the total number of units in the population.

$$\hat{P} = \frac{\sum\limits_{i \in S_r \cap C} w_i}{\sum\limits_{i \in S_r} w_i}$$

$$= \frac{\hat{N}_C}{\hat{N}}$$

where C is the collection of units having the given characteristic.

iv.   Estimating for domains of the population

Estimates may be required for domains such as age group, type of dwelling, size of household, or class of income.

-   The size of the population for a domain of interest for either qualitative or quantitative data is estimated as follows:

$$\hat{N}_{domain} = \sum\limits_{i \in S_r \cap domain} w_i$$

-   The estimate of a domain total for quantitative data is:

$$\hat{Y}_{domain} = \sum\limits_{i \in S_r \cap domain} w_i y_i$$

-   The estimate of a domain average for quantitative data is:

$$\hat{\bar{Y}}_{domain} = \frac{\sum\limits_{i \in S_r \cap domain} w_i y_i}{\sum\limits_{i \in S_r \cap domain} w_i}$$

$$= \frac{\hat{Y}_{domain}}{\hat{N}_{domain}}$$

- The estimate of a domain proportion for qualitative or quantitative data is:

$$\hat{P}_{domain} = \frac{\sum\limits_{i \in S_r \cap domain \cap C} w_i}{\sum\limits_{i \in S_r \cap domain} w_i}$$

$$= \frac{\hat{N}_{domain \cap C}}{\hat{N}_{domain}}$$

These estimation procedures are illustrated in the following sections.

7.2.2 Estimating Totals, Averages and Proportions

The correct use of the final weights in the estimation process is crucial in the production of estimates.

Example 7.6: Estimation When Final Weights are Unequal, SRS

A survey is conducted to provide information on a population of farms. A sample of $n=10$ farms is selected using a stratified sample design. All 10 farms respond and no weight adjustments are performed, so the final estimation weight is equal to the design weight. Estimates need to be produced from the following data file:

Stratum	Final Weight	Type of Farm	Income $
1	5.67	1	75,000
1	5.67	2	15,000
1	5.67	1	125,000
1	5.67	1	67,000
1	5.67	2	80,000
1	5.67	1	40,000
2	16.5	1	30,000
2	16.5	1	14,000
2	16.5	2	48,000
2	16.5	1	22,000

Type of Farm
1=Crop   (N_1=34, n_1=6)
2=Livestock   (N_2=66, n_2=4)

- The estimated number of farms in the population is:

$$\hat{N} = \sum_{i \in S_r} w_i$$

$$= 5.67 + 5.67 + 5.67 + 5.67 + 5.67 + 5.67 + 16.5 + 16.5 + 16.5 + 16.5$$

$$= 100$$

Note that if the weights had been ignored, then the estimate would have been incorrectly calculated to be 10.

-   The estimated number of livestock farms is:

$$\hat{N}_{livestock} = \sum_{i \in S_r \cap livestock} w_i$$

$$= 5.67 + 5.67 + 16.5$$

$$= 28$$

-   The estimated proportion of livestock farms is:

$$\hat{P} = \frac{\displaystyle\sum_{i \in S_r \cap livestock} w_i}{\displaystyle\sum_{i \in S_r} w_i}$$

$$= \frac{28}{100}$$

$$= 0.28$$

-   The estimated total income for the entire population of farms is:

$$\hat{Y} = \sum_{i \in S_r} w_i y_i$$

$$= 5.67 \times 75,000 + 5.67 \times 15,000 + \ldots + 16.5 \times 22,000$$

$$= 4,160,340$$

-   The estimated average income for the entire population of farms is:

$$\hat{\bar{Y}} = \frac{\displaystyle\sum_{i \in S_r} w_i y_i}{\displaystyle\sum_{i \in S_r} w_i}$$

$$= \frac{4,160,340}{100.02}$$

$$= 41,595$$

-   The estimated total income for livestock farms is given by:

$$\hat{Y}_{livestock} = \sum_{i \in S_r \cap livestock} w_i y_i$$

$$= 5.67 \times 84,000 + 5.67 \times 48,000 + 16.5 \times 23,000$$

$$= 1,330,650$$

- The estimated average income for livestock farms is given by:

$$
\begin{aligned}
\hat{\bar{Y}}_{livestock} &= \frac{\displaystyle\sum_{i \in S_r \cap livestock} w_i\, y_i}{\displaystyle\sum_{i \in S_r \cap livestock} w_i} \\[2mm]
&= \frac{5.67 \times 84{,}000 + 5.67 \times 48{,}000 + 16.5 \times 23{,}000}{5.67 + 5.67 + 16.5} \\[2mm]
&= \frac{1{,}330{,}650}{27.8} \\[2mm]
&= 47{,}796
\end{aligned}
$$

Note that if the sampling weights were ignored, the estimates would be incorrect, as illustrated in the table below:

Table 7: Comparing Estimates Calculated with and without the Weights

Parameter	Correct Estimate, using Weights	Incorrect Estimate, Ignoring Weights
N	100	10
$N_{livestock}$	28	3
P	0.28	0.30
Y	\$4,160,340	\$516,000
$\bar{Y}$	\$41,595	\$51,600
$Y_{livestock}$	\$1,330,650	\$155,000
$\bar{Y}_{livestock}$	\$47,796	\$51,667

It is possible to produce estimates for qualitative data using the techniques usually reserved for quantitative variables. An *indicator variable* can be defined for each category of the qualitative variable that takes the value 1 if the unit belongs to the category and 0 otherwise. The estimate of the total number of units possessing the characteristic is obtained by calculating the product of the value of the indicator variable (1 or 0) and the weight for each respondent unit, and then summing over all responding units. With this approach, the procedures for estimation of qualitative and quantitative data are the same.

7.2.3   Estimation Issues

7.2.3.1 Estimation for Small Domains

Whenever possible, the sample design should take into consideration the domains of interest through stratification. This will ensure adequate sample size and precision. However, restrictions on sample size and other design criteria (such as survey frame information) may mean that only a modest number of strata can be formed, so for some domains, particularly small ones, the sample size may be inadequate.

Inadequate sample size in a domain can pose a problem at estimation. Various techniques are available to generate estimates in such cases. These include synthetic estimation, composite estimation and others. These methods usually require correlated information from another source, or the use of good models. The application of these techniques can become complex and is beyond the scope of this manual. More information on this advanced topic can be found in Särndal, Swensson and Wretman (1992), Ghosh and

Rao (1994), Singh, Gambino and Mantel (1994).

7.2.3.2 Outliers

Barnett and Lewis (1995) define an outlier to be *an observation or subset of observations which appears to be inconsistent with the remainder of the dataset.* There are a variety of methods available to reduce the impact of outliers on the survey estimates. Simply ignoring them can result in a loss in precision; giving them a weight of one or zero can bias the results. Alternatively, auxiliary information and post-stratification can be used to ensure that outliers do not contribute an unreasonably large amount to the estimates. Treatment of outliers will be covered further in **Chapter 10 - Processing**. More information on this advanced topic can be found in Kish (1965), Hidiroglou and Srinath (1981).

7.3   Estimating the Sampling Error of Survey Estimates

Estimates produced from a survey are subject to error. In **Chapter 3 - Introduction to Survey Design**, it was stated that there are two basic types of error – sampling error and nonsampling errors. Nonsampling errors often cause bias and are difficult to measure; sampling error causes variability – it measures the extent to which an estimate from different possible samples of the same size and design, using the same estimator, differ from one another.

Chapter 6 - Sample Designs explained the importance of having an estimate of the sampling variance at the design stage in order to compare the statistical efficiency of different sample designs**. Chapter 8 - Sample Size Determination and Allocation** shows how an estimate of the sampling variance is used to determine the size of the sample required to satisfy a given level of precision.

The purpose of this chapter is to illustrate how sampling variance is measured and the importance of correctly incorporating the sample design. This chapter only presents variance estimators for an estimated mean or total for an SRS or Stratified SRS, assuming no adjustments to the original design weights. Variance estimation for a proportion estimated from an SRS and more complex designs (using a design effect) are presented in **Chapter 8 - Sample Size Determination and Allocation**.

Each sampling strategy has its own specific formula for estimating sampling variance, at times very complicated. In order to estimate correctly the sampling variance for a survey with complex data (i.e., for more complex designs and/or in the presence of weight adjustments), a survey statistician familiar with this type of problem should be consulted.

The formulas presented in this chapter can be found in any introductory book on sampling theory, for example, Cochran, 1977 or Lohr, 1999.

7.3.1   Sampling Variance

Mathematically, the sampling variance of an estimate is the average squared deviation about the estimator's average value, across all possible samples. **Chapter 3 - Introduction to Survey Design** listed the factors affecting the magnitude of the sampling variance:
- the variability of the characteristic of interest in the population;
- the size of the population;
- the response rate;

- the sample design and method of estimation.

The affect of these factors on the sampling variance is illustrated below using the estimator for the sampling variance of a population average estimated from an SRSWOR with 100% response rate. (See also **Chapter 8 - Sample Size Determination and Allocation**.)

The value of each variable, y_i, usually varies from one unit to another in the population. The population variance, σ^2, of all units, y_i, in the population is defined as follows:

$$\sigma^2 = \frac{(N-1)}{N} S^2$$

where

$$S^2 = \sum_{i \in U} \frac{(y_i - \overline{Y})^2}{N-1} .$$

and U is the set of units in the population and there are N units in the population.

An unbiased estimator of the population average for an SRSWOR of size n with 100% response rate is:

$$\hat{\overline{Y}} = \sum_{i \in S_r} \frac{y_i}{n}$$

where S_r is the set of respondents in the sample and there are n units in the sample.

The estimate, $\hat{\overline{Y}}$, varies from sample to sample. An expression for the sampling variance of $\hat{\overline{Y}}$ for an SRSWOR of size n is:

$$Var(\hat{\overline{Y}}) = (1 - \frac{n}{N}) \frac{S^2}{n}$$

It is clear from the above equation that an estimate for a characteristic with large unit to unit differences – high variability in the population – has greater sampling variance than that of an estimate for a characteristic with low population variability. Usually, S^2 is unknown and must be estimated (see section 7.3.2.3.).

It is also clear that the size of the population has an impact on the sampling variance: the term $f=n/N$ is referred to as the sampling fraction and the term $(1-f)=1-n/N$ as the finite population correction factor (fpc). As the sample size, n, increases the sampling variance decreases and for a census (where $n=N$) there is no sampling variance. When the sampling fraction is small (i.e., the sample size is small compared to the population), the fpc can be ignored. (Cochran, 1977, states that this factor can be ignored whenever it does not exceed 5% and for many purposes even if it is as high as 10%.) Notice also that nonresponse increases the sampling variance by effectively decreasing the sample size.

As explained in **Chapter 6 - Sample Designs**, some sampling strategies are more efficient than others. For example, stratification and the use of ratio estimators can improve an estimate's precision.

In the following discussion of sampling variance, it is assumed that the estimator is unbiased. There are, however, some instances when a biased estimator is preferred (for example, when its precision is much better than any alternative unbiased estimator). If bias is present for whatever reason – due to a biased

estimator or arising from nonsampling error – then the sampling variance formulas presented in the following sections calculate the mean square error (MSE), which is a measure of sampling variance and bias. This can lead to problems with confidence intervals, see **Chapter 11 -Analysis of Survey Data** for more details.

7.3.1.1 Calculating the True Sampling Variance

The following example illustrates how to calculate the true sampling variance of the estimated average video expenditure for an SRSWOR of size n=2.

Example 7.7:

The expenditure on video products for a population of 4 households is given below. For an SRSWOR of size n=2 what is the true sampling variance of the estimated average expenditure?

Table 8: Video Expenditure per Household

Household	Video Expenditure ($)
1	10
2	20
3	30
4	40

First, note that the value of the parameter the *population average video expenditure* is:

$$\bar{Y} = \sum_{i \in U} \frac{y_i}{N}$$
$$= \frac{10 + 20 + 30 + 40}{4}$$
$$= 25$$

The usual estimator for the *estimated average* for an SRS is:

$$\hat{\bar{Y}} = \sum_{i \in S_r} \frac{y_i}{n}$$
$$= \sum_{i \in S_r} \frac{y_i}{2}$$

We can calculate the true sampling variance of the estimated average, $Var(\hat{\bar{Y}})$, for an SRSWOR of size n=2 by looking at the results of all possible SRSWOR samples of size 2. These are presented in the table below:

Table 9: Calculating the True Sampling Variance of $\hat{\bar{Y}}$

Sample	Units in sample	Sample Estimate (\$), $\hat{\bar{Y}}$	$(\hat{\bar{Y}} - \bar{Y})$	$(\hat{\bar{Y}} - \bar{Y})^2$
1	(1,2)	15	-10	100
2	(1,3)	20	-5	25
3	(2,3)	25	0	0
4	(1,4)	25	0	0
5	(2,4)	30	5	25
6	(3,4)	35	10	100
Average		**25**	**0**	**41.7**

1. Calculate the average of all possible sample averages:

$$\bar{\hat{\bar{Y}}} = \frac{\hat{\bar{Y}}_{(1)} + \hat{\bar{Y}}_{(2)} + \hat{\bar{Y}}_{(3)} + \hat{\bar{Y}}_{(4)} + \hat{\bar{Y}}_{(5)} + \hat{\bar{Y}}_{(6)}}{6}$$

$$= \frac{15 + 20 + 25 + 25 + 30 + 35}{6}$$

$$= 25$$

$$= \bar{Y}$$

Note that the average value of the estimate across all possible samples is equal to the population average, $\bar{Y}$. This is to be expected since the estimator for $\hat{\bar{Y}}$ is unbiased.

2. Calculate the difference between each sample's estimate and the average estimate across all samples (i.e., $\hat{\bar{Y}}_j - \bar{Y}$, for the jth sample), seen in the fourth column of the table above.

3. Compute the square of these differences (i.e., $(\hat{\bar{Y}}_j - \bar{Y})^2$), seen in the fifth column of the table.

4. For the set, J, of all samples in the population, compute the average squared difference:

$$Var(\hat{\bar{Y}}) = \sum_{j \in J} \frac{(\hat{\bar{Y}}_j - \bar{Y})^2}{6}$$

$$= \frac{100 + 25 + 0 + 0 + 25 + 100}{6}$$

$$= 41.7$$

Therefore, for this population the true sampling variance of the estimated average video expenditures from an SRSWOR of size $n=2$ is $Var(\hat{\bar{Y}}) = 41.7$.

The problem with the above approach is that it is not practical to select all possible samples from the population. One alternative is to select many replicated samples, as mentioned in section 6.2.9 of **Chapter 6 - Sample Designs** and in the following section 7.3.4. Alternatively, the equation presented

earlier could be used directly:

$$Var(\hat{\overline{Y}}) = (1 - \frac{n}{N}) \frac{S^2}{n}$$

where:

$$S^2 = \sum_{i \in U} \frac{(y_i - \overline{Y})^2}{N-1}$$
$$= \frac{(10-25)^2 + (20-25)^2 + (30-25)^2 + (40-25)^2}{(4-1)}$$
$$= 166.7$$

Therefore:

$$Var(\hat{\overline{Y}}) = (1 - \frac{n}{N}) \frac{S^2}{n}$$
$$= (1 - \frac{2}{4}) \frac{166.7}{2}$$
$$= 41.7$$

The problem with the above equation is that unless a census has previously been conducted the population variability – S^2 – is unknown and must be estimated from a single sample. If probability sampling is used, then the sampling distribution of the estimator can be calculated and the population variance can be estimated on the basis of a single sample.

For standard sample designs (SRS, stratified sampling, etc.), formulas for $\hat{S}^2$ can be found in any sampling theory textbook. When the sample design or the estimation procedure is complex, alternative methods such as those described in section 7.3.4 have to be used.

For an SRSWOR, it can be shown that an unbiased estimate of the sampling variance of the estimated mean, $\hat{\overline{Y}}$, is:

$$V\hat{a}r(\hat{\overline{Y}}) = (1 - \frac{n}{N}) \frac{\hat{S}^2}{n}$$

where:

$$\hat{S}^2 = \sum_{i \in S} \frac{(y_i - \overline{y})^2}{n-1}$$

and

$$\overline{y} = \sum_{i \in S} \frac{y_i}{n}$$

This formula will be illustrated in section 7.3.2.3.

It can be shown that for an SRSWOR, an unbiased estimate of the sampling variance of the estimated total, $\hat{Y}$, is:

$$Var(\hat{Y}) = Var(N \times \hat{\bar{Y}}) = N^2 Var(\hat{\bar{Y}}) = N^2(1 - \frac{n}{N})\frac{\hat{S}^2}{n}$$

For the sampling variance of an estimated proportion, $\hat{P}$, see **Chapter 8 - Sample Size Determination and Allocation**.

7.3.2   Other Measures of Sampling Error

Before illustrating how to *estimate* sampling variance, other common measures of sampling error will be presented, such as the:
- standard error;
- coefficient of variation;
- margin of error;
- confidence interval .

These are all related expressions; it is possible to go from one to the other using simple mathematical operations.

7.3.2.1 Standard Error and Coefficient of Variation

The standard error of an estimator is the square root of its sampling variance. This measure is easier to interpret since it provides an indication of sampling error using the same scale as the estimate whereas the variance is based on squared differences.

However, even standard error might be difficult to interpret in terms of 'How big a standard error is acceptable?' What is large depends on the magnitude of the estimate. For example, a standard error of 100 would be considered large for measuring the average weight of people but would not be considered large for estimating average annual income.

It is more useful in many situations to assess the size of the standard error relative to the estimate of the characteristic being measured. The ***coefficient of variation*** provides such a measure. It is the ***ratio of the standard error of the survey estimate to the average value of the estimate itself, across all possible samples.*** *The coefficient of variation is usually computed as the estimate of the standard error of the survey estimate to the estimate itself.* This relative measure of sampling error is usually expressed as a percentage (10% instead of 0.1). It is very useful in comparing the precision of sample estimates, where their sizes or scale differ from one another. However, it is not as useful for estimators of characteristics whose true value can be zero or negative, including estimates of changes (e.g., the change in average income since last year).

7.3.2.2 Margin of Error and Confidence Interval

It is common to see the results of a survey reported in a newspaper as follows:

> According to a recent survey, 15% of Ottawa residents attend religious services every week. The results, based on a sample of 1,345 residents, are considered accurate within plus or minus three percentage points 19 times out of 20.

What does this statement mean? It indicates that the true value, the true percentage of people who attend religious services every week, is likely to be within three percentage points of the estimate (15%). In the above example, the *margin of error* is *plus or minus three percentage points* or simply three percentage points while the *confidence interval* is the range 12% to 18%. Margins of error always include a confidence statement, the level of comfort that is felt about this interval. In this example, the confidence statement is *19 times out of 20*. This means that, if the survey were repeated many times, then 19 times out of 20 (or 95% of the time), the confidence interval would cover the true population value.

The theory behind the construction of confidence intervals can be described as follows. Suppose that for a large sample there is an estimate of the population average, $\hat{\overline{Y}}$, and an estimate of its standard error, $S\hat{E}(\hat{\overline{Y}})$. Then, because of the Central Limit Theorem and the normal distribution, the chances are:

- .10 that the absolute error $|\hat{\overline{Y}} - \overline{Y}|$ exceeds $1.65 \times S\hat{E}(\hat{\overline{Y}})$ (this corresponds to a 90% confidence interval);

- .05 that the absolute error $|\hat{\overline{Y}} - \overline{Y}|$ exceeds $1.96 \times S\hat{E}(\hat{\overline{Y}})$ (this corresponds to a 95% confidence interval);

- .01 that the absolute error $|\hat{\overline{Y}} - \overline{Y}|$ exceeds $2.58 \times S\hat{E}(\hat{\overline{Y}})$ (this corresponds to a 99% confidence interval).

These formulas apply to all normally distributed estimators. It should be noted that standard errors are useful not just for the calculation of confidence intervals but also for inferential data analysis, such as hypothesis testing (see **Chapter 11 - Analysis of Survey Data**).

For more details on the theory behind confidence intervals, refer to any book on sampling theory (e.g., Cochran (1977), Lohr (1999), Särndal, Swensson and Wretman (1992), Stuart (1968)).

7.3.2.3 Estimating Sampling Variance and Other Measures of Sampling Error for an SRSWOR

The following example illustrates how to estimate measures of sampling error from a single, realised sample that was obtained using SRSWOR (assuming a 100% response rate and no adjustment for auxiliary data).

Example 7.8: Estimating the Sampling Variance, Standard Error, Coefficient of Variation, Margin of Error and Confidence Interval for $\hat{\overline{Y}}$, SRSWOR

An SRSWOR of *n*=10 persons (100% response rate) is selected from a population of *N*=500 persons. The age of each sampled unit is provided in the table below (sorted by age). What is the estimated sampling variance of the estimated average age? What are the estimated standard error and coefficient of variation? What are the margin of error and the confidence interval for a confidence level of 95%?

Table 10: Calculating the Estimated Sampling Variance of $\hat{\bar{Y}}$

Person	Age of the Sample unit, y_i	$(y_i - \bar{y})$	$(y_i - \bar{y})^2$
1	21	-13.4	179.56
2	26	-8.4	70.56
3	27	-7.4	54.76
4	32	-2.4	5.76
5	34	-.4	.16
6	37	2.6	6.76
7	38	3.6	12.96
8	40	5.6	31.36
9	42	7.6	57.76
10	47	12.6	158.76

1. Estimate the population average age:

$$\hat{\bar{Y}} = \sum_{i \in S_r} \frac{y_i}{n}$$

$$= \frac{21 + 26 + 27 + 32 + 34 + 37 + 38 + 40 + 42 + 47}{10}$$

$$= 34.4$$

Therefore the estimated average age is 34.4 years old. Note that for an SRS (with no weight adjustment factors for nonresponse or auxiliary data), the estimated population average is the simple sample average.

2. The estimated sampling variance of $\hat{\bar{Y}}$ for an SRSWOR is:

$$V\hat{a}r(\hat{\bar{Y}}) = (1 - \frac{n}{N}) \frac{\hat{S}^2}{n}$$

where $\hat{S}^2$ is:

$$\hat{S}^2 = \sum_{i \in S_r} \frac{(y_i - \bar{y})^2}{n - 1}$$

$$= \frac{179.56 + 70.56 + 54.76 + ... + 31.36 + 57.76 + 158.76}{10 - 1}$$

$$= 64.3$$

thus:

$$V\hat{a}r(\hat{\bar{Y}}) = (1 - \frac{n}{N}) \frac{\hat{S}^2}{n}$$

$$= (1 - \frac{10}{500}) \frac{64.3}{10}$$

$$= 6.3$$

Therefore, the estimated sampling variance is 6.3.

3. Estimate the standard error, $S\hat{E}(\hat{\bar{Y}})$, and the coefficient of variation, $C\hat{V}(\hat{\bar{Y}})$:

$$S\hat{E}(\hat{\bar{Y}}) = \sqrt{V\hat{a}r(\hat{\bar{Y}})}$$
$$= \sqrt{6.3}$$
$$= 2.5$$

$$C\hat{V}(\hat{\bar{Y}}) = \frac{S\hat{E}(\hat{\bar{Y}})}{\bar{y}}$$
$$= \frac{2.5}{34.4}$$
$$= 0.073$$
$$= 7.3\%$$

4. Compute the margin of error and the confidence interval with a confidence level of 95%

$$\text{margin of error} = 1.96 \times S\hat{E}(\hat{\bar{Y}})$$
$$= 1.96 \times 2.5$$
$$= 4.9$$
$$\text{confidence interval} = \hat{\bar{Y}} \pm 1.96 \times S\hat{E}(\hat{\bar{Y}})$$
$$= 34.4 \pm 4.9$$
$$= (29.5, 39.3)$$

Thus, it can be said with 95% confidence that the true population average age lies between 29.5 and 39.3. (Note that strictly speaking, the correct interpretation is that in repeated sampling, the confidence interval would contain the true population value on average 95% of the time.)

7.3.2.4 Estimating Sampling Variance for a Stratified SRSWOR

The following illustrates the impact of ignoring the true sample design and simply calculating the sampling variance using the equation for a simple random sample. The software market offers a wide array of personal computer data processing and statistical software products; few, not even some claiming to specialise in survey processing, correctly account for the survey design. A number of reviews of statistical software have been done over the last ten years; reading a few of them would be a prudent and wise choice; a list is maintained at http://www.fas.harvard.edu/~stats/survey-soft/survey-soft.html.

Example 7.6 (continued): Estimation of Sampling Variance

If the sample were the result of a simple random sample of size n=10 (100% response rate) from a population of size N=100, then the following estimates of the mean income and the sampling variance of the estimated mean income would be obtained.

$$\hat{\bar{Y}} = \sum_{i \in S_r} \frac{y_i}{n}$$
$$= 51,600$$

(versus 41,595 when the sample design is correctly taken into account).

The estimated sampling variance (in 1,000's) is:

$$Vâr_{SRS}(\hat{\bar{Y}}) = (1 - \frac{n}{N}) \frac{\hat{S}^2}{n}$$

$$= (1 - \frac{10}{100}) \frac{1,247}{10}$$

$$= 112.2$$

and the standard error is (in 1,000's) $\sqrt{Vâr_{SRS}(\hat{\bar{Y}})} = S\hat{E}_{SRS}(\hat{\bar{Y}}) = 10.6$.

In order to correctly estimate the sampling variance of the mean from a stratified sample, the estimated sampling variance within each stratum h must be computed and then the stratum contributions added up to give the complete estimate (in 1,000's):

$$\hat{V}_{STR}(\hat{\bar{Y}}) = \frac{1}{N^2} \sum_h N_h^2 \left(1 - \frac{n_h}{N_h}\right) \frac{\hat{S}_h^2}{n_h}$$

$$= \frac{1}{100^2} \left(34^2 \left(1 - \frac{6}{34}\right) \frac{1406}{6} + 66^2 \left(1 - \frac{4}{66}\right) \frac{211.6}{4}\right)$$

$$= 44$$

and the standard error is (in 1,000's) $\sqrt{Vâr_{STR}(\hat{\bar{Y}})} = S\hat{E}_{STR}(\hat{\bar{Y}}) = 6.6$.

If the sample design had not been taken into account in the estimated sampling variance and the estimator for an SRS had been used instead, the sampling variance would have been overestimated. Note that if the sample design had been a cluster design, the SRS formula would have probably underestimated the true sampling variance.

7.3.3   Design Effect

The *design effect* compares the variance of estimators from one sample design to those from an SRS. It is *the ratio of the sampling variance of an estimator under a given design to the sampling variance of an estimator under SRS of the same sample size*.

As mentioned in **Chapter 6 - Sample Designs**, this measure is often used to compare the efficiency of estimators from different designs. If the ratio is less than one this indicates that the sample design is more efficient than SRS; greater than one indicates that the sample design is less efficient than SRS.

For the example presented earlier,

$$deff = \frac{Vâr_{STR}(\hat{\bar{Y}})}{Vâr_{SRS}(\hat{\bar{Y}})} = \frac{44,000}{112,200} = 0.39$$

indicating that stratification greatly improved the precision of the survey's estimated mean.

Design effects can also be used to provide rough estimates of variance for complex designs. If an estimate of the design effect is available from a previous survey that used the same sample design, it can be used to compute the required sample size of a survey (this will be discussed in **Chapter 8 - Sample Size Determination and Allocation**).

For more information on design effects, see Kish (1965).

7.3.4   Estimating the Sampling Variance using Replicated Sampling

The variances of simple statistics such as means and totals can be estimated using the previously stated procedures for simple designs. However, for more complex sample designs or complex estimators (e.g., functions of totals) determining the sampling variance formula can be difficult.

There exist alternative methods (besides applying a design effect) whereby the sampling variance can be estimated for a selected set of sample designs and estimation procedures. One such method is *replicated sampling*. In replicated sampling, instead of selecting one sample of size *n, k* independent samples of the size *n/k* are selected. For each of these *k* samples, an estimate of the characteristic of interest is produced. The variability among the *k* sample estimates is then used to estimate the sampling variance. The estimate, *t*, of the characteristic of interest is given by the average of the estimates produced for each sample:

$$t = \sum_{j \in K} \frac{t_j}{k}$$

where *K* is the set of samples, *k* is the number of samples and t_j is the estimate for the jth sample.

The estimated sampling variance of *t*, $V\hat{a}r(t)$, is given by the expression:

$$V\hat{a}r(t) = \sum_{j \in K} \frac{(t_j - t)^2}{k(k-1)}$$

Example 7.9: Estimating the Sampling Variance of $\hat{\bar{Y}}$ Using Replicated Sampling, SRS

In Example 7.8, instead of selecting one sample of size *n*=10 and using the previous equation to estimate $Var(t) = Var(\hat{\bar{Y}})$, two samples of size *n*=5 are selected. The results are described in the following table:

Table 11: Calculating the Estimated Sampling Variance of $\hat{\bar{Y}}$ Using Replicated Sampling

Sample 1	Age of Sample Units	Sample 2	Age of sample Units
1	21	1	26
2	27	2	32
3	34	3	37
4	38	4	40
5	42	5	47
Average Age	32.4		36.4

1. The estimated average age of the population is:

$$\hat{\bar{Y}} = \sum_{j \in K} \frac{\hat{\bar{Y}}_j}{k}$$

$$= \frac{32.4 + 36.4}{2}$$

$$= 34.4$$

2. The estimated sampling variance of the average age, given by the replicated sampling method is:

$$Var(\hat{\bar{Y}}) = \sum_{j \in K} \frac{(\hat{\bar{Y}}_j - \hat{\bar{Y}})^2}{k(k-1)}$$

$$= \frac{(32.4 - 34.4)^2 + (36.4 - 34.4)^2}{2}$$

$$= 4$$

The estimated standard error, $S\hat{E}(\hat{\bar{Y}})$, is 2.

Other replication methods such as the Jackknife and the Bootstrap are also frequently used in surveys with complex data. For a description of these methods, see Rust and Rao (1996), Wolter (1985) or Efron (1981). For an example of the Jackknife in a household survey with a complex design and estimator, see Gambino et al (1998). Other techniques not based on replicates such as Taylor series approximation can also be used when the sample design is complex; see Hidiroglou and Paton (1987), Binder (1996), Särndal, Swensson and Wretman (1992) and Wolter (1985).

7.4   Summary

The following list provides an overview of the important points to consider in the estimation of survey data:

i.   Estimation must take into account the sample design. To that end, design weights should be incorporated in the estimation process.

ii.   The initial design weights should be adjusted for nonresponse.

iii.   Auxiliary information, if of adequate quality and correlated with the main survey variables, should be used, whenever possible, to improve the consistency and precision of the estimates.

iv.   The sample design and sample allocation should be used to meet the requirements of domains of interest. If this is not possible at the design stage, special estimation methods should be considered at the estimation stage.

v.   Outliers can lead to large sampling variability in the estimates. Outlier detection and treatment should be considered at estimation.

vi.   Survey estimates should include an estimate of their sampling error, in the form of sampling

variance, standard error, coefficient of variation, margin of error or confidence interval.

For a discussion of more analytic uses of the data that go beyond the estimation of summary measures see **Chapter 11 - Analysis of Survey Data**.

Bibliography

Arora, H.R. and G.J. Brackstone. 1977. An Investigation of the Properties of Raking Ratio Estimators: I, With Simple Random Sampling. *Survey Methodology,* 3(1): 62-83.

Bankier, M.D. 1978. An Estimate of the Efficiency of Raking Ratio Estimators under Simple Random Sampling. *Survey Methodology,* 4(1): 115-124.

Barnett, V. and T. Lewis. 1995, *Outliers in Statistical Data*. John Wiley and Sons, Chichester.

Binder, D.A. 1983. On the Variance of Asymptotically Normal Estimators from Complex Surveys. *International Statistical Review,* 51: 279-292.

Binder, D.A. 1996. Linearization Methods for Single Phase and Two-Phase Samples: A Cookbook Approach. *Survey Methodology,* 22(1): 17-22.

Binder, D.A. 1998. Estimating the Variance of Raking Ratio Estimators. *Canadian Journal of Statistics,* 16: 47-55.

Brackstone, G. and J.N.K. Rao. 1979. An Investigation of Raking Ratio Estimators. *Sankhyà*, Series C, 42: 97-114.

Chambers, R.L. 1986. Outlier Robust Finite Population Estimation. *Journal of the American Statistical Association,* 81: 1063-1069.

Cochran, W.G. 1977. *Sampling Techniques*. John Wiley and Sons, New York.

Cox, B.G., D.A. Binder, B.N. Chinnappa, A. Christianson, M.J. Colledge and P.S. Kott, eds. 1995. *Business Survey Methods*. John Wiley and Sons, New York.

Deming, W.E. and F.F. Stephan. 1940. On the least squares adjustment of a sampled frequency table when the expected marginal totals are known. *Annals of Mathematical Statistics,* 11: 427-444.

Deville, J.C. and C.E. Särndal. 1992. Calibration estimators in survey sampling. *Journal of the American Statistical Association,* 87: 376-382.

Efron, B. 1981. *The Jackknife, the Bootstrap and Other Resampling Plans*. SIAM. 38. Philadelphia.

Eltinge, J.L. and I.S. Yansaneh. 1997. Diagnostics for Formation of Nonresponse Adjustment Cells, with an Application to Income Nonresponse in the U.S. Consumer Expenditure Survey. *Survey Methodology*, 23(1): 33-40.

Estevao, V., M.A. Hidiroglou and C.E. Särndal. 1995. Methodological Principles for a Generalized Estimation System at Statistics Canada. *Journal of Official Statistics,* 11: 181-204.

Fink, A. 1995. *The Survey Kit*. Sage Publications, California.

Fowler, F.J. 1984. *Survey Research Methods*. 1. Sage Publications, California.

Gambino, J.G., M.P. Singh, J. Dufour, B. Kennedy and J. Lindeyer. 1998. *Methodology of the Canadian Labour Force Survey*. Statistics Canada. 71-526.

Ghosh, M. and J.N.K. Rao. 1994. Small Area Estimation: An Appraisal. *Statistical Science,* 9: 55-93.

Groves, R. and M.P. Couper. 1998. *Nonresponse in Household Interview Surveys*. John Wiley and Sons, New York.

Hidiroglou, M.A. and D.G. Paton. 1987. Some Experiences in Computing Estimates and their Variances Using Data from Complex Survey Designs. In *Applied Probability, Stochastic Processes, and Sampling Theory*. I.B. MacNeill and G.J. Umphrey, eds. D. Riedel Publishing.

Hidiroglou, M.A. and C.-E. Särndal. 1998. Use of Auxiliary Information for Two-phase Sampling. *Survey Methodology,* 24(1): 11-20.

Hidiroglou, M.A. and K.P. Srinath. 1981. Some Estimators of Population Total Containing Large Units. *Journal of the American Statistical Association,* 47: 663-685.

Holt, D. and T.M.F. Smith. 1979. Post-Stratification. *Journal of the Royal Statistical Society,* A, 142: 33-46.

Kalton, G. and D. Kasprzyk. 1986. The Treatment of Missing Survey Data. *Survey Methodology,* 12(1): 1-16.

Kish, L. 1965. *Survey Sampling*. John Wiley and Sons, New York.

Kovar, J.G., J.N.K. Rao and C.F.J. Wu. 1988. Bootstrap and Other Methods to Measure Error in Survey Estimates. *Canadian Journal of Statistics,* 16, Supplement: 25-45.

Lehtonen, R. and E.J. Pahkinen. 1995. *Practical Methods for Design and Analysis of Complex Surveys*. John Wiley and Sons, New York.

Levy, P. and S. Lemeshow. 1999. *Sampling of Populations*, John Wiley and Sons, New York.

Lohr, Sharon. 1999. *Sampling: Design and Analysis*. Duxbury Press, U.S.A.

Madow, W.G., H. Nisselson, I. Olkin and D.B. Rubin, eds. 1983. *Incomplete Data in Sample Surveys, Volume 1*. Academic Press, New York.

Madow, W.G., I. Olkin and D.B. Rubin, eds. 1983. *Incomplete Data in Sample Surveys, Volume 2*. Academic Press, New York.

Madow, W.G. and I. Olkin, eds. 1983. *Incomplete Data in Sample Surveys, Volume 3*. Academic Press, New York.

Moser, C.A. and G. Kalton. 1971. *Survey Methods in Social Investigation*. Heinemann Educational Books Limited, London.

Platek, R., J.N.K. Rao, C.E. Särndal and M.P. Singh, eds. 1987. *Small Area Statistics*. John Wiley and Sons, New York.

Pollock, K.H., S.C. Turner and C.A. Brown. 1994. Use of Capture-Recapture Techniques to Estimate Population Size and Population Totals When a Complete Frame is Unavailable. *Survey Methodology,* 20(2): 117-124.

Rancourt, E., H. Lee and C.E. Särndal. 1993. Variance Estimation Under More than One Imputation Method. *Proceedings of the International Conference on Establishment Surveys*. American Statistical Association. 374-379.

Rao, J.N.K. and C.F.J. Wu. 1988. Resampling Inference with Complex Survey Data. *Journal of the American Staistical Association,* 83: 231-241.

Rao, J.N.K. 1996. On the Estimation with Imputed Survey Data. *Journal of the American Statistical Association,* 91: 499-506.

Rao, J.N.K, C.F.J. Wu and K. Yue. 1992. Some Recent Work on Resampling Methods for Complex Surveys. *Survey Methodology,* 18(2): 209-217.

Rust, K.F. and J.N.K. Rao. 1996. Variance Estimation for Complex Surveys using Replication Techniques. *Statistical Methods in Medical Research,* 5: 283-310.

Särndal, C.E., B. Swensson and J. Wretman. 1992. *Model Assisted Survey Sampling*. Springer-Verlag, New York.

Satin, A. and W. Shastry. 1993. *Survey Sampling: A Non-Mathematical Guide – Second Edition*. Statistics Canada. 12-602E.

Schnell, D., W.J. Kennedy, G. Sullivan, H.J. Park and W.A. Fuller. 1988. Personal Computer Variance Software for Complex Surveys. *Survey Methodology,* 14(1): 59-69.

Singh, A.C. 1996. Combining Information in Survey Sampling by Modified Regression. Proceedings of the Section on Survey Research Methods. *American Statistical Association*. 120-129.

Singh, M.P., J. Gambino and H.J. Mantel. 1994. *Issues and Strategies for Small Area Data*. Survey Methodology, 20(1): 3-22.

Skinner, C.K., D. Holt and T.M.F. Smith. 1989. *Analysis of Complex Surveys*. John Wiley and Sons, Chichester.

Stuart, A. 1968. *Basic Ideas of Scientific Sampling*. Charles Griffin and Company Limited, London.

Thompson, M. 1997. *Theory of Sample Surveys*. Chapman and Hill, United Kingdom.

Thompson, S.K. 1992. *Sampling*. John Wiley and Sons, New York

Wolter, K.M. 1985. *Introduction to Variance Estimation*. Springer-Verlag, New York.

Yung, W. and J.N.K. Rao. 1996. Jackknife Linearization Estimation Variance Estimators under Stratified Multistage Sampling. *Survey Methodology,* 22(1): 23-31.

Chapter 8 - Sample Size Determination and Allocation

8.0 Introduction

One of the questions most frequently asked of a statistician is: How big should the sample be? Managers are anxious to obtain an answer to this fundamental question during the planning phase of the survey since it impacts directly on operational considerations such as the number of interviewers required.

There is no magical solution and no perfect recipe for determining sample size. It is rather a process of compromise in which the precision requirements of the estimates are weighed against various operational constraints such as available budget, resources and time.

Recall that factors affecting precision (presented in **Chapter 7 - Estimation**) include: the variability of the population, the size of the population, the sample design and estimator and the response rate. The formula to calculate the size of the sample needed to satisfy a specific level of precision must take into account these factors.

In addition to these factors, operational constraints influence the size of the sample. Sometimes, these are the most influential factors. How large a sample can the client afford? How much time is available to conduct the entire survey? How many interviewers are available? While these constraints are often excluded from the sample size formula, they must be taken into consideration.

If a stratified sample design is used, the statistical agency will need to know not just how big the total sample should be, but how it should be distributed across the strata. This is called sample allocation. Two strategies are possible. The first is to determine the total sample size and then allocate it across the strata. The second is to set a precision requirement and determine the sample size required in each stratum.

Many different allocation methods are possible. N-proportional allocation results in the same proportion of population units being sampled in each stratum. Disproportional allocation results in strata being sampled at different rates. Disproportional allocation methods include: Y-proportional, $\sqrt{N}$-proportional, $\sqrt{Y}$-proportional, optimum, Neyman and optimum when variances are equal.

The purpose of this chapter is to illustrate how to calculate the sample size given a target level of precision, how to allocate a stratified sample and guidance regarding which method of allocation is most suitable.

8.1 Sample Size Determination

As explained in **Chapter 7 - Estimation**, the precision of the survey estimates and the sample size are interrelated: since the sampling variance decreases as the sample size increases, the greater the precision required of the estimates, the larger the sample size needed. Therefore, the appropriate sample size depends on the desired precision of the survey estimates. This precision of an estimate, *t*, may be expressed in terms of the allowable standard error, *SE(t)*, the margin of error, $z \times SE(t)$, or the coefficient of variation $SE(t)/t$. The determination of the sample size for a survey often includes the specification of desired precision in terms of one or more of these measures.

Note that sample size determination attempts to control for sampling errors and for nonresponse that occurs randomly. It does not attempt to control for other nonsampling errors. To ensure accurate survey results, bias due to non-sampling errors should be minimised wherever possible (see **Chapter 5 - Questionnaire Design** and **Chapter 3 - Introduction to Survey Design** for more details on non-sampling errors).

Before presenting the formulas to calculate the sample size for a given level of precision, this chapter will discuss how to determine what level of precision is appropriate and factors affecting precision.

8.1.1   Precision Requirement Considerations

The statistical agency should consider several pertinent questions before deciding on the appropriate level of precision for the client's survey estimates. The agency and client should review what is required of the survey estimates with respect to data tabulations and analysis and decisions that will be made based on the survey estimates.

i.   How will the survey estimates be used? How much sampling variance is acceptable in the survey estimates?

How much uncertainty can the client tolerate in the survey estimates? For example, is a margin of error of ±6% with 95% confidence suitable for the client's purposes, or are more (or less) precise estimates necessary to satisfy the survey objectives?

If the survey results are to be used to make important decisions that have important implications or involve significant risk, the client may require more precise survey estimates than if he or she simply wishes to get a rough estimate of the characteristic of interest.

ii.   Are estimates required for subgroups (domains) of the survey population?

The survey results may include estimates for many subgroups or domains. For example, in addition to producing survey estimates at the national level, provincial or sub-provincial estimates may be required, or estimates may be needed for other important subgroups in the survey population based on sex, age, education level, etc. An appropriate precision level should be specified to meet these data requirement needs. A different level of precision may be specified for different domains. For example, in a national survey, the survey sponsor may require a ±3% margin of error for all national estimates, but may be satisfied with a margin of error of ±5% for provincial estimates, and a margin of error of ±10% for sub-provincial estimates. In this case, strata are usually formed for each domain of interest.

iii.   How big is the sampling variance relative to the survey estimate?

Precision requirements should be specified after considering the size of the estimate. For example, say because of a new policy, Federal government offices are required to provide service in a minority official language if at least $P=.05$ (or 5%) of their requests are in that language. Suppose that various government offices decide to conduct a survey of their clientele in order to estimate the demand for service in a minority official language. Intuitively, a margin of error of ±.05 seems high in relation to a survey estimate expected to be around .05. In this case, a smaller margin of error, perhaps no greater than ±.01 or ±.02, should be specified (i.e., the confidence interval should be .05 ± .01 or .05 ± .02).

In fact, the client should consider the size of the smallest required estimate when specifying the precision requirements. Suppose that the survey is estimating proportions. Some of these proportions might be

$P = .50$ or higher, but others might be as low as $P = .05$ or $P = .10$. If the smallest proportion to be estimated is expected to be $P = .05$ and this proportion is important to the objectives of the survey, then the statistical agency (and client) will want the margin of error to be less than .05.

iv.   What are the practical implications of the precision requirement? How much precision is to be gained by increasing the sample size?

Precision improves as the sample size increases. However, the gain in precision is not directly proportional to the increase in sample size. Consider a qualitative variable that has two possible categories, *A* and *B* (e.g., *men* and *women*), and the client is interested in estimating the proportion of the population that falls under category *A*.

Table 1 illustrates the resulting margin of error in the estimated proportion for a simple random sample (SRS) for various sample sizes and a 95% confidence level, where the true proportion of the population falling into category *A* is *P*=.5 (or 50%) and the size of the population is *N*=100,000. (See section 8.1.3 for the formula for the sampling variance of an estimated proportion.)

Table 1: Sample Size and Margin of Error in Estimate of *P*, using SRS, when *P*=.5

Sample Size	Margin of Error
50	.139
100	±.098
500	±.044
1,000	±.031

Note that in the above table, when the sample size doubles from 50 to 100, the margin of error of the estimate of the proportion improves from ±.139 to ±.098. However, the margin of error is not halved to ±.070 as might be expected. Nor does doubling the sample size from 500 to 1,000 reduce the margin of error by half. Although most people seem to expect one, there is not a linear relationship between the sample size and the margin of error.

This example points out that the statistical agency and client must decide whether it is worth the effort and resources required to interview 1,000 people rather than 500 people to improve the precision from a margin of error of ±.045 to a margin of error of ±.032.

The best solution may not always be to choose the largest possible sample size yielding the smallest margin of error. Sometimes, suitably accurate results can be obtained by accepting a larger margin of error and using resources more efficiently. It may be more effective to use the cost savings from a smaller sample size on other factors that affect the accuracy of the survey results, such as reducing nonsampling error (e.g., follow-up of nonrespondents, testing the questionnaire, training interviewers, etc.).

8.1.2   Factors Affecting Precision

Chapter 3 - Introduction to Survey Design and **Chapter 7 - Estimation** presented the various factors affecting precision. This section illustrates the impact of these factors and considerations when determining the sample size for a given level of precision.

8.1.2.1 Variability in the Population

The characteristic, or variable of interest, typically differs from one person, household, business, farm, etc. to another in a survey population. Although this variability cannot be controlled, its magnitude affects the sample size necessary to satisfy a given level of precision for a characteristic of interest.

Consider Table 2 below. Suppose a first-time survey seeks to estimate the proportion of customers who are satisfied with the services of a certain enterprise and that only two values are possible for the variable *customer satisfaction*: *satisfied* or *dissatisfied*. Some possible values for the true proportion of satisfied and dissatisfied customers are listed below:

Table 2: For the True Population, Possible Distribution of Customer Satisfaction

1.	100 % Satisfied	0 % Dissatisfied
2.	90 % Satisfied	10 % Dissatisfied
3.	80 % Satisfied	20 % Dissatisfied
4.	70 % Satisfied	30 % Dissatisfied
5.	60 % Satisfied	40 % Dissatisfied
6.	**50 % Satisfied**	**50 % Dissatisfied**
7.	40 % Satisfied	60 % Dissatisfied
8.	30 % Satisfied	70 % Dissatisfied
9.	20 % Satisfied	80 % Dissatisfied
10.	10 % Satisfied	90 % Dissatisfied
11.	0 % Satisfied	100 % Dissatisfied

With respect to the variability of customer satisfaction in the population, numbers 1 and 11 from the above list of possibilities are the same, that is, there is no variability – all customers have the same opinion. As well, numbers 2 and 10 from the list reflect very little variability, with 90% of customers having one opinion and only 10% of customers having the opposite opinion. Similarly, each of the following sets of numbers – 3 and 9, 4 and 8, and 5 and 7 – has the same variability. Proceeding from numbers 1 to 6, or similarly, from numbers 11 to 6, the variability of the characteristic *customer satisfaction* increases. The situation represented by number 6, that is, a *50-50 split,* where 50% of customers are satisfied and 50% of customers are dissatisfied, is the point of *maximum variability* in the population with respect to customer satisfaction. If it were true that all customers were satisfied with the services provided, then there would be no variability with respect to customer satisfaction, so a sample of just *one* customer would provide a reliable estimate of customer satisfaction. However, as the true variability of a characteristic of interest increases in the survey population, so too must the sample size to provide an estimate of this characteristic with good precision.

It is difficult to measure accurately characteristics that have high degrees of variability. Increasingly larger sample sizes are required to provide precise estimates of such variables. Considering the precision of the estimates, the required sample size is largest when the variability of the characteristic of interest is at its maximum. For a characteristic with only two values, this occurs when there is a 50-50 split in the population. Therefore, to determine the sample size required for a survey, an estimate of the variability of a characteristic in the survey population is first required since the true variability is generally not known in advance. This can be obtained from a previous study on the same subject, or from a pilot survey.

If, once the survey has been conducted, the statistical agency realises that the characteristic of interest varies more than expected at the point of sample size determination, the survey estimates will be less precise than expected. Conversely, if there is less variability in the characteristic of interest than expected, then the required sample size will be overestimated and the survey estimates will be more precise than required. To ensure that a survey's precision requirement is achieved, it is usually recommended that a

conservative estimate of the population variability of a characteristic be used when calculating the required sample size. In other words, in practice, when there is no advance knowledge of the variability of the characteristic to be measured in the survey, it is often a good idea to assume the greatest variability. So, for a variable with only two possible values, a 50-50 split in the population should be assumed.

Sample surveys usually measure more than one characteristic, each with differing variability. A sample that is large enough for one characteristic may not be large enough for another that has greater variability. To ensure that the sample size is large enough for the key characteristics, the sample size should be determined for the characteristic that is thought to have the highest variability, or for the one(s) deemed to be most important.

8.1.2.2 Size of the Population

The role played by the size of the survey population in sample size determination differs with the size of the population. It plays an important role for small populations, a moderately important role for medium-size populations and a minor role for large populations.

For example, using the customer satisfaction survey, say the true proportion of satisfied customers is P=.5 (50%). Suppose that the statistical agency intends to sample the population using an SRS and that for the estimate of P it wants a margin of error of ±.05 with a confidence level of 95% (i.e., a confidence interval of .50±.05). Table 3 and Chart 1 show the required sample size for different population sizes.

Table 3: Sample Size Required to Estimate P with a Margin of Error of .05 and a 95%
Confidence Level, using SRS, when P=.5

Population Size	Required Sample Size
50	44
100	80
500	222
1,000	286
5,000	370
10,000	385
100,000	398
1,000,000	400
10,000,000	400

It can be seen that to satisfy the required level of precision, the sample size increases at a diminishing rate as the size of the population increases. Although the statistical agency would require a sample size of 44 completed questionnaires for a population of 50, it does not need to double the sample size to 88 for a survey population of twice the size. The required sample size quickly approaches n=400 for survey populations of N=5,000 and more. Therefore, for an SRS, 400 completed questionnaires would be enough to satisfy the given precision requirements for populations larger than 5,000, when the true population proportion is P=0.5.

For very small populations, often a substantial proportion of the population must be surveyed in order to achieve the desired precision. This is why, in practice, censuses are often conducted for small populations.

Chart 1: Sample Size Required to Estimate *P* with a Margin of Error of .05 and a 95% Confidence Level, using SRS, when *P*=.5
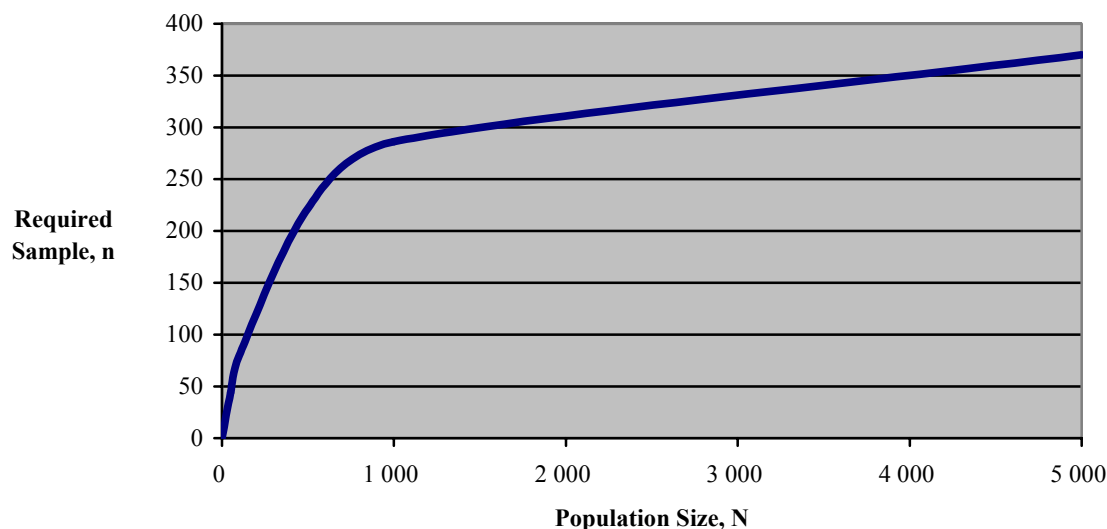
8.1.2.3 Sample Design and Estimator

The sampling strategy – the sample design and estimator used – affect the precision. Techniques for calculating the sample size for a given level of precision often use the sampling variance formula for a SRS. As discussed in **Chapter 6 - Sample Designs** and **Chapter 7 - Estimation**, more complex sample designs using the same estimator and equivalent sample size may have more or less precise estimates. So, if the sample size formula assumes SRS an adjustment is required in order to take into effect the sample design.

In general, when the formula to calculate sample size assumes SRS, but a more complex sample design is used, the sample size required to satisfy a given level of precision should be multiplied by a factor called the *design effect (deff)*. Recall from **Chapter 7 - Estimation** that ***the design effect is the ratio of the sampling variance of an estimator under a given design to the sampling variance of an estimator under SRS of the same sample size***. Therefore, for a simple random sample design, *deff* = 1, and usually *deff* ≤ 1 for a stratified sample design and *deff* ≥ 1 for a cluster sample design.

It is usually possible to obtain an estimate of the design effect for the main survey variables from a previous survey that used the same, or very similar, sample design and similar subject matter. Another option is to obtain the design effect from a pilot survey. If the statistical agency plans to use a stratified sample design and there is no suitable advance estimate of the design effect available from a previous survey, *deff* = 1 can be used to calculate the sample size (i.e., assume SRS). The resulting precision of the survey estimates should be no worse than that obtained with a simple random sample, and if stratification is effective, the precision will be better. It is much more difficult to decide what the design effect should be when a cluster sample design is planned and there is no prior knowledge of the effect of clustering on the sampling variance. In this case, a design effect of at least 2 might be used, although the design effect of a highly clustered design may be as high as 6 or 7.

8.1.2.4 Survey Response Rate

To achieve the desired precision for the survey estimates, the statistical agency needs to adjust the sample size for the anticipated response rate. This is done by selecting a larger sample based on an expected response rate estimated from similar surveys or a pilot survey on the same population.

For example, if the initial sample size is calculated to be 400 and a response rate of 75% is expected, then the statistical agency should select a sample of:

$$n = \frac{400}{.75}$$
$$= 533$$

Once the statistical agency and client have decided upon a certain expected response rate, the agency needs to do everything possible to achieve at least this response rate. Failure to achieve the expected response rate will affect the precision of the survey results. A lower response rate will result in a smaller sample size than necessary to achieve the precision requirement, on the other hand, a higher response rate will have the opposite effect.

Note that this adjustment is based on the assumption that the units are missing at random, i.e., that the nonrespondents have similar characteristics as the respondents. In order to deal appropriately with total nonresponse, simply increasing the sample size is inadequate. Potential bias could still result if the nonrespondents differ from the respondents with respect to the characteristics of interest in the survey. (See **Chapter 7 - Estimation** and **Chapter 10 - Processing** for ways to deal with nonresponse bias).

8.1.3   Sample Size Formulas

The following formulas can be used to calculate the sample size required to provide a given level of precision for an estimated average or proportion.

i.   Precision of an Estimated Average, $\hat{\bar{Y}}$, for a Simple Random Sample (100% Response)

The margin of error and the formula for the standard error of the estimate for an SRS is often used to determine the sample size. The expression for the estimated standard error of an estimated average, $\hat{\bar{Y}}$, for an SRS without replacement is:

$$S\hat{E}(\hat{\bar{Y}}) = \sqrt{(1 - \frac{n}{N})} \frac{\hat{S}}{\sqrt{n}} \qquad (1)$$

where $\hat{S}$ is an estimate of the square root of the population variance of y_i (see also **Chapter 7 - Estimation**).

Setting the required margin of error to e, then:

$$e = z \sqrt{(1 - \frac{n}{N})} \frac{\hat{S}}{\sqrt{n}} \qquad (2)$$

where z depends on the level of confidence.

Solving for n, yields:

$$n = \frac{z^2 \hat{S}^2}{e^2 + \frac{z^2 \hat{S}^2}{N}} \qquad\qquad (3)$$

Therefore, in order to determine n, the following are required:
- a desired margin of error, e;
- a value corresponding to a desired level of confidence, z;
- the size of the population, N;
- an estimate of the population variability, $\hat{S}^2$.

The latter is the hardest to obtain and is often approximated using previous studies on a similar population. (It is also possible to calculate the required sample size based on a given coefficient of variation. This is discussed in section 8.2.1.2 for an estimated total from a Stratified SRS.)

ii.   Precision of an Estimated Proportion, $\hat{P}$, for a Simple Random Sample (100% Response)

In this case, the required precision will be specified in terms of the margin of error and the characteristic of interest will be the proportion of the population, P, falling in one of two categories. It is known that for large populations, the estimated proportion, $\hat{P}$, is approximately normally distributed and the population variability of the binary characteristic, y_i, can be estimated as follows:

$$\hat{S}^2 = \hat{P}(1 - \hat{P})$$

So equation (3) becomes:

$$n = \frac{z^2 \hat{P}(1 - \hat{P})}{e^2 + \frac{z^2 \hat{P}(1 - \hat{P})}{N}}$$

If, prior to the survey, a good estimate of the proportion, $\hat{P}$, is available, then it should be used in the above equation. Otherwise, if nothing is known about the population, $\hat{P} = .5$ may be used, which yields the maximum sample size given the other assumptions.

In the following section, it will be shown that if the sample design is not an SRS, an estimate of the design effect is also required and if the response rate to the survey is less than 100%, an estimate of the response rate, r, is required.

iii.   Step by Step Approach for Sample Size Determination, Given the Precision of an Estimated Proportion, $\hat{P}$, for any Sample Design (When the Response Rate is <100%)

In the following examples, a step by step approach to calculating the sample size will be used, where first an initial sample size is calculated, then it is adjusted for the size of the population, the design effect and the response rate.

1. Initial Sample Size

Note that equation (1) uses the finite population correction factor, *(1-n/N)*, to correct for the size of the population. If this factor is ignored, a preliminary estimate of the sample size, n_1, can be obtained by simply using:

$$n_1 = \frac{z^2 \hat{P}(1-\hat{P})}{e^2}$$

Note that, the formula for n_1 also holds if *e* and $\hat{P}$ are all expressed as percentages instead of proportions.

2. Adjust for the size of the population using the following equation (remember that this only has an effect for small and moderate sized populations):

$$n_2 = n_1 \frac{N}{N + n_1}$$

3. If the sample design is not a simple random sample, the following formula can be used to adjust the sample size for the effect of the sample design:

$$n_3 = deff \times n_2$$

where *deff* is the design effect and usually:
-   *deff* = 1 for simple random sampling designs;
-   *deff* < 1 for stratified sampling designs;
-   *deff* > 1 for cluster or multi-stage sample designs.

4. Finally, adjust for response to determine the final sample size, *n*:

$$n = \frac{n_3}{r}$$

where *r* is the expected response rate.

8.1.3.1 Examples of Sample Size Determination

The following examples illustrate the step-by-step approach to calculating sample size.

Example 8.1: SRS

A magazine publisher wants to obtain an estimate of the overall satisfaction of the readers of the magazine. While it would be possible to contact all 2,500 subscribers through a mail-out survey, because of time restrictions, the publisher has decided to interview a simple random sample by telephone. How many readers should be interviewed?

Assumptions for this example include:
-   the publisher will be satisfied if the true population proportion is within ±.10 of the estimated population proportion based on the sample results, i.e., the required margin of error, *e*, is .10;

-   the publisher wishes to have a level of confidence of 95% in the survey estimates (this means there would only be a 1 in 20 chance of getting a sample that produces an estimate outside the range $\hat{P} \pm .10$, therefore, z=1.96.);
-   SRS will be used;
-   a response rate of approximately 65% is expected, so r=.65;
-   there is no advance estimate of $\hat{P}$, the level of customer satisfaction, consequently, $\hat{P} = .5$ is assumed.

The required sample size is calculated as follows:

1. Calculate the initial sample size, n_1:

$$n_1 = \frac{z^2 \hat{P}(1 - \hat{P})}{e^2}$$

$$= \frac{(1.96)^2 (.50)(.50)}{(.10)^2}$$

$$= 96$$

2. Adjust the sample size to account for the size of the population:

$$n_2 = n_1 \frac{N}{N + n_1}$$

$$= 96 \frac{2500}{(2500 + 96)}$$

$$= 92$$

3. Adjust the sample size for the effect of the sample design:

$$n_3 = deff \times n_2$$

$$= n_2$$

$$= 92$$

For this example, $deff = 1$ since it is assumed that an SRS will be used.

4. Adjust for response to determine the final sample size, n:

$$n = \frac{n_3}{r}$$

$$= \frac{92}{.65}$$

$$= 142$$

Note that if a response rate of at least 65% is not achieved when the survey is conducted, the final sample size will be smaller than planned, and therefore, the survey estimates may be less precise than the planning requirement. If a higher response rate is realised, the resulting sample will be larger than anticipated, and survey estimates may be more precise.

Following these steps, the publisher should draw an SRS of 142 of the 2,500 subscribers in order to estimate the readership's level of satisfaction with the magazine with a margin of error of .10 at a 95% confidence level, given an expected response rate of 65%.

Example 8.2: Stratified SRS

A public opinion survey is to be conducted to determine the proportion of the population in favour of establishing a new provincial park. The population consists of all adults living in two cities and one rural area. A simple random sample of adults from each city and another simple random sample from the rural area will be selected. The required sample size in each stratum must be determined.

The population size is 657,500 with the following breakdown:

Table 4: Population with Three Strata

H	Stratum	Population (N_h)
1	City 1	400,000
2	City 2	250,000
3	Rural area	7,500
	Total	**657,500**

The required sample size depends on the specific data requirements of the survey. The following two options can be considered.

Option 1: Margin of Error for Estimates of the Whole Population

Suppose that precise estimates for the individual strata are *not* required. An estimate with a margin of error of ± .05 at a 95% confidence level for the *area as a whole* is sufficient. A preliminary estimate of the proportion is unavailable, so $\hat{P} = .5$ is assumed. A response rate of 50% is expected.

1. Calculate the initial sample size, n_1:

$$n_1 = \frac{z^2 \hat{P}(1-\hat{P})}{e^2}$$

$$= \frac{(1.96)^2(.50)(.50)}{(.05)^2}$$

$$= 384$$

2. Calculate the modified sample size, n_2:

$$n_2 = n_1 \frac{N}{N+n_1}$$

$$= 384 \frac{657,500}{657,500+384}$$

$$= 384$$

(Note: If n_1/N is negligible, then it can be assumed that $n_2 = n_1$)

3. Adjust for the design effect:

$$n_3 = deff \times n_2$$
$$= n_2$$
$$= 384$$

For stratified random sampling, usually *deff* < 1. Here, no estimate of *deff* is available, so setting *deff* = 1 should have the effect of producing a more conservative (i.e., larger) sample size estimate.

4. Adjust for response to determine the final sample size, *n*:

$$n = \frac{n_3}{r}$$
$$= \frac{384}{.50}$$
$$= 768$$

The required sample size is 768. See section 8.2 to determine how the 768 sampled units can be distributed across the three strata.

Option 2: Margin of Error for each Stratum Estimate

Suppose that the client requires results with a ±.05 margin of error at a 95% confidence level for *each* stratum. Now, individual sample size calculations for each of the strata are required (i.e., each stratum is treated as a population in its own right).

Note that Cities 1 and 2 have large populations and therefore their population size can be expected to have no influence on the sample size. Consequently, if the same assumptions as above are made, the sample size in each of these two strata is 768. However, for the rural area, the smaller population can be expected to have an impact on the sample size.
Rural area:

$$n_1 = \frac{z^2 \hat{P}(1-\hat{P})}{e^2} = \frac{(1.96)^2(.50)(.50)}{(.05)^2} = 384$$

$$n_2 = n_1 \frac{N}{N+n_1} = 384\frac{7,500}{7,500+384} = 366$$

$$n_3 = 366$$

$$n = \frac{n_3}{r} = \frac{366}{.50} = 732$$

Therefore, the *total* sample size is 768 (City 1) + 768 (City 2) + 732 (rural) = 2,268.

Comparing Options 1 and 2, the total sample size of 2,268 for Option 2 is almost three times greater than the sample size of 768 for Option 1. In other words, if only an estimate for the total population across all strata is required, the sample size requirement is less than if precise estimates by stratum are required, since then adequate sample sizes in each stratum are required.

This example clearly illustrates the importance of examining the precision requirements for each separate domain. If many domains are required, the impact on the total sample size can be significant, and may even lead to a sample size that goes beyond the client's budget and operational resources. In general, the more domain estimates are required, the bigger is the required sample size. Compromises, therefore, may have to be made to ensure that acceptable levels of error are obtained. This can be done by increasing the tolerable levels of error in each stratum or by combining two or more domains. For more on this topic, see section 8.2.2.2.

8.1.4   Cost, Time and Operational Constraints

Thus far, only one aspect of sample size has been addressed – the sample size needed to obtain a specific level of precision for the most important survey estimates. In practice, time, cost and other operational restrictions are also paramount.

In many surveys, funds are allocated and deadlines are set even before the specifics of the survey have been decided. It may turn out that the sample size required to carry out a survey is larger than existing funds can accommodate. If more money cannot be found, the sample size may have to be reduced, thereby lowering the precision of the estimates. Or some domain estimates may be dropped. The same holds true for time considerations. If the time allowed is not sufficient, the size and scale of the survey may have to be limited to accommodate the deadlines.

Operational constraints imposed by the method used to collect data, the availability of field staff, the availability of coding and editing staff, and processing facilities also have an impact on sample size. In fact, these can be the most important determinants of sample size. For example, as discussed in **Chapter 4 - Data Collection Methods**, while personal interviews allow more complex information to be collected and tend to generate high response rates, they are expensive to conduct. Therefore, they are not always practical for large samples.

8.2   Sample Allocation for Stratified SRS Designs

An important consideration in determining the efficiency of stratified sampling is the way in which the total sample size, n, is allocated to each stratum. Recall from **Chapter 6 - Sample Designs** that with a stratified sample design, the total number of units in the population, denoted by N, is divided into L non-overlapping strata of size $N_1, N_2, \dots , N_L$, respectively. Therefore, the population size is equal to the sum, over all strata, of the number of units in the population: $N = N_1 + N_2 + \dots + N_L$. A sample is independently drawn from each stratum. The size of the sample in each stratum is denoted by n_h ($h = 1, 2, \dots, L$), where $n = n_1 + n_2 + \dots + n_L$.

The allocation or distribution of the sample, n, to the L strata can be carried out using one of two criteria. The total sample size can be determined using the methods described earlier in this chapter and then distributed across the strata (called fixed sample size), or the sample size required in each stratum to meet a precision requirement can be determined and summed to determine the total sample size (called fixed coefficient of variation, if the precision requirement is expressed in terms of the coefficient of variation).

8.2.1   Allocation Criteria

This section describes in detail the difference between fixed sample size and fixed coefficient of variation allocations.

8.2.1.1 Fixed Sample Size

In this case, a fixed sample size n is allocated to the strata in a specified manner. The proportion of the sample allocated to the hth stratum is denoted as $a_h = n_h/n$, where each a_h is between 0 and 1 inclusively (i.e., $0 \leq a_h \leq 1$) and the sum of the a_h's is equal to 1 (i.e. $\sum_{h=1}^{L} a_h = 1$).

Therefore, for each stratum h, the sample size n_h is equal to the product of the total sample size n and the proportion a_h of the sample coming from that particular stratum:

$$n_h = n \times a_h \qquad (4)$$

For example, if a stratum has a proportion $a_h = \frac{1}{2}$, then half of the entire sample is allocated to that stratum.

Under this allocation criterion, since the overall sample size n is already known, the sample size n_h for each stratum can be calculated as soon as the value of a_h is determined for each stratum. There are many ways to determine a_h: one is to find values of a_h that minimise the sampling variance of the characteristics of interest. Determining the value of a_h is presented in section 8.2.2.

8.2.1.2 Fixed Coefficient of Variation

The alternative to fixing the sample size, n, is to determine the sample size required in each stratum, n_h, given a certain level of precision for the *overall* estimate. This implies finding the sample size n_h ($h = 1$, 2, … , L) for each stratum, so that the coefficient of variation of the overall estimate does not exceed the desired value CV.

For example, consider the estimate of a total, $\hat{Y}$, from a stratified simple random sample. The equation for the coefficient of variation of an estimated total from a stratified sample can be manipulated into the following expression for the total sample size, n:[1]

---

[1] See section 7.3.2.4 of Chapter 7 - Estimation for the sampling variance of an estimated total for a Stratified SRS. The above equation can be derived by setting $CV(Y) = \sqrt{Var(\hat{Y})}/Y$ where $Var(Y) = N^2 Var(\hat{\bar{Y}})$ and $N = \sum_{h} N_h$.

$$n = \frac{\sum\limits_{h=1}^{L} N_h^2 S_h^2 / a_h}{CV^2 Y^2 + \sum\limits_{h=1}^{L} N_h S_h^2}$$

where:

N_h is the stratum size;

S_h^2 is the population variability of the units, y_i, in stratum h;

a_h is the proportion of the sample allocated to the stratum;

CV is the required coefficient of variation of Y;

Y is the total.

Note that the above formula assumes that $n_h = n \times a_h < N_h$, i.e., the allocated stratum sample size is less than the stratum population size. This is further discussed in section 8.2.3. The population variance, S_h^2, can be estimated by $\hat{S}_h^2$ as follows:

$$\hat{S}_h^2 = \frac{\sum\limits_{i=1}^{n_h} (y_{hi} - \bar{y}_h)^2}{n_h - 1}$$

where $\bar{y}_h$, the sample stratum average, is:

$$\bar{y}_h = \frac{\sum\limits_{i=1}^{n_h} y_{hi}}{n_h}$$

(Note that, if y_{hi} is a binary variable, then the stratum average is a proportion, i.e., $\bar{y}_h = \hat{P}_h$, and $\hat{S}_h^2 = \hat{P}_h(1 - \hat{P}_h)$).

Substituting $n_h = n \times a_h$, $\hat{S}_h^2$ and $\hat{Y}$ into the earlier equation for n results in the following equation for n_h:

$$n_h = a_h \frac{\sum\limits_{h=1}^{L} N_h^2 \hat{S}_h^2 / a_h}{CV^2 \hat{Y}^2 + \sum\limits_{h=1}^{L} N_h \hat{S}_h^2} \quad (5)$$

Therefore, after determining the value of a_h for each stratum, calculate each sample size n_h. Notice that, as with the sample size determination presented earlier in this chapter, in order to determine n_h, one needs to specify a precision requirement (here in the form of a coefficient of variation), the estimated variability of the population, $\hat{S}_h^2$, and the population size, N_h. An adjustment for nonresponse should be made to the final n_h.

Note that the fixed coefficient of variation approach to sample allocation is more complicated than the fixed sample size approach and only the latter will be used to illustrate sample allocation.

8.2.2   Sample Allocation Methods

Equations (4) and (5) are the basic tools for allocating a stratified sample. Either equation can be used as soon as values have been determined for each a_h. The choice of a_h for each stratum may be classified into two types of methods: proportional allocation or disproportional allocation. These methods are based on some quantities: the size of the population in the stratum, some other measure of the size of the stratum, the population variability of the stratum or the cost of surveying in the stratum.

8.2.2.1 Proportional Allocation

With Proportional allocation, or N-proportional allocation, the sample size, n_h, in each stratum is proportional to the population size, N_h, of the stratum. Therefore, larger strata receive more of the sample and smaller strata receive less of the sample. This results in the sampling fraction, $f_h=n_h/N_h$, being the same in each stratum and equal to the overall sampling fraction $f=n/N$. Therefore, the following expression is obtained:

$$n_h = \frac{N_h}{N} n$$

Thus, for N-proportional allocation, $a_h=n_h/n=N_h/N$. In other words, the allocation factor a_h for each stratum is equal to the ratio of the population size in the stratum to the entire population size. This type of allocation was illustrated in **Chapter 7 - Estimation**.

N-proportional allocation is often used when information on population stratum variances is unavailable. Hence, it is not used when calculating sample sizes for a fixed coefficient of variation since that approach requires knowledge about the variance of each stratum. N-proportional allocation is also used to make the sample design self-weighting (i.e., all units have the same inclusion probability, π, and hence the same design weight, $1/\pi$).

Stratified sampling using N-proportional allocation is considerably more efficient than simple random sampling of the whole population if the stratum averages, $\overline{Y}_h$, differ considerably from each other. However, if the strata are formed such that their averages, $\overline{Y}_h$, are about the same, stratification with N-proportional allocation affords only a slight reduction in the sampling variance. N-proportional allocation is never worse than simple random sampling and thus never has a design effect, *deff*, greater than 1.

The following example illustrates N-proportional allocation, using a fixed sample size, *n*.

Example 8.2 (continued):

In Example 8.2, option 1, the sample size *n* was calculated to be 768 persons. N-proportional allocation for a fixed sample size is used to determine how the 768 persons should be allocated to each of the three strata.

1.   Using N-proportional allocation, calculate the value of the allocation factor a_h for each stratum.

City 1:

$$a_1 = \frac{N_1}{N}$$

$$= \frac{400,000}{657,500}$$

$$= 0.6084$$

City 2:

$$a_2 = \frac{N_2}{N}$$

$$= \frac{250,000}{657,500}$$

$$= 0.3802$$

Rural area:

$$a_3 = \frac{N_3}{N}$$

$$= \frac{7,500}{657,500}$$

$$= 0.0114$$

2. Calculate the sample size n_h for each stratum.

City 1:

$$n_1 = na_1$$

$$= 768 \times .6084$$

$$= 467$$

City 2:

$$n_2 = na_2$$

$$= 768 \times .3802$$

$$= 292$$

Rural area:

$$n_3 = na_3$$

$$= 768 \times .0114$$

$$= 9$$

As can be seen, the majority of the sample is allocated to the larger strata, City 1 and City 2, where 467 and 292 persons are sampled respectively. The smaller stratum, the rural area, receives a small portion of the entire sample with a sample of only 9 persons. The results are summarised in the following table.

Table 5: N-proportional Allocation

H	Stratum	Population (N_h)	a_h	n_h	$f_h = n_h/N_h$
1	City 1	400,000	.6084	467	.0012
2	City 2	250,000	.3802	292	.0012
3	Rural area	7,500	.0114	9	.0012
	Total	**657,500**	**1**	**768**	**.0012**

The table above shows that N-proportional allocation produces a self-weighting design because the sampling fraction, f_h, is equal to .0012 in all three strata.

Note that the difference between the above allocation and the sample size determination in Example 8.2, option 2, is that the above allocation satisfies a precision requirement for an estimate for the *overall* population, while Example 8.2, option 2 satisfies precision requirements for *each* stratum.

8.2.2.2 Disproportional Allocation

With disproportional allocation, the sampling fractions differ across strata. The following disproportional allocation methods will be presented and explained: Y-proportional, $\sqrt{N}$-proportional, $\sqrt{Y}$-proportional, optimum allocation, Neyman allocation and optimum allocation when variances are equal. Terminology can lead to confusion as some of the disproportional allocation methods are referred to as proportional allocation methods (e.g., Y-proportional allocation). The important thing to remember is that as soon as the sampling fraction is different between at least two strata, the allocation method is considered disproportional.

8.2.2.2.1 Y-Proportional Allocation

Given a survey variable, y_{hi}, that is a measure of size for the ith unit in the hth stratum, the sample sizes, n_h, can be calculated as proportions of Y_h an aggregate measure of the size of stratum h. This type of

allocation is called Y-proportional. Here, $a_h=Y_h/Y$. This means that the allocation factor a_h for each stratum is equal to the ratio of the stratum measure of size to the entire population measure of size.

Y-proportional allocation is a very popular allocation method for business surveys where the distribution of y_{hi} is skewed (i.e., has extreme values in one tail of the distribution). Typical examples are *employment* in manufacturing industries, and *sales* for retailing industries. In such cases, a small number of businesses can account for a large percentage of *total employment* or *total sales*. On the other hand, the remaining large number of businesses can represent only a small fraction of *total employment* or *total sales*.

In business surveys, strata are usually built based on an available measure of size (e.g., number of employees, gross business income, net sales). For example, the size measure might be used to create three strata for small, medium and large businesses. The stratum containing the largest units is often more variable than the other strata. In one extreme form, Y-proportional allocation implies that the largest units of a skewed population are sampled with certainty.

Y-proportional allocation will result in better precision than N-proportional allocation for survey estimates that are more strongly correlated to Y_h than to the size of the stratum, N_h.

8.2.2.2.2 $\sqrt{N}$ -Proportional Allocation

So far, all of the allocation methods presented have only considered the precision of the overall estimate, $\hat{Y}$. But often the client is interested in having good precision for stratum estimates, $\hat{Y}_h$, as well. For example, if strata are provinces, provincial as well as national estimates are probably important. Allocation to strata using $\sqrt{N}$ -proportional allocation can improve the precision of the stratum estimates. In this case, the allocation parameter a_h is calculated as:

$$a_h = \frac{\sqrt{N_h}}{\sum_{h=1}^{L}\sqrt{N_h}}$$

In other words, the allocation parameter a_h is equal to the ratio of the square-root of the population size in the stratum to the sum of the square-root of the population size of all strata.
$\sqrt{N}$ -proportional allocation is not as efficient as other allocation methods in terms of maximal overall precision. However, it can provide better estimates at the stratum level. It is often used as a compromise between optimum allocation (see 8.2.2.2.4) and allocating to satisfy all domain constraints (where the domains are defined as strata). For example, optimum allocation for national estimates can result in large sampling variances for smaller domains of interest (e.g., provinces), while allocating the total sample to satisfy all domain constraints (as in Example 8.2, option 2) can result in inefficient allocation of the total sample. Square root N-proportional allocation provides a compromise between overall and domain level allocation.

The following example illustrates the use of $\sqrt{N}$ -proportional allocation, for a fixed sample size, n.

Example 8.2 (continued):

In the previous example, a fixed sample of 768 persons was allocated to the three strata using N-proportional allocation. Here, the allocation to the strata is done using the $\sqrt{N}$-proportional allocation method.

1. Using $\sqrt{N}$-proportional allocation, calculate the value of the allocation factor a_h for each stratum.

City 1:

$$a_1 = \frac{\sqrt{N_1}}{\sum_{h=1}^{3}\sqrt{N_h}}$$

$$= \frac{632.46}{1,219.06}$$

$$= 0.5188$$

City 2:

$$a_2 = \frac{\sqrt{N_2}}{\sum_{h=1}^{3}\sqrt{N_h}}$$

$$= \frac{500}{1,219.06}$$

$$= 0.4102$$

Rural area:

$$a_3 = \frac{\sqrt{N_3}}{\sum_{h=1}^{3}\sqrt{N_h}}$$

$$= \frac{86.60}{1,219.06}$$

$$= 0.0710$$

2. Calculate the sample size n_h for each stratum.

City 1:

$n_1 = na_1$

$= 768 \times .5188$

$= 398$

City 2:

$n_2 = na_2$

$= 768 \times .4102$

$= 315$

Rural area:

$n_3 = na_3$

$= 768 \times .0710$

$= 55$

The following table summarises the results and compares N-proportional allocation to $\sqrt{N}$-proportional allocation.

Table 6: Comparison of N-proportional Allocation and $\sqrt{N}$-proportional allocation

			N-proportional allocation			$\sqrt{N}$-proportional allocation			
H	**Stratum**	**Population (N_h)**	**A_h**	**n_h**	**f_h**	**$\sqrt{N_h}$**	**a_h**	**n_h**	**f_h**
1	City 1	400,000	.6084	467	.0012	632.46	.5188	398	.0010
2	City 2	250,000	.3802	292	.0012	500	.4102	315	.0013
3	Rural area	7,500	.0114	9	.0012	86.60	.0710	55	.0073
	Total	**657,500**	**1**	**768**	**.0012**	**1,219.06**	**1**	**768**	**.0012**

$\sqrt{N}$-proportional allocation gives a smaller sample size in City 1 than N-proportional allocation. Conversely, it gives a larger sample in City 2 and in the Rural area. Therefore, the precision of the estimate in City 2 and in the Rural area is better with the $\sqrt{N}$-proportional allocation than with N-proportional since the sample size is larger. (It would be difficult to get a good estimate of the rural area based on only 9 units.) The decrease in sample size in City 1 will have a small impact on the precision of the estimate. The increase in sample size in City 2 will only have a slightly positive impact on the precision of its results. However, the increased sampled size in the Rural area provides large gains in the precision of these estimates. The gain in precision in the Rural area more than compensates for the loss of precision in City 1.

8.2.2.2.3 $\sqrt{Y}$ -Proportional Allocation

Another way of ensuring good reliability for stratum estimates as well as the overall estimate is to use $\sqrt{Y}$ -allocation, where y_{hi} is a measure of size. It is an alternative to $\sqrt{N}$ -proportional allocation and is more precise than $\sqrt{N}$ -allocation for survey estimates that are correlated to the size variable, Y_h , more strongly than to the size of the stratum, N_h. The allocation parameter a_h is:

$$a_h = \frac{\sqrt{Y_h}}{\sum_{h=1}^{L} \sqrt{Y_h}}$$

This means that the allocation parameter a_h is equal to the ratio of the square-root of the measure of size of the stratum to the sum of the square-root of the measure of size of all strata.

As was the case for $\sqrt{N}$ -proportional allocation, using the $\sqrt{Y}$ -proportional allocation to calculate the values of a_h (and subsequently the values of n_h) is not as efficient as other allocation methods in terms of overall precision. However, it can provide more precise estimates at the stratum level.

$\sqrt{N}$ -Proportional and $\sqrt{Y}$ -Proportional allocations are sometimes referred to as *power allocations*, where a power allocation with respect to *Y,* for example, is defined in more general terms as:

$$a_h = \frac{Y_h^{p}}{\sum_{h=1}^{L} Y_h^{p}}$$

where *p* is usually some fraction (e.g., ½). For more details on power allocations, see Bankier (1988).

8.2.2.2.4 Optimum Allocation

When the cost of interviewing per unit differs between strata and the population variances, S_h^{2}, vary greatly, a disproportionate allocation method known as optimum allocation may be considered. This is the only allocation method presented here that takes cost into account.

In order to use optimum allocation, the statistical agency needs a function to model the cost. The simplest total cost function is of the form

$$C\hat{o}st = C = c_o + \sum_{h=1}^{L} c_h n_h$$

where c_h is the cost per unit of surveying in stratum *h* (*h* = 1, 2, … , *L*) and c_0 is a fixed overhead cost. This cost function is best when the major item of cost is that of interviewing, or taking the measurements on each unit.

The allocation parameter a_h used for optimal allocation is calculated as follows:

$$a_h = \frac{N_h S_h / \sqrt{c_h}}{\sum\limits_{h=1}^{L} N_h S_h / \sqrt{c_h}}$$

Optimum allocation minimises the variance of the estimate for a given cost or, equivalently, minimises the cost of the total sample for a given overall variance. To achieve this goal, sampling is increased in those strata with large variances or population sizes and decreased in those strata in which interviewing is expensive. As a general rule of thumb for optimum allocation, a larger sample is selected in a given stratum if:
- the stratum is larger;
- the stratum is more variable internally;
- conducting the survey is cheaper in the stratum.

In order to use optimum allocation, accurate information on stratum variances and unit costs is required. In practice, the variances and the costs may not be known. One way to overcome this limitation is to estimate the variances and costs from a preliminary sample or previous survey. One difficulty with optimum allocation is that the stratum estimated variances and costs may not be precise. Therefore, in practice, the design may not be optimal.

When costs and variances are equal for all strata, optimal allocation reduces to N-proportional allocation. In such a case, N-proportional allocation is the allocation for which the variance of the estimate is minimised. When only the costs are equal for all strata, optimum allocation reduces to what is generally called *Neyman allocation*, presented next.

8.2.2.2.5 Neyman Allocation

This special case of optimum allocation, called *Neyman allocation*, occurs when the cost of an interview is identical in each stratum. It provides an allocation of the total sample size to strata that minimises the overall variance of the estimate. Neyman allocation assigns more sample units to larger strata, and/or strata with the highest variances. Again, as was the case for optimum allocation, the variances may not be known, so estimates are typically used.

The allocation parameter a_h is defined as:

$$a_h = \frac{N_h S_h}{\sum\limits_{h=1}^{L} N_h S_h}$$

This means that the allocation parameter a_h is equal to the ratio of the product of the stratum size and the square root of the variance to the sum of the product of the stratum size and the square root of the variance for all strata.

When it is not possible to get an accurate value for the variances, the ratio of the stratum variance to the stratum average ($S_h / \overline{Y}_h$) can be considered constant across strata. This assumption reduces Neyman allocation to Y-proportional allocation. One difficulty with Neyman allocation, as with optimum allocation, is that the stratum estimate of the variances may not be precise and hence the design may not be optimal.

8.2.2.2.6   Optimum Allocation when Variances are Equal

Another special case of optimum allocation occurs when the variances are equal in all strata – which is unusual, hence this allocation is rarely used. It is used when nothing is known about the population variances, or when these variances can be assumed roughly equal, and the predominant allocation factor is cost, in which case, this type of allocation puts more sample units in strata that are larger and/or have the smallest costs. The allocation parameter a_h is defined as:

$$a_h = \frac{N_h / \sqrt{c_h}}{\sum_{h=1}^{L} N_h / \sqrt{c_h}}$$

8.2.3   Special Considerations During Allocation

The following concerns should be kept in mind during allocation:

i.   Using auxiliary data for Y-proportional and $\sqrt{Y}$ -proportional allocation

When implementing a stratified sample design and allocating proportional to Y or the square root of Y, in practice, the value of Y is not known for all of the units in the population – if it were, there would be no need to conduct a survey for this variable. So, for these allocation methods, auxiliary data that are highly correlated with Y are used, usually from previous surveys or administrative data. There is no guarantee that the specified coefficient of variation for the survey variable will be attained since the statistical agency is using an auxiliary size measure. The efficiency of size-stratification and the accuracy of the allocation then depend on the strength of the correlation between the survey variable and the auxiliary variable used.

ii.   Over-allocation

In a stratified design using optimum allocation, Neyman allocation, Y-proportional allocation or $\sqrt{Y}$ -proportional allocation, it is possible for the allocated n_h to be larger than the population size N_h. This is called over-allocation. When it occurs, a census should be conducted in the over-allocated strata. The overall sample size resulting from such over-allocation will then be smaller than the original sample size, so the overall precision requirements might not be met. The solution is to increase the sample in the remaining strata where n_h is smaller than N_h using the surplus in the sample sizes obtained from the over-allocated strata.

iii.   Minimum stratum sample size

In each stratum, it is usually advisable to have at least two units allocated. Two units is in fact the minimum to be able to produce an unbiased estimate of the variance of the estimates. Note that considering total nonresponse, the minimum stratum sample size should in fact be more than two.

Unfortunately, all sample allocation methods seen in Section 8.2.2 might produce sample sizes that are less than two, or even less than one. In that case, the most usual solution is to increase the sample size to two in those strata where such a problem occurred. Note that this will increase the total sample size allocated. Another solution is to allocate a sample of size of two to all strata, and then allocate the

remaining sample size to all strata using one of the allocation methods presented earlier. This solution has the desirable property not to increase the total sample size.

iv.   Allocating according to several variables

Allocation that is suitable for one variable may not be suitable for another survey variable. To allocate the sample based on more than one variable, a *compromise* allocation is needed. Multivariate allocation schemes (some of them using linear programming) have been developed to provide a solution to such problems (see Bethel, 1989).

It is important to remember that the statistical agency wants to allocate the sample in order to meet the precision requirements for the major variables of interest of the survey. This usually means that estimates for the less important variables in the survey will not be as precise as the major variables.

8.3   Summary

Sample size determination is a process of making practical choices and trade-offs amongst the often conflicting requirements of precision and such operational constraints as the overall budget, the cost of surveying in each stratum, the available time and the number of interviewers that are required and available. Decisions on sample size may require a re-examination and a possible modification of original objectives, data requirements, levels of precision and elements of the survey plan, field operations, etc. Often, the statistical agency and client look for cost efficiencies so that the client can afford the required sample size, for example, by shortening the interviews, using an alternative data collection method, dropping some domains of interest or considering an alternative sample design.

When stratified sampling is used, the sample must be distributed across the strata. This can be done one of two ways: by determining the total sample size and distributing it across the strata to minimise the variability or, given a precision requirement, by determining the sample size required in each stratum. Both of these methods require a formula for the allocation, a_h, within each stratum. There are a variety of different allocation methods. N-proportional allocation is the only proportional allocation method, resulting in equal sampling fractions in all strata. Disproportional allocation methods distribute the sample across strata according to: the size of the population in the stratum or some other measure of the size of the stratum, the population variability of the stratum or the cost of surveying in the stratum.

Bibliography

Bankier, M. 1988. Power Allocations: Determining Sample Sizes for Subnational Areas. *The American Statistician,* 42: 174-177.

Bethel, J. 1989. Sample Allocation in Multivariate Surveys. *Survey Methodology,* 15(1): 47-57.

Cochran, W.G. 1977. *Sampling Techniques*. John Wiley and Sons, New York.

Fink, A. 1995. *The Survey Kit*. Sage Publications, California.

Fowler, Floyd, J. 1984. *Survey Research Methods*. 1. Sage Publications, California.

Hidiroglou, M. 1986. The Construction of a Self-Representing Stratum of Large Units in Survey Design. *The American Statistician,* 40: 27-31.

Hidiroglou, M. 1993. *Some Sample Size Determination and Allocation Procedures for Business Surveys*. Statistics Canada.

Glasser, G.J. 1962. On the Complete Coverage of Large Units in a Statistical Study. *Review of the International Statistical Institute,* 30: 28-32.

Gower, A. and K. Kelly. 1993. *How Big Should the Sample Be?* Statistics Canada.

Kish, L. 1965. *Survey Sampling*. John Wiley and Sons, New York.

Latouche, M. 1988. *Sample Size Determination and Allocation*. Statistics Canada. BSMD 88-021E/F.

Lavallée, P. and M.A. Hidiroglou. 1988. On the Stratification of Skewed Populations. *Survey Methodology,* 14(1): 33-43.

Lehtonen, R. and E.J. Pahkinen. 1995. *Practical Methods for the Design and Analysis of Complex Surveys, Statistics in Practice*. John Wiley and Sons, New York.

Levy, P. and S. Lemeshow. 1999. *Sampling of Populations*. John Wiley and Sons, New York.

Lohr, S. 1999. *Sampling: Design and Analysis*. Duxbury Press, U.S.A.

Moser C.A. and G. Kalton. 1971. *Survey Methods in Social Investigation*. Heinemann Educational Books Limited, London.

Särndal, C.E., B. Swensson and J. Wretman. 1992. *Model Assisted Survey Sampling*. Springer-Verlag, New York.

Satin, A. and W. Shastry. 1993. *Survey Sampling: A Non-Mathematical Guide – Second Edition*. Statistics Canada. 12-602E.

Sethi, Y.K. 1963. A Note on Optimum Stratification of Populations for Estimating the Population Means. *Australian Journal of Statistics,* 5: 20-33.

Thompson, M. 1997. *Theory of Sample Surveys*. Chapman and Hill, United Kingdom.

Thompson, S.K. 1992. *Sampling*. John Wiley and Sons, New York.

Chapter 9 - Data Collection Operations

9.0   Introduction

Data collection is typically the greatest single expense in a survey. Because of this and because problems arising during collection can be very expensive to fix – and could result in overall failure of the project – careful thought and planning must be given to this survey step. **Chapter 4 - Data Collection Methods** discussed different methods of data collection. This chapter presents the various activities that occur during data collection and how they should be organised and conducted, with an emphasis on interviewer-assisted surveys since these have the most comprehensive operational requirements.

Data collection should be organised as efficiently as possible while maintaining consistent interviewing practices across all interviewers. One method of organisation, employed at Statistics Canada and presented here, uses regional offices which report to a central head office.

Public relations are important to gain respondent co-operation. Part of this entails maintaining a good reputation as a statistical agency. It also involves publicity campaigns and various tools such as introductory letters, survey brochures and survey material provided in a form that can be used by newspapers, radio and television to elicit interest in a survey and encourage respondent participation.

Hiring good interviewers and other personnel is crucial to successful data collection. The quality of data collection and the survey results depends on the consistency and quality of these workers. Training and manuals are therefore also important.

Before the interview can be conducted or the self-enumeration questionnaire distributed, listing and tracing are sometimes performed. Listing is required when area frames are used. The purpose of listing is to create a list of units to be sampled (e.g., dwellings or businesses) within a specific geographic area. Tracing is performed when the sample unit cannot be located using information on the survey frame. For example, the survey frame's telephone numbers might be out-of-date.

Once the respondent has been traced and contacted, the interviews or self-enumeration can begin. This involves more than simply asking questions, it includes: scheduling interviews, eliciting respondent co-operation, minimising response errors, following up edit failures, coding responses, controlling documents and monitoring the quality of data collection. Only after all these activities are finished is data collection considered complete.

9.1   Organisation of Data Collection

While data collection operations can be organised in many possible fashions, one of the most common is to divide the country into regions and assign each region a regional office that reports to a central head office. Using this structure, the regional offices are able to take full advantage of local knowledge to improve respondent relations and improve efficiency by reducing the cost of follow-up of incomplete questionnaires, refusals, other nonrespondents, etc. Regional offices are responsible for managing data collection and data capture activities in their areas (data capture is the transformation of responses into a machine-readable form, see also **Chapter 4 - Data Collection Methods** and **Chapter 10 - Processing)**. Head office ensures that consistent and standard concepts and procedures are used across the regions. Head office is responsible for the overall management of the survey as well as the design of data collection procedures.

There are a number of things to consider when structuring regional offices. For a very large survey or census, district offices may be required that report to a regional office. When considering the number of regions and/or offices, the following factors should be considered:
- size of the survey;
- sample size and location of sample units;
- remoteness of the location;
- difficulty contacting respondents;
- difficulty eliciting respondent co-operation;
- language of the respondents;
- structure of provincial, regional or local governments;
- labour markets (e.g., staff availability, educational levels, language profiles);
- transportation routes (e.g., highways, ports, shipping hubs).

9.1.1   Head Office

Head office is generally responsible for planning and designing the following activities and tools:

i.   Data collection procedures

Head office typically designs and develops manuals for interviewers, supervisors and other data collection personnel. These procedures include: interviewing, listing sampled units and updating the survey frame, tracing respondents, following-up nonrespondents, and editing and coding to be performed in the field. Some of these tasks are detailed in **Chapter 10 - Processing**.

ii.   Data processing

Processing transforms survey responses obtained during collection into a form that is suitable for tabulation and data analysis. Processing activities include data coding, data capture, editing and imputation. Head office is responsible for the development of the processing procedures and programs along with quality control and quality assurance procedures to be used in the regional offices. Processing activities are discussed in **Chapter 10 - Processing**. Quality Control and Quality Assurance are discussed in **Appendix B - Quality Control and Quality Assurance**.

iii.   Training procedures

This includes the development of exercises, mock interview scripts, and audio-visual materials as well as training guides.

iv.   Data collection schedule

A timetable for data collection is established, detailing survey milestones and reporting periods so that the target date can be achieved. The schedule includes target resolved rates for each reporting period as well as target response rates (see section 9.5.3 for details).

v.   Reporting and control systems

In order to ensure that all data collection operations are under control, control forms for the whole sample and by interviewer (called the interviewer's assignment) are developed and regular reporting procedures to update the status of each sampled unit are established. This is generally called the 'Management

Information System' (MIS). With computer-assisted interviewing, tracking a unit's status and creating appropriate monitoring reports is programmed into the computer software.

The MIS should have the ability to track quality measures as well as expenditure and other performance measures during data collection. All data collection costs such as the cost of postage, telephone calls, travel, computing, and person-day consumption should be tracked. Important quality measures, including response rates, follow-up rates and counts of total nonresponse by reason, should be measured and monitored throughout the collection process. Measures of quality and productivity can be used together to determine logical end points for data collection (e.g., when the response rate has reached a predetermined target, or when improving the response rate by a further set amount would cost too much money) and if the target end date for collection cannot be met, what adjustments should be made. These quality measures also serve to assess methods that might be applied to other surveys and provide information for the data quality evaluation.

vi.   Public relations campaign

This includes the development and production of brochures, posters, etc. For large surveys, some elements of the public relations campaign is conducted directly from head office. However, since public sentiment can vary considerably from region to region in a large country, much of this work is done from the regional offices.

9.1.2   Regional Office

The main responsibilities of regional offices are data collection, data capture and public relations. Data capture is often done by the regional offices since it is easier to control, manage and transmit to head office electronic files rather than paper questionnaires. It is also easier for the regional office to capture their smaller batches of questionnaires than for the head office to capture the data for all regions.

Using a regional office infrastructure ensures that the day-to-day management of data collection activities is conducted as closely as possible to the scene of operations, facilitating the identification and resolution of problems as they arise.

For most surveys conducted from regional offices, the following hierarchy of collection employees is used:

i.   Regional Project Manager

The regional project manager is given overall responsibility for ensuring that data collection is completed on time and meets the predetermined quality standard. The regional manager is also responsible for the regional budget. Typically, the manager takes the overall survey schedule and adds the detailed regional milestones and control points necessary to keep the survey on track. The regional manager acts as the liaison person with head office and the contact point for all shipments to and from head office. The manager, in turn, is responsible for distributing materials and providing information to the supervisor(s). For very large surveys such as the Canadian Census of Population, there are assistant regional managers and district managers.

ii.   Supervisor

Depending on the size of the survey, there may be more than one supervisor, each responsible for a team of interviewers. The ratio of supervisors to interviewers varies depending on the:

- complexity of the survey;
- experience of the supervisors and interviewing staff;
- location of the sample;
- travel difficulties;
- ease of use of the Management Information System.

In conjunction with the regional manager, the supervisor hires and trains interviewers and acquires and distributes equipment and supplies. The supervisor is responsible for the day-to-day management of data collection, including the supervision of interviewers and the close monitoring of progress and quality. Another important supervisor task is the follow-up of refusals (see section 9.4.6).

iii.   Interviewer

The interviewer conducts the actual data collection and reports problems and progress regularly to the supervisor. The role of the interviewer is discussed in Section 9.4.

9.2.1   Public Relations

The purpose of a public relations campaign is to sensitise the population to the existence of the survey, so that people are not suspicious of strangers in their neighbourhood knocking on doors, and to motivate interest, thereby increasing the response rate and the accuracy of responses.

For any statistical agency, the best public relations strategy is to establish and maintain a credible and professional reputation by ensuring that the data that it collects are reliable, widely available, used and appreciated and that the confidentiality of respondents' answers is respected.

In addition to the agency's good reputation, in order to obtain a good response rate it is important that interviewers be provided with the tools to respond to questions and complaints. Various other tools are also helpful such as an introductory letter, a survey brochure and a general agency brochure. For larger surveys, publicity campaigns are often conducted.

This section on public relations only covers contact with the general public. There are however other forms of communication with people outside the survey team that should occur throughout the survey process. For example, early on in the planning phase, the survey planners should identify possible issues that could arise with the proposed survey, how to deal with them and whether to proceed with the survey or not. For example, a survey's proposed topic may be too sensitive for a portion of the respondents. Also during the planning process it is important to consult with stakeholders, respondents, local governments and other interested parties to ensure proper content development of the questionnaire. And at the end of the survey process, these interested parties should be consulted or debriefed on the results.

For more on confidentiality and survey planning, see **Chapter 12 - Data Dissemination** and **Chapter 13 - Survey Planning and Management**, respectively.

9.2.2   Publicity Campaigns

Publicity campaigns can include any or all of the following, depending on the survey topic, budget and target population:

- active media relations (supplying public announcements, stories and spokespersons for newspapers, radio and television stations) and media relations during data collection to deal with any problems that crop up during the process;

- contacting groups who will promote the survey during data collection as well as those who may come out against it;

- letters to important public officials (or representatives of associations or institutions that are related to the target population of the survey) to solicit their support and to supply these officials with information that could be included in a speech or newsletter, etc. (These officials will often speak actively in support of the survey.);

- letters to law enforcement officials to advise them of the survey in the event that respondents, suspicious of survey personnel, contact them;

- posters in public areas such as post offices and libraries or in locations where the target population is likely to see them.

9.2.3   Respondent Relations

Most of the public relations campaign focuses on the respondents in order to increase their awareness and co-operation. The materials most often used are:

i.   The introductory letter

This letter provides the purpose and an explanation of the importance of the survey, as well as the collection method and dates. Introductory letters are generally signed by the most senior regional official (Regional Director). For mail surveys, the introductory letters (and brochures, if appropriate) are sent with the questionnaires. For interviewer-administered surveys, letters (and brochures, if appropriate) are usually sent out one week in advance. This way, respondents are not surprised and are more likely to co-operate when an interviewer appears at their home.

ii.   The survey brochure

This is a simple fact sheet describing the importance of the survey to the public good. It should contain examples of the uses of the data as well as a source where the data can be obtained. Brochures can be sent to all respondents, or used only in cases where respondents are reluctant.

iii.   The general agency brochure

A general-purpose handout, illustrating the variety of data the agency collects and disseminates, adds to the credibility of the agency and is often used for respondent relations as well.

iv.   Support during collection to deal with any unexpected respondent problems.

v.   The interviewer's manual

A well-developed interviewer's manual should provide answers to expected questions and objections.

vi.   Specialists trained to convert refusals

Typically, interviewers refer refusals to their supervisors who are trained in methods to convert refusals.

The following is an example of an introductory letter used by Statistics Canada for the British Columbia Farm Resource Management Survey conducted in 1998. The letter establishes the authority under which the survey is conducted, provides reassurances about confidentiality and stresses the importance of the participation of the respondent. The letter closes with the name and telephone number of a person the respondent can contact in case of questions, and the appropriate signature, in this case, that of the Regional Director.

Dear respondent:

Your operation has been randomly selected to participate in the British Columbia Farm Resource Management Survey, an important study on farm management practices relating to three principal resources: soil, water and manure/fertilizer. This voluntary survey, focusing specifically on livestock operations, is the first of a comprehensive series that will ultimately provide consistent data for all commodity groups in the province. This study is being conducted in conjunction with the British Columbia Ministry of Agriculture and Food, to ensure that agriculture programs reflect the changing way resources are being managed on farms today.

Between October 5 and October 24 a Statistics Canada interviewer will call you to conduct a five to ten minute interview over the telephone. No detailed financial questions will be asked and you will not need to refer to your records. We will, however, ask for the number and type of livestock on your operation in order to provide perspective on the management practices used.

All information collected by Statistics Canada is kept strictly confidential and is protected by law. It will only be used to produce statistical tables in which individual respondents and their information cannot be identified.

Statistics Canada recognises the tremendous contribution that respondents in the agriculture industry make in completing surveys. This contribution means that up to date and relevant data are available on this rapidly changing sector. I would like to express my sincere appreciation for your co-operation in past surveys, and to thank you in advance for your participation in this important study.

If you would like more information about this survey, please call Jane Doe, Manager of Agriculture Surveys, in our Pacific Region office in Vancouver, toll-free at 1-800-555-5555.

John Smith
Director
Pacific Region

9.3   Preparation of Data Collection Procedures

Before data collection can begin many tasks must be performed, for example:
- writing manuals;
- hiring and training staff;
- designing listing procedures;
- designing tracing procedures.

This section discusses these tasks.

9.3.1   Manuals

The key to successful data collection is quality interviewers and other personnel. Good interviewers and survey personnel must have the abilities and personal qualities to be effective. The consistency and quality of their work determines the quality of the survey results. Manuals delineate standard procedures as well as instructions for dealing with foreseeable problems. Generally, the survey team produces an interviewer's manual, a supervisor's manual, and, where necessary, listing instructions for area frames.

9.3.1.1 The Interviewers' Manual

The interviewers' manual is the principal and sometimes only source of information that the interviewer relies on for information about his or her work. It is divided into sections or chapters dealing with the following topics:

i.   General information

This section states the survey's purpose and importance, intended uses of the data and agency rules for data collection (confidentiality, language of the interviewer, mandate of the agency, etc.). A copy of the introductory letter sent to respondents is usually included. Basic information about how the sample was selected is provided.

ii.   The introduction

This section explains how to establish the first contact with a respondent, how to make sure that the right respondent has been contacted, how to verify or correct the frame information (phone number, etc.) and guidelines for proxy interviewing (Section 9.4.7).

iii.   Questionnaire content

This section provides a copy of the questionnaire(s) and includes definitions of survey concepts and terminology. It is important that the interviewer understand the meaning and purpose of each question. This section also deals with likely problems and respondent questions and how these can be addressed.

iv.   Field edits/grooming of questionnaires

Edits are rules that are applied to identify missing, invalid or inconsistent entries that point to data that are potentially in error. Interviewers are required to perform edits while in the field (i.e., edits performed during or shortly after the interview). Edit rules must be clearly described along with how the interviewer is expected to apply them.

v.   Individual sample unit management

This section deals with edit failure and nonresponse follow-up and the number of times an interviewer should attempt to obtain a response. This section states how to assign a final status code to each questionnaire (e.g., completed questionnaire, refusal, etc.). For more details, see section 9.5.2.

vi.   Assignment management

This section covers administrative details such as: how interviewers report progress for their assignment of questionnaires, how they return questionnaires to the regional office, how they submit field expense documents (e.g., transportation expenses, hotels, etc.), how they are paid and how supplies and equipment are distributed and returned.

vii.   Safety and security while in the field

This section explains occupational health and safety as well as effective control systems to ensure the security of questionnaires and the transmission of data from regional to head offices.

viii.   Questions and answers

This last section includes a list of common questions posed by the respondent (for example: How was I selected for the survey?) and appropriate answers.

General interviewing skills and techniques can also be included in the interviewers' manual, with examples specific to the particular survey.

9.3.1.2 Supervisors' Manual

Supervisors must be thoroughly familiar with the contents of the interviewers' manual. A special *s*upervisor's manual is also produced to provide instructions for the management of the survey.

The following topics are usually included in the supervisors' manual:
- hiring and training interviewers;
- creating interviewer assignments;
- occupational health and safety;
- quality and performance controls (i.e., observing interviews, monitoring survey progress against predetermined quality, expenditure and timing measures);
- logistics (e.g., the distribution and return of supplies, payment of interviewers, return and submission of questionnaires to data capture, etc.);
- security and privacy protection;
- alternative collection methods to deal with disabled persons, language problems, ambiguity about inclusion to the target population (e.g., foreigners, visitors), etc.;
- conversion of refusals to respondents.

9.3.2   Hiring and Training Interviewers

Interviewers are critical to the success of an interviewer-administered survey. It is important to ensure that those who are hired have the required abilities and personal qualities and that they have the appropriate training and tools.

The statistical agency should maintain a list of trained interviewers so that hiring can be done using this list. If the survey needs are great, it may be necessary to seek additional staff. Announcements can be made or advertisements placed in local newspapers or on the radio inviting potential applicants, or suitable personnel may be recruited (for example, mail delivery personnel).

The qualifications required for the survey must be specified and criteria for hiring established. Education, interpersonal skills, fluency in local languages, organisation skills and trustworthiness are important factors to consider when hiring interviewers (typically a security check is performed). In the case of personal interviews, location and knowledge of the area may also be important. Usually a team, consisting of the supervisor and senior regional manager, interview potential candidates.

Interviewer training must be carefully planned to guarantee uniform performance and comprehension of survey concepts across all interviewers. Supervisors are usually trained first. Then, the supervisors train the interviewers. Often, representatives from head office observe training and provide guidance. Several days of intensive training are generally carried out using the techniques listed below:

i.   Home study

Interviewers thoroughly review manuals and (possibly) complete written exercises.

ii.   Classroom training

In class, the supervisors and interviewers study what can be done to foster good respondent relations and thereby elicit responses. Good interviewing practices, skills and techniques are presented. The supervisors review and correct errors in exercises from home study. The interviewers then review the entire questionnaire content to become familiar with the questions and concepts (screen by screen for computer-assisted interviewing). Special and problem cases are reviewed, allowing plenty of time for questions and clarification.

iii.   Mock interviews

Mock interviews provide interviewers with the opportunity to practice their skills before going out into the field. They also allow interviewers to observe and comment on the skills and techniques shown by their peers. Here the supervisor or another interviewer acts as the respondent. Various scenarios are tested, including both typical and problem cases.

iv.   Live interviews

If possible, interviews should also be performed on real respondents before the survey is taken out into the field. The respondents here are sometimes agency staff unfamiliar with the survey or sometimes they are respondents sampled from the target population (but not part of the sample to be used for the real survey). Live interviews could also be performed as part of a pilot test (see **Chapter 5 - Questionnaire Design**).

v.   Review first few interviews

It is useful for the supervisor to meet with each interviewer to review the first few completed interviews. If an interviewer is experiencing problems they can be identified early on and corrected.

Administrative procedures (e.g., weekly reporting, control forms, etc.) for managing the assignment is usually the last topic covered in training. Once training is complete, each interviewer is provided with his or her assignment.

9.3.3   Listing

Listing is required when sampling from an area frame. Recall from **Chapter 6 - Sample Designs** that a common sample design for an area frame is a two-stage cluster design where the first stage samples geographic areas from an area frame (these are the primary sampling units or PSU's). Within these PSU's, a systematic sample of dwellings (the secondary stage units or SSU's) may then be drawn. In order to sample the dwellings, a list must first be created of all in-scope dwellings in the PSU (i.e., dwellings that are eligible for sampling must be listed, where eligibility is defined with respect to the survey's target population).

Since familiarity with the geographic area (PSU) is an advantage for conducting the interview, the same set of interviewers are often responsible for both listing and interviewing with the PSU. In order for listing to be accurate, it should be done a short time before interviewing.

Before listing, each interviewer (or whoever is performing listing) should be given the following items and trained in their use:

i.   A PSU map with boundaries clearly marked

The boundaries of each PSU must be clearly defined, so that there are no overlapping PSU's or missing segments. The map should be the most detailed and up-to-date available with reference points (rail lines, bridges, waterways, street names, etc) delineated as well. These sometimes come from municipal or land survey sources.

ii.   Listing instructions

This includes instructions on how to plot a route through the PSU, covering the entire area without backtracking (which risks duplication) or missing areas. It also includes instructions on how to identify an in-scope sample unit. For example, if the sample unit is a dwelling, there should be instructions on how to find and identify hidden and multi-unit dwellings, the definition of an unoccupied dwelling, etc.

iii.   A listing form with the information to be collected for each in-scope sample unit

The definition of an in-scope unit and the amount of information collected depend on the survey. Typically, data collected during listing are limited to the information required to locate the unit (address or location on the street, name, phone number, etc.) and any data required for the next stage of sampling.

Once listing has been completed, data on the listing forms are generally captured electronically and sent back to head office so that the next stage of sampling can be performed.

To illustrate listing, the following is a cluster map from Statistics Canada's Labour Force Survey, with the boundary of the PSU marked in a solid line, the starting point for listing marked with an 'X', and the route with dashes (---). The interviewer is instructed to begin at the Northwest corner and proceed in a clockwise direction around each block, listing all habitable dwellings on his or her right. The same general listing method (beginning at a predetermined starting point, proceeding clockwise, listing units on the right) is used in rural areas as well. If the dwelling is a farm listing is more complicated since farms can straddle PSU boundaries; in this instance, a solution is to list a farm in a PSU if its main gate or principal entrance is in the PSU.
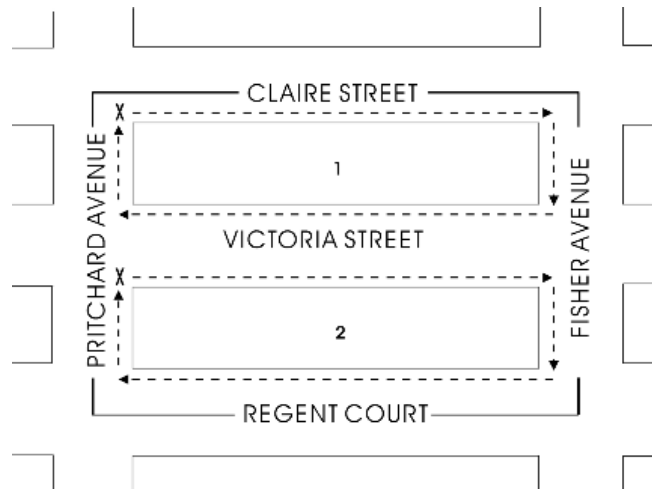
Sometimes, if the method of sampling is very simple, the interviewer may draw the sample and conduct the interviews at the same time as listing. For example, for the Canadian Census of Population, four out of five households in an Enumeration Area (EA) receive a short questionnaire while every fifth household receives a longer, more detailed questionnaire. Using systematic sampling with a random start within each EA, the enumerator lists households and gives every fifth the long questionnaire.

See **Chapter 3 - Introduction to Survey Design** and **Chapter 6 - Sample Designs** for details on area frames.

9.3.4 Tracing

Tracing is used when more information than is available on the survey frame is needed to locate the respondent. For example, for telephone surveys, some of the telephone numbers on the frame might be out of date. In mail surveys, some questionnaires mailed out are returned by the post office because of incomplete or incorrect addresses, or because the establishment has ceased to exist or the respondent has moved. Some tracing may be done before the survey is conducted if it is suspected that the survey frame information may be out-of-date.

The objective of tracing is therefore to:
- locate the sampled unit;
- update the basic identification information on the sampling frame (e.g., name, address, phone number, contact name, or for an area frame, pinpointing the geographic location of a farm on a map, etc.);
- determine whether the unit is still in-scope for the survey (e.g., Has the establishment ceased to exist? Has the respondent moved out of the geographic scope of the survey?).

The most common tools used for tracing include:
- up-to-date telephone directories, business directories, and directory assistance;
- information from other more up-to-date frames;
- files from other government agencies (for example, lists of business licenses in a particular municipality, lists of licensed drivers in a province, etc.);

- for repeated surveys, tracing information provided by the sampled unit on a previous occasion (for example, addresses or telephone number of relatives who can be used to trace the respondent).

Some tracing can be done by interviewers, but it is often more efficient for the regional office to have a team of employees devoted to tracing with access to all the necessary files and directories. Once traced, contact information on the survey frame information can be updated, or if tracing is done after collection has begun, the traced units can be sent back to the original interviewers, or they can be assigned to a special 'clean up' interviewer.

Along with the talent and initiative of the tracer, the success of tracing depends on the quality of the auxiliary information on the survey frame. For example, Statistics Canada conducts a survey of university graduates two years after they graduate. The frame comes from the universities, and has each student's last known address and phone number. Since recent graduates are highly mobile, many are no longer at their last address. If auxiliary data also include the name and address of the parents, the interviewer can trace the student by contacting them. A key consideration during tracing is ensuring that interviewers do not give out confidential information.

9.4   Conducting Interviews

Once all data collection activities have been planned, manuals prepared, staff hired and trained, listing and any preliminary tracing performed, the interviews must be conducted. This step involves more than simply contacting respondents and asking questions. The interviewer is responsible for:
- preparing and scheduling interviews;
- ensuring that information is collected from the correct sample unit;
- eliciting the respondent's co-operation to minimise nonresponse;
- asking the questions and recording answers accurately to avoid errors;
- editing responses;
- adhering to all security procedures to ensure data confidentiality.

In addition to these tasks, the interviewer or other data collection personnel are responsible for:
- following-up edit failures and nonresponse;
- coding the data (if questionnaires are not fully pre-coded);
- controlling documents (tracking forms as they go through the process, for example, the number of questionnaires mailed out, returned, outstanding, etc.);
- monitoring the quality of data collection.

The following sections 9.4.1 - 9.4.8 discuss how to prepare and schedule interviews and interviewing techniques including: introductory techniques, how to use the questionnaire, how to probe for answers, how to end the interview, deal with refusals and other delicate situations, and proxy interviewing. Monitoring the quality of data collection is discussed in section 9.5.

Editing and coding data are discussed in **Chapter 10 - Processing**.

9.4.1   Preparing and Scheduling Interviews

The interviewer is more efficient and effective when he or she has planned the working day, scheduled calls or visits and is thoroughly familiar with the survey's questionnaire, control forms and materials. The following are some guidelines for an interviewer to organise his or her assignment:

i.   Organising time

The interviewer who organises work daily knows exactly how many calls he or she intends to make. The interviewer should allow enough time between calls to complete the necessary notes made during the interview and to complete editing required for paper questionnaires.

ii.   Entering comments

The interviewer should enter any comments on the appropriate computer screen or questionnaire space. He or she should include information such as: the best time to call the respondent, what type of follow-up action has been agreed upon and when it is to be completed, and the name of the best or most knowledgeable person to talk to.

iii.   Making appointments

The interviewer should always have a calendar or diary on hand to book interviews and should enter the appointment on the appropriate computer screen or questionnaire. The interviewer should not write the dates and times of scheduled appointments on scraps of paper where they are likely to get lost.

When scheduling interviews, the interviewer should keep the following in mind:

a.   When contacting a household, avoid very early or very late calls. Many people do not like to be telephoned late in the evening or answer the door after dark (some respondents are frightened by knocking on the door in the evening). For personal interviews, the interviewer may leave the introductory letter in the mailbox, along with a personal note saying when the interviewer plans to return or a phone number where the respondent can call the interviewer to confirm or re-schedule the interview. If the interviewer happens to disturb someone's mealtime, an apology goes a long way to encourage a positive reaction by the respondent.

b.   Business respondents are often busy when the interviewer first calls, so it may be necessary to schedule a convenient time, or leave a phone number where the respondent can call the interviewer back to schedule a time. The respondent should not have any difficulty reaching the interviewer; the interviewer should provide a phone number where he or she can always be reached or state times when the interviewer is unavailable.

c.   If the respondent is unavailable when the interviewer first calls, then the interviewer should establish friendly relations with the person who answers the call, and determine the best time to contact the respondent.

d.   If unable to contact a respondent, the interviewer should call on a different day and at a different hour. For personal interviews, after the interviewer has called twice and still cannot locate the respondent, he or she may try asking a neighbour about the best time to find someone at the selected dwelling. Most personal interview surveys at Statistics Canada require that at least three attempts be made; telephone surveys can require up to ten attempts.

9.4.2   Introductory Techniques

At the start of the interview, it is important that the interviewer establish a good relationship with the respondent. The first impression the interviewer makes greatly influences the interview's outcome. To

create the best impression, it is vital to project a professional yet friendly image. This will help establish a rapport that will encourage the respondent to provide complete and accurate answers.

The foundation of a good interviewer-respondent relationship begins with the introduction. The introduction should be brief (especially on the phone) and sincere. The introduction should include:
-    the interviewer's name and the name of the organisation;
-    the name and purpose of the survey;
-    how the data are to be used (to establish the importance of the survey);
-    the authority under which the data are collected;
-    an assurance of confidentiality.

For personal interviews, an introductory letter and/or a brochure about the survey delivered before the interview is conducted is a good way to introduce and establish the legitimacy of the survey. At the time of the interview, respondents then remember having received something about the survey. When visiting a respondent, the interviewer should carry and present his or her interviewer's identification card.

Establishing a good rapport at the outset is critical to the success of the interview. The interviewer must listen to and be prepared to answer the respondent's questions (The interviewer's manual should contain answers to the most common questions.). If the respondent is reluctant to continue, the interviewer should try to determine the respondent's main concerns and deal with them. Concerns expressed may be one of the following:

i.   Why did you pick me?

Providing a simple explanation about random selection will assure respondents that they have been selected by chance and that their responses are important because they actually represent others in the population.

ii.   Who is going to see my data? How will you use my answers?

The main concern here is confidentiality regarding the information that the respondent may provide. The interviewer should tell the respondents that their answers will be aggregated with others and only be used to produce statistical tables or aggregate (summary) results. The statistical tables may help policy and decision makers to consider whether the situation addressed by the survey is satisfactory or whether some action is required.

iii.   I do not have the time right now.

The interviewer must be honest about the length of the interview. The interviewer should approach each interview as if it will take place immediately. The interviewer should never assume the respondent is too busy. If, however, the respondent cannot do the interview immediately, the interviewer should suggest an alternative time and make a firm arrangement to reschedule the interview. Some respondents will refuse to participate if they do not clearly understand the importance of the survey and the uses of the data. The interviewer should be sure that these are clearly explained in the introduction.

9.4.3   Using the Questionnaire

The data collected from all interviews must be collected in a uniform manner. This means that all respondents must be asked the same questions in the same way. The following guidelines demonstrate how to use the questionnaire to collect consistent data:

i.   Questions should be asked exactly as worded

Research has shown that even inadvertent or very slight word changes can change the response obtained.

ii.   Questions should be asked in the order presented

Question sequence is planned for continuity. The sequence is also arranged so that early questions do not adversely affect the respondent's answers to later questions.

iii.   Every applicable question should be asked

Sometimes the respondent, in answering one question, also answers another question that appears later in the interview. Still, it is important that the interviewer ask the later question when it comes up. In this situation, he or she might say, *You have already told me something about this, but . . .* This indicates that the interviewer is aware of the earlier response and is asking for the respondent's co-operation to answer the question again.

iv.   Questions should be asked in a positive manner

Some interviewers feel uncomfortable when asking certain types of questions and adopt an apologetic attitude, for example: *You might not want to answer this question, but . . .*or *This question probably will not make much sense to you . . .*Such statements negatively affect the flow of the interview and have a tendency to change the respondent's answers. By asking the question using a positive or neutral tone, the message relays to the respondent that this is just another question, and it can be answered without fear of judgement from the interviewer.

v.   Delays between questions should be explained, especially during telephone interviews

Some answers take longer to record than others. The interviewer can explain this to the respondent by saying: *Please excuse the delay, I am writing down/entering the information you gave me.*

vi.   Questions that are misunderstood or misinterpreted should be repeated

Questions should be designed to be understood by all respondents, and most of the respondents will understand them (if the questionnaire is well designed). Occasionally, however, a respondent may misunderstand or misinterpret the question. When this happens, the interviewer should repeat the question as it is written. If the response is still not appropriate, the interviewer may have to probe (see section 9.4.4).

vii.   Skip patterns deserve special attention

A filter or skip question determines whether subsequent questions are applicable and directs the flow through the questionnaire. The interviewer must pay particular attention to filter questions and watch for 'instructions to interviewer' on the questionnaire. Skip patterns are programmed for computer-assisted interviewing (CAI); however, the interviewer should still become familiar with the flow patterns.

viii.   A neutral attitude towards information received should be maintained

Respondents may provide what they consider to be socially acceptable answers if they perceive that the interviewer is judging them. The respondent must not feel that some answers are more acceptable than others. Nothing in the interviewer's words or manner should imply criticism, surprise, approval or

disapproval, agreement or disagreement with the respondent's answers. The interviewer has to accept the respondent's answer if it falls within the range of acceptable answers.

For more on questionnaire design and response errors, see **Chapter 5 - Questionnaire Design**.

9.4.4 Probing

Probing is a technique used when the interviewer recognises that the answer fails to meet the objective of the question. The respondent may not know the answer, or may misunderstand or misinterpret the question, resulting in an answer that is incomplete, unclear or inconsistent with other information. When this happens, interviewers must formulate a neutral type of probe to elicit the needed information.

Before probing, the first step is to repeat the question as worded in case the respondent simply did not hear the question. When the interviewer needs to clarify the question, the definitions provided should be used. If this fails to generate a satisfactory response, then a neutral statement can be used to ask for more information, such as:

> *I am not sure what you mean by that…*

or
> *Could you tell me a little more?*

or
> *Anything else?*

The interviewer may also be able to help the respondent by focussing on the correct response category:

> *Which figure would you say comes closest?*

or
> *Is it greater than, or less than…?* (for numerical responses)

or
> *Was it spring, summer, fall, or winter?*

It is possible to rephrase the question, but this must be done very carefully. The questions should not be rephrased to suggest an answer. For example, if the question is *How many weeks did you work last year?* it should not be rephrased as *Did you work all year?*. It could be rephrased as *Did you work last year?* and if so *For how many weeks?*.

9.4.5 Ending the Interview

The final step of the interview process is to ensure that all the necessary information has been received and is legibly recorded. At the end of each interview, the interviewer checks over the questionnaire thoroughly and performs any necessary edits. He or she may not have enough time to do this in the respondent's presence. Therefore, it is important to thank the respondent courteously for all the information, but leave an opening for a future follow-up call if any clarification is required. The interviewer should offer to answer any questions the respondent may still have about the survey. It is important that the respondent feel that his or her time was well spent and that, by participating in the survey, he or she made an important and worthwhile contribution.

9.4.6 Refusals and Other Delicate Situations

When a respondent refuses to participate it is usually due to a lack of information about the survey or the statistical agency, or due to bad timing. The following guidelines can be used to help interviewers prevent or deal with refusals or other delicate situations:

i. For information obtained from businesses and institutions, the survey manager should ensure that the appropriate person within the organisation is contacted at the appropriate time and that the information is easily available. Whenever feasible, such respondents should be allowed to provide the data using a method and format that are convenient for them.

ii. If the timing of the interview is bad, the interviewer should apologise (rather than risk a refusal) and suggest a call-back time.

iii. It may be possible to negotiate with a reluctant respondent. The interviewer may suggest that the respondent try a few questions; once the interview gets started, the respondent may decide to continue. As a matter of courtesy, a respondent who might otherwise become a complete refusal should be made aware that he or she can refuse to answer individual questions.

iv. When faced with an adamant and vocal refusal, the interviewer should withdraw politely and report the incident to his or her supervisor for follow-up. Persisting with the interview may jeopardise the supervisor's success of converting a refusal.

v. Avoid asking the respondent to supply answers in front of others. If the respondent would prefer, the interviewer should arrange to call back at a better time, or arrange for a private spot for the interview.

vi. If there is a language difficulty and the respondent does not mind using an interpreter, a family members can sometimes be used to interpret each question and response.

vii. If a respondent is suffering personal hardship such as a serious illness or bereavement, the interviewer must assess the situation and decide whether to proceed with the interview, arrange for a convenient call-back time or terminate the interview if there is no chance of success or if it would be insensitive to continue.

viii. Contacting a respondent who lives in high-rise apartments is sometimes a problem, because the intercom is a poor way to request an interview. The interviewer may try to establish contact with the superintendent, landlord or owner of the building to explain the purpose of the visit and request permission to enter the building, thereby allowing a face-to-face introduction.

ix. The interviewer must never argue with or threaten a respondent, either directly or by implication. Reliable and complete information requires willing co-operation. The interviewer must never embark on controversial topics of conversation, such as politics.

x. The interviewer must never resort to unethical practices to conduct an interview. If the respondent is not at home, the interviewer (having identified him or herself) may ask a neighbour when a good time might be to call back. But the interviewer should be careful to avoid raising any suspicion and should limit their questions to when to contact the respondent.

xi.   Last but not least, the interviewer should remember his or her personal rights. If threatened with abuse, verbal threats, physical harassment or violence, the interviewer should withdraw immediately and report the incident to his or her supervisor.

9.4.7   Proxy Interviewing

For some surveys, information for an absent respondent can be obtained from another knowledgeable person – this is known as a proxy response. Proxy response is only suitable for surveys collecting facts generally known to persons other than the intended respondent and therefore is not usually appropriate for sensitive, personal or opinion questions.

During training, the interviewer should be told if proxy interviewing is allowed, and if so, who are acceptable proxy respondents. Unless told otherwise, the interviewers should assume that interviewing is to be non-proxy. In non-proxy situations with language difficulties, with the permission of the respondent, other household members can still be used as translators.

Non-proxy interviewing generally requires more effort than proxy interviewing and achieves a lower response rate. The interviewers should remember that the number of call-backs and appointments needed to secure non-proxy interviews should be carefully planned to avoid response burden and to control survey costs.

9.4.8   Keys to Effective Interviewing

The following are keys to effective interviewing:

i.   Confidence

The interviewer must have confidence in his or her abilities. This is only possible with a good understanding of the survey and the interviewer's role.

ii.   Listening skills

The interviewer should wait for the respondent to finish speaking before he or she stops listening. The interviewer can indicate that he or she is listening with an occasional *Yes, I see*. However, the interviewer should not make assumptions about what a respondent is going to say, or try to finish a sentence. It is better to ask questions if the interviewer feels that the respondent or the interviewer missed a point.

iii.   Empathy

The interviewer should be sensitive to a respondent's situation at the time of the call or visit. If the respondent describes a personal incident, the interviewer should show interest (but never pass judgement), then try to refocus the respondent back to the interview.

iv.   Speech

Vocal expression is important, and particularly so in telephone interviewing. The interviewer should speak very clearly, and try to speak at a moderate speed. If the interviewer speaks too quickly, respondents could miss parts of a question. Speaking too slowly causes respondents to begin answering before the interviewer has finished the question. Lowering the head lowers the pitch of the voice. A lower

pitch voice is clearer and carries better, particularly on the telephone. The proper speed and pitch should be demonstrated during training.

v.   Know the questionnaire

The interviewer must know the questionnaire, concepts and terminology used by the survey. There will not be time during an interview to look up definitions or answers to questions in the manual. Nothing breaks the rapport more quickly than long pauses, especially in telephone interviews.

9.5   Monitoring Quality and Performance

For computer-assisted interviewing (CAI) surveys, the interviewer assignment management as well as the overall monitoring of progress and many quality and performance indicators are automated by computer software. The quality and performance measurements are part of the CAI programming, however the principles are the same as those for paper based surveys. This section uses the requirements for paper-based surveys to illustrate the necessary controls to be used for any survey. For more detail, see **Appendix B - Quality Control and Quality Assurance** and **Chapter 10 - Processing**.

9.5.1   Monitoring the Quality of Data Collection

The quality of data collection should be monitored by the supervisor in the following ways:

i.   Close supervision of interviewers

The supervisor listens to live interviews, particularly for new interviewers and in the early stages of collection, to ensure that the questionnaire is being used properly and that the interviewing techniques are effective and consistent across interviewers. Since interviewers can provide valuable feedback regarding data collection procedures and questionnaire design, they should be encouraged to suggest improvements to the survey.

ii.   Checking (or spot-checking) completed questionnaires

This ensures that interviewer field edits are applied correctly and that missing information can be obtained from respondents, in a timely way, while the survey is still in the field. The supervisor's edit checks can also provide survey management with an advance warning of the types of edit failures to expect during the computer edit stage after collection.

iii.   Monitoring quality and performance measures

This is discussed in detail in 9.5.3. These measures provide an indication of quality as data collection progresses. By spotting and addressing problems early on, the supervisor can manage data collection so that target response rates and other quality indicators are achieved or exceeded.

iv.   Strict document control

Every questionnaire must be accounted for at each stage of data collection with such entries as 'date received from interviewer', 'date sent to tracing', 'date sent to keying', etc. The supervisor's sample control form (with its link to individual interviewer identifiers) is the key to effective sample and document control. While interviewers can report their assignment's progress on paper, automation of the

overall sample control is recommended in order to simplify the supervisor's job. At the end of collection, every questionnaire must receive a final status code (e.g., completed, refusal, etc.).

v.   Debriefing interviewers

Debriefing survey staff at the end of data collection can uncover problems with the data collection process. Such problems can be important inputs for post-collection processing (i.e., identifying post-collection edits that need to be performed). Improvements can also be made to the Management Information System, public relations campaigns, etc. in the case of repeated surveys.

vi.   Tracking changes made to the data

The survey manager may want to track changes made to the data during subsequent survey processes. The frequency of post-collection edit failures and the number and type of corrections applied to the data may provide useful information regarding quality, that can serve as signals that collection procedures or tools should be changed in future survey cycles.

9.5.2   Interviewer Assignment Management

Periodically throughout collection (usually once a week), the interviewer is required to report on the status of the whole assignment on an assignment control sheet. Sample units that have yet to be contacted or are still in progress are assigned a status of 'pending' (further broken down into 'not attempted yet' and 'attempted'). Sample units that have been dealt with to the best of the interviewer's ability, are assigned a 'resolved' status code of:

i.   Complete: A fully completed interview has been obtained.

ii.   Partially complete*:* The respondent did not complete the whole questionnaire but did answer the key questions. Before going out onto the field, key questions are identified as the minimal set of responses constituting a usable questionnaire.

iii.   Incomplete/Total nonresponse by reason of:
         - refusal;
         - absent for the duration of survey period;
         - unable to trace;
         - out-of-scope (e.g., deceased, out-of-business, dwelling demolished);
         - temporarily out-of-scope (e.g., vacant dwelling);
         - no contact (e.g., no one home).

Refusals and 'unable to trace' may be referred to follow-up. Assignment summary reports monitor the total number of sample units in each category. In addition to providing weekly summary reports, interviewers forward to the regional office on a weekly basis all resolved questionnaires, to allow timely follow-up of refusals and timely data capture.

9.5.3   Monitoring by Supervisors

Performance and quality targets are established at the outset of data collection. Supervisors should monitor and manage their operations, both on an interviewer assignment basis and overall, to ensure the targets are met.

The performance target is based on the proportion of resolved records:

$$\text{resolved rate} = \frac{\text{number of resolved units}}{\text{total sample (i.e., resolved + pending)}}$$

This rate provides an indication of the amount of an interviewer's scheduled work that has been completed. The weekly resolved rate is compared to the target rate to ensure that the survey can be completed on time. Expenditures are usually incorporated into this assessment to determine whether the survey can remain within its budget. Two common cost-performance measures are *cost per resolved unit* and *budget left per unresolved unit*.

Another performance indicator is the response rate. The effects of non-response are covered in **Chapter 3 - Introduction to Survey Design** and **Chapter 7 - Estimation**. For most surveys, non-response is a significant contributor to nonsampling error (in the form of bias) and sampling error (which results in a loss in precision in the estimates). The quality target is based primarily on the response rate, which at collection can be calculated as follows:

$$\text{response rate} = \frac{\text{number of responding units (i.e., complete + partial)}}{\text{resolved in-scope units + unresolved units}} \,[1]$$

For example, suppose a sample of 1000 units is selected and 800 are resolved (complete, partial, refusal, out-of-scope, etc.) after one week of data collection. Of the resolved units, 700 are in-scope for the survey. Of the in-scope units, 550 respond to the survey (either complete or partial response). Then, the response rate after the first week of the survey is 550/(700+200)= 61.1%.

Sometimes an adjustment factor is applied to the unresolved units to take account of the fact that some would be out-of-scope if they were resolved. In the above example, this would mean that of the 200 unresolved units, approximately 175 would likely be in-scope (assuming the same proportion as for the resolved units). Therefore, the adjusted response rate would be 550/(700+175) = 62.9%.

Besides response rates and the proportion of resolved records, supervisors should also monitor other indicators for signs of potential quality problems. High refusal or no-contact rates on an assignment basis could indicate problems with a particular interviewer. If certain codes (particularly 'vacant') occur more frequently for some interviewers, this could also indicate a problem (e.g., were the dwellings truly vacant, or were the residents temporarily absent? The interviewer may not know how to distinguish between the two). Across the whole sample, high refusal rates indicate public resistance that could make it difficult to achieve the desired data quality in the time and budget allowed. A higher than expected number of 'out-of-scopes' could indicate frame problems. In the case of business surveys, large businesses may be monitored separately since these can influence the final survey estimates.

For information on Statistics Canada's Standards and Guidelines for measuring nonresponse, see Standards and Guidelines for Reporting of Nonresponse rates (2001).

9.5.4   Advanced Techniques for Measuring Quality

For many surveys, response rates in combination with some of the other measures discussed above are the only indicators of the quality of data collection. For very large repeated surveys it is possible to design

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[1] This is equivalent to the total number of units in the sample minus the number of out-of-scope units.

experiments to attempt to measure the extent of the bias introduced by data collection activities. The most common of these studies are:

Listing checks: Were all in-scope units in the PSU listed? Were all in-scope members of a household listed? Was there any duplication? What are the characteristics of missing or duplicated units? This is an attempt at measuring coverage errors.

i.   Vacancy checks

Were units listed as vacant (or out-of-scope) really vacant or were they misclassified? What are the characteristics of the misclassified units? This attempts to measure frame undercoverage.

ii.   Reinterview to measure response errors

A subsample of respondents are reinterviewed, by a different interviewer (sometimes a supervisor) to determine whether the original responses to key questions are correct. Reinterview responses are compared to original responses. Some or all cases, where responses are different, are reconciled to determine which were correct.

iii.   Nonresponse follow-up study

A special study on nonresponse may be performed to evaluate bias caused by total nonreponse through special follow-up interviews done with survey nonrespondents (i.e., try to obtain responses from a subset of nonrespondents).

Since their objective is to measure bias due to nonsampling error, these studies are complex – and potentially costly – surveys in their own right, which must be designed according to principles discussed in earlier chapters.

See **Chapter 3 - Introduction to Survey Design** for more information on nonsampling error.

9.6   Summary

This chapter showed how data collection operations can be organised, with various levels of responsibilities, organisation, and control. Special attention was paid to the respective roles of the supervisor and the interviewer. Public relations issues were addressed, including survey publicity campaigns, respondent relations and general public relations. Data collection preparations, such as relevant manuals, interviewing hiring and training, listing, tracing and frame updates, as well as interviewing techniques were covered. Finally, methods of monitoring quality and performance were examined.

To ensure that the survey data collected are as complete and accurate as possible, the following guidelines should be observed:

i.   Interviewers are critical to the success of interviewer-assisted surveys. Those hired should have the required abilities and personal qualities and the appropriate training and tools.

ii. Data collection procedures should be applied consistently across all sampled units and these procedures should be as error-free as possible: all interviewers should receive the same training and manuals, all coders should receive the same instructions, etc.

iii. Appropriate sample control procedures for all data collection operations should be put into place. Such procedures track the status of questionnaires from the beginning through to the completion of data collection and data entry.

iv. To optimise response rates and the quality of the information obtained from businesses and institutions, the survey manager should ensure that the appropriate person within the organisation is contacted at the appropriate time for the information to be easily available. Whenever feasible, such respondents should be allowed to provide the data using a method and format that are convenient for them.

v. Effective control systems should be established to ensure the security of questionnaires and the transmission of data from regional to head offices.

vi. A Management Information System to track quality measures as well as expenditure and other performance measures during data collection should be implemented.

vii. The survey manager may want to track changes made to the data during subsequent survey processes. The frequency of post-collection edit failures and the number and type of corrections applied to the data may provide useful information regarding quality that can serve as signals that collection procedures or tools should be changed in future survey cycles.

Bibliography

Cialdini, R., M. Couper and R.M. Groves. 1992. Understanding the Decision to Participate in a Survey. *Public Opinion Quarterly,* 56: 475-495.

Couper, M.P. and R.M. Groves. 1992. The Role of the Interviewer in Survey Participation. *Survey Methodology,* 18(2): 263-277.

Statistics Canada. 2001. *Standards and Guidelines for Reporting of Nonresponse Rates*.

Statistics Canada. 1995. *Survey Interviewing Skills: A Guide to Successful Interviewing*. 12F0047XPE.

Statistics Canada. 1996a. Policy on Informing Survey Respondents. *Policy Manual*. 1.1.

Statistics Canada. 1998. *Statistics Canada Quality Guidelines*. 12-539-XIE

Chapter 10 - Processing

10.0 Introduction

Processing transforms survey responses obtained during collection into a form that is suitable for tabulation and data analysis. It includes all data handling activities – automated and manual – after collection and prior to estimation. It is time-consuming, resource-intensive and has an impact on the quality and cost of the final data. It is therefore important that it be well planned, the quality of its implementation monitored and corrective actions taken when required.

The extent and order of the processing activities depend, among others, on the nature of the data that are collected, the collection method, the survey budget and objectives in terms of data quality. Coding, for instance, can occur before or after data capture while editing typically occurs throughout the survey. The following is an example of processing activities for a paper questionnaire:

i.   After collection, check the data on the questionnaire. This step ensures that all necessary information has been received and legibly recorded, that interviewer notes have been reviewed and some preliminary edits performed to check for gross errors and inconsistencies.

ii.   Code any data on the questionnaire that requires coding (e.g., written answers to open questions).

iii.   Capture the data electronically into a computer. Data capture may be followed by more coding.

iv.   Perform detailed editing, then imputation. Questionnaires that fail one or more checks are put aside for further examination, either for follow-up with the respondent, or for imputation.

v.   Perform outlier detection to identify suspicious or extreme values.

vi.   Store the data on a database to facilitate data manipulation during the post-processing activities.

In order to streamline processing, several of the above activities – namely, capture, editing and coding – may be combined through automation using computer-assisted collection methods.

Since errors are likely to occur at each stage of processing – particularly for those manual and repetitive activities such as coding, capture and editing – processing should be monitored and corrective actions taken when necessary in order to maintain or improve quality. This is done by implementing quality control and quality assurance procedures.

The purpose of this chapter is to cover the main processing activities: coding, data capture, editing, imputation, outlier detection and treatment and creating a database. For details on quality assurance and quality control, see **Appendix B - Quality Assurance and Quality Control**.

10.1 Coding

Coding is the process of assigning a numerical value to responses to facilitate data capture and processing in general. As stated in **Chapter 3 - Introduction to Survey Design**, coding entails either assigning a code to a given response or comparing the response to a set of codes and selecting the one that best describes the response.

Difficulties in determining a set of response categories to a question was discussed in **Chapter 5 - Questionnaire Design**. In the case of closed questions, the response categories are determined before collection, with the numerical code usually appearing on the questionnaire beside each response category. For open questions, coding occurs after collection and may be either manual or automated. Manual coding requires interpretation and judgement on the part of the coder, and may vary between coders.

When determining the coding scheme, the goal should be to classify responses into a meaningful set of exhaustive and mutually exclusive categories that bring out the essential pattern of responses. For some questions, coding may be straightforward (e.g., marital status). In other cases, such as geography, industry and occupation, a standard coding system may exist. But for many questions no standard coding system exists and determining a good coding scheme is a nontrivial task. The coding scheme should be consistent and logical and take into account how detailed the codes should be in light of the purpose of the survey and tabulations or data analysis to be performed. It is best to start with a broad list, since too few categories can be misleading and a large *other* category can be uninformative. Categories can always be collapsed but it is difficult to split categories after the fact.

As mentioned in **Chapter 5 - Questionnaire Design**, the type of interview should be considered when determining the response categories for a closed question. For a self-enumeration survey, supplying a list of 50 categories on paper to respondents is feasible (though not ideal); for a telephone interview, listing 50 response categories over the telephone is impractical. To simplify coding, ideally all questions on a questionnaire would be closed with a short list of response categories. In practice, this is not always possible and sometimes open questions are necessary.

10.1.1 Pre-coding Closed Questions

The response categories for closed questions can be pre-coded on the questionnaire. For paper questionnaires, boxes for codes can be placed either next to the item to be coded or down the margin of the questionnaire. This greatly improves the efficiency of data capture after collection: instead of typing in the selected response category, a numeric code is captured (numerical codes are also easier to analyse than strings of words). With computer-assisted collection methods, the codes are automatically captured when the interviewer or respondent selects an answer.

For example, the following coding system was used for the 2002 Public Service Employee Survey:

> *In the past three years how many promotions have you had?*
> ❍ *none*
> ❍ *one*
> ❍ *more than one*

The benefits of closed questions were discussed in **Chapter 5 - Questionnaire Design**. The main benefits are that they are less burdensome to respondents, and data collection, capture and analysis are cheaper, faster and easier than for open questions. One disadvantage of closed questions is that the respondent's natural wording is unknown. This can make it difficult to verify the quality of the coding. For example, if an open question were used to determine a person's occupation, the respondent's description of his or her work could lead to a different occupation code than if the respondent or interviewer were to select from amongst a choice of occupational codes provided by a closed question.

10.1.2 Manual Coding of Open Questions

When manually coding open questions, the coder (typically after collection) must read, interpret and manually convert a written response to an open question into a numeric code. This numeric code is then either recorded on the questionnaire or entered into a computer. In order to assign a code, the coder may simply be required to note whether the answer contains a key word or reference to a particular item. Sometimes, coding is based on the answer to only one question, sometimes it is based on the answer to several related questions. In this case, the quality of the coding depends very much on the clarity and completeness of the written response and how well the initial editing was done, the soundness of the coding scheme and the skill of the coder.

Coders must be trained carefully since applying the coding scheme requires taking into consideration the following:
-    the number of possible answers;
-    complexity (judgement);
-    possible ambiguity in the response (i.e., the quality of the response).

Variability between individual coders is inevitable. A detailed check of a coder's first batch of questionnaires should be performed to detect mistakes and identify whether or not further training is required. After that, periodic checks should be done on the quality of the coding and corrective action taken if required. This is often done using quality control methods (see **Appendix B - Quality Assurance and Quality Control**).

10.1.3 Automated Coding of Open Questions

Traditionally, coding open questions has been a manual operation. However, due to advances in technology, resource constraints and, most importantly, concerns about timeliness and quality, coding is becoming more and more an automated process.

In general, two files are input to an automated coding system. One file contains the survey responses that are to be coded, referred to as the write-in file. The second file is called the reference file and contains typical written responses (or phrases) and their corresponding numeric codes.

Most often, the first step of automated coding is parsing. Parsing is the process of standardising a phrase in order to allow the computer to recognise equivalent phrases. Parsing usually consists of the removal of extraneous characters, such as punctuation, and the removal of double words, trivial words, certain suffixes and prefixes, etc. Both the survey write-in files and the reference file are parsed before continuing.

The next step involves, for every write-in in the survey file, a search of the reference file for an exact match. If found, the code in the reference file is copied to the survey file and the record[1] is considered coded. However, if an exact match cannot be found, an attempt can be made to find the closest match possible among the reference file records. Every record on the reference file is assigned a score, which is a measure of how similar the reference file phrase is to the survey response. Scores are evaluated based on predetermined parameters (which are specified to reduce the risk of making an error) and if a close-enough match is found, the code is transferred to the survey response and the record is considered coded.

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[1] In this chapter, *questionnaire* generally refers to the hard-copy document whereas *record* refers to the electronic version of the completed questionnaire.

Sometimes several reference file records are found with similar scores and sometimes no reference file record is found to be close to the survey response. In these situations, the records are generally sent to a small manual coding operation staffed with expert coders who are responsible for coding any records left uncoded at the end of the automated phase and for quality control of the output of the automated system (see **Appendix B - Quality Assurance and Quality Control**).

10.2   Data Capture

Data capture is the transformation of responses into a machine-readable format. With paper-based collection methods, capture occurs after collection (usually after the questionnaire has been groomed and some preliminary edits have been performed). For example, data capture might consist of a clerk (referred to as a keyer) manually typing into a computer the reported values on the questionnaire. With computer-based collection methods, capture occurs at the time of collection.

There are several ways to improve the efficiency of data capture. One is to use computer-assisted data collection methods. The main benefit of computer-assisted methods is that collection and capture are combined, resulting in an integrated, faster and more efficient data collection and capture process than paper-based methods. One disadvantage of computer-assisted methods is that the software programs require extensive development and testing. (For more on the advantages and disadvantages of computer-assisted data collection, see **Chapter 4 - Data Collection Methods**.)

For paper-based collection methods, pre-coding closed questions can greatly improve the efficiency of manual data capture. Another option is to optically scan completed questionnaires. Optical scanning works best for closed questions and is less reliable at capturing answers to open questions. Scanning can reduce data capture errors compared to manual capture, but scanning errors do occur and should be evaluated and minimised. In the case of long questionnaires, the logistics of optical scanning are more cumbersome: staples have to be removed, questionnaire identifiers added to every page, scanners reset to read in different pages, etc. Another option is to have all answers coded on a single sheet of paper. This simplifies scanning but it can be burdensome for the interviewer to read a question from one sheet of paper and record it on another. It also limits questions to closed questions and on a large sheet full of answer boxes, it is easy for the interviewer to code the wrong answer or to code the answer in the wrong answer box. Finally, it is difficult for the interviewer to refer back to an answer given by the respondent since the questions and answers are in different places.

With paper-based collection methods it is particularly important that quality assurance and quality control procedures be implemented to minimise and correct errors introduced during data capture (see **Appendix B - Quality Assurance and Quality Control**).

10.3   Editing

In an ideal world, every questionnaire would be completed without any errors. Unfortunately, responses to some questions may be missing, incomplete or incorrect. ***Editing is the application of checks to identify missing, invalid or inconsistent entries that point to data records that are potentially in error***. Editing usually identifies nonsampling errors arising from measurement (response) errors, nonresponse or processing. The purpose of editing is to:
-    better understand the survey processes and the survey data;
-    detect erroneous or missing data;
-    follow-up with the respondent;

- send a record to imputation;
- delete a record.

In order to identify erroneous records, edit rules are applied. Some examples of edit rules are:
- each question must have one and only one response;
- the valid responses for Question X are *1* or *2*;
- the sum of the parts for Question X cannot be less than the response to Question Y.

Editing can occur at several points throughout the survey process and ranges from simple preliminary checks performed by interviewers in the field to more complex automated verifications performed by a computer program after the data have been captured. In general, edit rules are based upon what is logically or validly possible, based upon:
- expert knowledge of the subject matter;
- other related surveys or data;
- the structure of the questionnaire and its questions;
- statistical theory.

Subject matter experts should be knowledgeable of how variables relate to one another and what answers are reasonable. Such individuals are instrumental in specifying what types of rules are appropriate. Typically, they are analysts who have experience with the types of data being edited. For example, a transportation analyst may be aware of the acceptable range of values for fuel consumption rates for various makes and models of vehicles. Analysis of other surveys or datasets relating to the same sorts of variables as the ones being edited can be useful in establishing some of the edit rules.

Equally important, the layout and structure of the questionnaire have an impact on the edit rules. Edits should verify that responses respect the logical flow of the questionnaire. This is often manifested through the use of *go to* or *skip* instructions which imply that certain questionnaire items do not apply to certain categories of respondents and therefore the respondent is to skip to another question.

There are three main categories of edits: *validity, consistency* and *distribution* edits. Validity and consistency edits are applied one questionnaire at a time. Validity edits verify the syntax of responses and include such things as checking for non-numeric characters reported in numeric fields and checking for missing values. The first two examples of edit rules above are validity edits. Validity edits can also check that the coded data lie within an allowed range of values. For example, a range edit might be put on the reported age of a respondent to ensure that it lies between 0 and 125 years.

Consistency edits verify that relationships between questions are respected. The third example of an edit rule above is a consistency edit. Consistency edits can be based on logical, legal, accounting or structural relationships between questions or parts of a question. The relationship between date of birth and marital status is one example where an edit might be: 'a person less than 15 years of age cannot have any marital status other than *never married*.' Consistency edits may also be based on the logical flow of the questionnaire, for example: 'if Question X is answered *no* then Question Y cannot be answered'. Consistency edits may also involve the use of historical data (e.g., year-to-year ratios). In the case of household surveys, there may be edits between household members.

Distribution edits are performed by looking at data across questionnaires. These attempt to identify records that are outliers with respect to the distribution of the data. Distribution edits are sometimes referred to as statistical edits (Hidiroglou and Berthelot, 1986) or outlier detection. For more information, see Section 10.5. For a discussion of nonsampling errors, see **Chapter 3 - Introduction to Survey Design**.

10.3.1 Edits During Data Collection

Edits during data collection are often referred to as field edits and generally consist of validity edits and some simple consistency edits. The purpose of editing during data collection is to:
-    identify the need for improvement to the collection vehicle;
-    identify the need for more training;
-    detect obvious errors and perform immediate follow-up with the respondent;
-    clean-up entries.

Editing during data collection may be performed by:
-    the respondent (in the case of self-enumeration);
-    the interviewer during the interview;
-    the interviewer immediately after the interview;
-    the interviewer's supervisor;
-    clerical staff.

Field edits are used to identify problems with data collection procedures and the design of the questionnaire as well as the need for more interviewer training. They are also used to detect mistakes made during the interview by the respondent or the interviewer and to identify missing information during collection in order to reduce the need for follow-up later on. Editing during collection is considerably easier to implement when it is automated through a computer-assisted collection method.

For self-enumeration questionnaires, respondents may edit their own answers. In almost all interviewer-assisted surveys, some editing is performing during the interview and interviewers are instructed and trained to review the answers they record on a questionnaire immediately after the interview is concluded – either after leaving the dwelling or after hanging up the telephone. This way they still have an opportunity to detect and treat records that failed edit rules, either because the correct information may still be fresh in their mind or because they can easily and inexpensively follow-up with the respondent to ascertain the correct values. Any edit failures left unresolved are usually dealt with later by imputation.

Another purpose of field edits is to clean-up responses. Often during an interview, the interviewer writes short notes in the margin of the questionnaire or in the notes section of the CATI application. This may be because the interviewer does not know the coding scheme for an open question, or he or she may want to refer to the interviewer's manual for the interpretation of an answer. In these cases, interviewers edit their questionnaires after the interview in order to clean-up these notes.

One of the tasks assigned to supervisors is to check the work of their interviewers to detect errors and then feed this information back to the interviewer. Usually the kinds of failures detected are similar to those that could be detected by the interviewer immediately after the interview and usually there is still some opportunity to follow-up with the respondent to determine the correct values. The supervisors should also be looking for patterns of errors that occur. Lessons learned from one interviewer should be passed on to the whole team.

In many surveys, completed questionnaires are transmitted by respondents or by interviewers to a Regional Office for log-in and clerical *grooming*. This grooming often consists of the same or additional edits to those carried out by the interviewers or supervisors. Grooming includes deciphering handwritten answers, interpreting interviewer remarks, standardising measurement scales (e.g., changing a value reported in feet to metres), etc. It may also involve making sure interviewers have completed all administrative fields on the questionnaire such as response status codes (e.g., indicating a fully or partially completed questionnaire). This process provides for a systematic, independent review or edit of the questionnaire data before they are sent on to data capture. Checking the questionnaire identification codes

can be an important element of this exercise since, without complete identification, questionnaires cannot be logged in or data captured. The degree of editing depends upon the available budget and the extent to which the clerical staff doing the editing can be expected to identify and resolve difficulties encountered. Where possible, this kind of editing is combined with any coding, tallying or batching of questionnaire items that might be required before data capture is started. In some cases, Regional Office staff may follow-up with the respondent to resolve important edit failures.

10.3.2 Edits After Data Collection

The most comprehensive and complicated edits are generally carried out as a separate edit and imputation stage after data collection. During data capture, edits can be carried out by keyers or automatically by computer programs, or by the computer application in the case of computer-assisted collection methods. For paper questionnaires with manual data capture, it is economical to use data capture as an opportunity to apply rules to clean the data sufficiently to make the subsequent processing stages more efficient. Generally, editing during data capture is minimised since responding to an edit failure slows down data capture. Edits during this stage of processing are mainly validity edits and simple consistency edits.

More complex edit rules are generally reserved for the separate edit stage after data capture – along with validity edits, more complex consistency edits are often performed along with selective editing and outlier detection (see section 10.5).

For edit failures after data collection, the usual procedure is to flag the field that failed an edit and then either impute the field or exclude the record from further processing.

Most edit failures at this stage are flagged for imputation. Values that fail an edit should be flagged with a special code to indicate that an unacceptable value or invalid blank was reported. These flags are particularly useful when assessing the quality of the survey data. In some cases, the record or questionnaire may fail so many edit rules – or a small number of critical edits – that it is rendered useless for further processing. In such cases, the record is usually treated as a nonrespondent, removed from the processing stream and a nonresponse weight adjustment performed (see **Chapter 7 - Estimation** for details of weight adjustments).

10.3.3 Selective Editing

In editing, there is a trade-off between getting every record perfect and spending a reasonable amount of resources (i.e., time and money) tidying up the data. Historically, much time and effort has been spent trying to ensure that any and all survey errors are identified. Not only is over-editing the data a poor use of resources, but it can lead to biased results. Typically, the data are expected to follow a pre-defined model and when the data do not follow the model, they are said to fail an edit. If the data are changed every time an edit fails, this can severely bias the data towards the model and away from the real life situation. Also, excessive editing and follow-ups with respondents can result in high response burden and lower the respondent's co-operation on future occasions.

To avoid spending excessive time and resources editing data that have little impact on the final estimates, selective editing practices are recommended, particularly for business surveys (i.e., where the population is skewed and a few businesses dominate the estimates). The selective editing approach is based upon the idea that only critical edit failures need be treated. Selective editing generally applies to quantitative data. An example of an application of selective editing is a procedure that modifies individual records according to their potential impact on the survey estimates or through the analysis of aggregate data.

Selective edit failures may result in following-up with the respondent, excluding the record from further processing or specifying records that require imputation.

The advantages of selective editing include:
- cost savings;
- data quality can be improved by redirecting resources to high impact records or to other activities;
- timeliness can be improved by reducing processing time;
- response burden can be reduced as a result of fewer follow-ups.

The disadvantages of selective editing include:
- less attention is given to the data quality at the level of the individual unit;
- inconsistencies may be left in the data, which may give users the impression of poor data quality;
- the nonsampling error for small domains can be greater than if all questionnaires are individually edited;
- there may be resistance from data processing clerks, subject matter experts, management or data users who may have less confidence in the data.

Some selective editing approaches include:

i.   Top-Down Approach

With this method, the most influential weighted data values are listed from top to bottom for a given domain of estimation and examined one by one. Data examination and verification stops when the next most influential data value does not affect the domain estimate significantly. For example, consider a sample of five businesses from a population of 100 businesses for a survey that wants to estimate the total number of employees in the population. The survey's estimate of the total number of employees is 737. The analyst feels that this estimate is too high (since he expects the average number of employees per business to be 3). In order to examine this value, the contribution of each record is examined as a proportion of the estimate. As can be seen from Table 1, the first record contributes 81.4% to the estimate of the total. Because of its influence on the estimate, this record is examined more closely. It quickly becomes evident that the number of employees reported by this company is higher than expected and the weight is much higher than for other records (perhaps due to a nonresponse adjustment). This record is consequently treated as an influential observation (see Section 10.5). Since all the other weighted values contribute only a small proportion to the overall total, they are not examined more closely.

Table 1: Example of Top-Down Editing

Record	Number of employees	Weight	Contribution to Total
1	12	50	81.4%
2	7	8	7.6%
3	3	12	4.9%
4	2	15	3.3%
5	1	15	2.0%

ii.   Aggregate Method

With the aggregate method, suspicious *domain estimates* are identified. The weighted data of *all* records belonging to the domain are then examined. For example, for a survey estimating average household size, if the average household size in a given village is found to be 23, all of the weighted individual records for that village would be examined to see if there are any values that seem to be substantially higher than the others.

iii.   Graphical Method

Here, the data are graphed to identify suspicious values. For example, the distribution of the data can be graphed to identify unlikely tails of the distribution.

iv.   Questionnaire Score Method

Berthelot and Latouche (1992) propose the use of a score function, where each respondent is assigned a score based on some measure of size, the number of suspicious data items on the questionnaire and the relative importance of the variables. Only records with a high score are examined.

10.3.4 Manual versus Automated Edits

Editing can be automated by means of a computer program. Depending on the volume of editing to be done (in terms of the number of data items or number of questionnaires), the nature and complexity of the edit rules involved, the impact of the unit, the importance of the variables and the stage of survey processing to which the edit rules apply, manual or automated processing may be appropriate. The more complex the edit rules, the more difficult and error-prone is a manual process. Conversely, for some surveys (e.g., paper based ones) it is difficult – if not impossible – to incorporate automated edits during the data collection. Other factors that affect whether or not editing should be manual or automated include the need to monitor interviews and the need for an audit trail. Editing performed after data capture is, however, usually automated. A generally accepted principle for this editing phase – and its related imputation phase – is that it should not require reference back to the individual hard-copy questionnaire unless absolutely necessary. In other words, the electronic records resulting from data capture should contain all the necessary information required for the subsequent editing and imputation to be carried out.

10.3.5 Constraints to Editing

Some constraints to editing are:
-   available resources (time, budget and people);
-   available software;
-   respondent burden;
-   intended use of the data;
-   co-ordination with imputation.

i.   Resources (time, budget and people)

In a manual editing environment, the process of editing can be quite labour intensive. It is necessary to:
-   develop and document the edit rules to be followed and the actions to be followed when there is an edit failure;
-   train those who are going to do the editing;
-   establish a mechanism for supervising and checking the work of those doing the editing (i.e., implement Quality Assurance and Quality Control procedures);
-   establish a method of evaluating the impact of editing on the original data.

In an automated environment, the implication for time, cost and resources for front-end development can be enormous. Tasks include:
-   developing and documenting the edit rules;
-   writing a computer program or adapt a software to identify edit failures;

- testing the computer program;
- editing the survey data by running the program.

In either case, it is important to be sure that the investment in editing is worthwhile. It is a waste of resources to institute an expensive and time-consuming editing strategy to catch a handful of records whose impact on survey results is negligible. On the other hand, it is risky to have only a rudimentary editing strategy only to find there are major errors and inconsistencies in the survey responses. How many records are likely to fail the edit rules? What will be the impact of these failures on the resulting data quality? Are all the records equally important? These kinds of questions are important but not always easy to answer. The responses to these questions depend on, amongst other things, how well designed is the questionnaire, how survey-literate are the respondents and how well-trained are the interviewers.

Often, especially in the case of repeated surveys, it is desirable to analyse the raw (i.e., unedited) survey data before embarking upon an editing strategy. This allows the statistical agency to assess in advance the likely volume of edit failures and the kinds of relationships that exist between questions. Editing should, in fact, be viewed as a continuous process that does not necessarily have a start and a finish. It is a learning process aimed at constant improvement of the entire survey process over time.

ii.   Software

Some specialised software packages exist for editing and imputing survey data (e.g., Statistics Canada's Generalized Edit and Imputation System, GEIS, or the Canadian Census Edit and Imputation System, CANCEIS). Such packages can allow for the use of comprehensive edit rules for a relatively small front-end investment in systems design. Alternatively, statistical agencies can program their own editing strategy.

iii.   Respondent burden

One of the implications of editing questionnaires is the possibility of follow-up with the respondent to treat missing or erroneous data. In the vast majority of situations, the respondent is the most accurate source of information for questionnaire items. However, follow-up is burdensome for the respondent and costly for the statistical agency. Moreover, there may be a significant time interval between the original interview and the time of follow-up so that the respondent no longer remembers the correct answer. These considerations mean that follow-up (as a way of treating edit failures) is generally limited to edits failures identified during collection or arising from selective editing. Since follow-up after collection is generally impractical and undesirable, imputation is required.

iv.   Intended use of the data

The amount of editing that is performed should depend, to a large extent, on the uses of the resulting data. Datasets or data items that will be used primarily for qualitative assessments – where decisions will not be based on precise measurements – may not need to be as rigorously edited as those which will have a strategic importance in decision making. Moreover, within a given dataset, some items may be much more important than others and it may therefore be desirable to devote more time and resources to ensuring that they are clean.

Alternatively, some records in a dataset may carry more importance than others and may contribute significantly to survey estimates. This is especially true in business surveys where 5% of the companies may contribute 95% of the total earnings in a given industry. Focussing on the most influential fields or records is one of the purposes of selective editing (section 10.3.3) and outlier detection (section 10.5).

v.   Co-ordination with imputation

Editing alone is of minimal value if some action is not taken to treat items that fail the edit rules. When the respondent is not followed up, this corrective action is generally referred to as imputation. The dual actions of editing and imputation are closely related. It is therefore important to consider how the latter will be done when developing specifications for the former. In many cases, imputation is done when the edit failure is detected (before proceeding with the examination of subsequent rules). This approach is desirable in situations where it is obvious what action should be performed given the nature of the question or given the answers to related questions. Frequently, however, imputation is performed as a separate step after all the data have been processed through all the edit rules.

10.3.6 Guidelines for Editing

The following are some guidelines for editing:

i.   Edits should be developed by staff who have expertise in the subject matter, questionnaire design, data analysis and with other similar surveys.

ii.   Editing should be performed at several stages of the survey.

iii.   Edits applied at each stage should not contradict edits at some other stage (edits applied throughout collection and processing should be consistent with each other).

iv.   Editing should be used to provide information about the survey process, either in the form of quality measures for the current survey or to suggest improvements for future surveys.

v.   When starting a survey, some assumptions are made about the data. During editing, it is possible to test the validity of these assumptions. For example, it may become obvious that some range edits were too strict or that some sequencing edits failed too frequently, indicating inappropriate edit rules (or some problems with the questionnaire). This information should be used to adjust the edits in the future (or to improve the design of the questionnaire).

vi.   Information on the types of edits performed and the impact of editing on the survey data should be communicated to users.

vii.   Quality assurance and quality control procedures should be applied to minimise and correct errors introduced during editing (see **Appendix B - Quality Assurance and Quality Control**).

10.4   Imputation

Imputation is a process used to determine and assign replacement values to resolve problems of missing, invalid or inconsistent data. This is done by changing some of the responses and all of the missing values on the record being edited to ensure that a plausible, internally consistent record is created. Some problems are rectified earlier by contact with the respondent or through manual study of the questionnaire but, as mentioned previously, it is usually impossible to resolve all problems this way so imputation is used to handle the remaining edit failures.

One alternative to imputation is to let the user treat the missing, invalid or inconsistent data. This approach is not recommended. If the user decides to ignore or delete all records with edit failures, this could result in the loss of a great deal of data since many records may be affected. If the user attempts to replace the missing data, this can lead to inconsistent estimates by different users and can undermine the reputation of the statistical agency that conducted the survey. Since the user has access to fewer variables for imputation than the statistical agency it is likely that the user cannot treat the edit failures as well.

Note that in the case of total nonresponse – when very little or no data have been collected – a common approach is to perform a nonresponse weight adjustment (see **Chapter 7 - Estimation)**.

10.4.1 Methods of Imputation

The methods of imputation can be grouped into two categories – stochastic or deterministic. *Deterministic imputation* means that, given the respondent data, there is only one possible imputed value. *Stochastic imputation* has an element of randomness: if imputation were repeated on the same dataset, deterministic methods would impute the same value each time while stochastic methods might impute a different value each time.

Methods of deterministic imputation include:
- deductive;
- mean value;
- ratio/regression;
- sequential hot-deck;
- sequential cold-deck;
- nearest-neighbour.

With the exception of deductive imputation, each deterministic method has a stochastic counterpart. When imputing quantitative data, this can be achieved by adding a random residual from an appropriate distribution or model to the imputed value. The stochastic counterpart of sequential hot-deck is random hot-deck imputation. Stochastic imputation may better preserve the frequency structure of the dataset and may restore more realistic variability in the imputed values than deterministic methods.

With the exception of donor imputation methods where one donor can be used to impute all the missing or inconsistent data for a recipient record, the following methods consider the imputation of one item at a time.

10.4.1.1 Deductive Imputation

Deductive imputation is a method whereby a missing or inconsistent value can be deduced with certainty. Often this is based upon the pattern of responses given to other items on the questionnaire. Usually deductive imputation is performed before any other method. For example, in a sum of four items, if the total is reported to be 100 with two items reported to be 60 and 40 and the other two left blank, then it can be deduced that the 2 missing values are zero.

More commonly, imputation must substitute a value that is not known for certain to be true. The following provides brief descriptions of some common imputation methods. For all of these methods, it is best to group together similar records, as is done for nonresponse weight adjustments (see **Chapter 7 - Estimation**). These groupings are referred to as imputation classes.

10.4.1.2 Mean Value Imputation

With mean value imputation, the missing or inconsistent value is replaced with the mean value for the imputation class. For example, suppose that a questionnaire for a housing survey is missing the value for the monthly rent payment for an apartment. The missing value can be imputed by the average monthly rent payment for respondents who correctly reported their monthly rent (the imputation class could consist of respondents in the same geographic area as the questionnaire requiring imputation).

For the missing data, imputing the mean value is equivalent to applying the same nonresponse weight adjustment to all respondents in the same imputation class. It assumes that nonresponse is uniform and that nonrespondents have similar characteristics to respondents.

While mean value imputation may produce reasonable point estimates (i.e., estimates of totals, means, etc.), it destroys distributions and multivariate relationships by creating an artificial spike at the class mean. This artificially lowers the estimated sampling variance of the final estimates if conventional formulas for the sampling variance are used.

To avoid disrupting the distribution of the data, mean value imputation is often used as a last resort, when no auxiliary information is available or when there are very few records to impute.

10.4.1.3 Ratio/Regression Imputation

Ratio/regression imputation uses auxiliary information or valid responses from other records to create a ratio or regression model that makes use of the relationship that exists between two or more variables. For example, ratio imputation uses the following model:

$$y_i = Rx_i + \varepsilon_i$$

where
> y_i is the value of the y variable for the ith unit,
> x_i is the value of a related x variable for the ith unit,
> R is the slope of the line (i.e., the change in y_i for one unit increase in x_i),
> ε_i is assumed to be a random error variable with mean 0 and variance equal to σ^2.

In other words, the model assumes that y_i is approximately linearly related to x_i and that observed values of y_i deviate above and below this line by a random amount, ε_i.

Values of y_i could then be imputed by:

$$\widetilde{y}_i = \frac{\overline{y}}{\overline{x}} x_i$$

where:
> $\widetilde{y}_i$ is the imputed value for variable y for record i,
> $\overline{x}$ is the average reported x-value for the imputation class,
> $\overline{y}$ is the average reported y-value for the imputation class.

For example, suppose a questionnaire on employment, payrolls and hours contains an invalid entry for the payroll, y_i, for a two-week period, but the number of paid employees, x_i, is properly reported and the industry of the firm is known. Using other questionnaires on the current file within this industry (i.e., imputation class) where both the payroll and the number of paid employees are correctly reported, it is

possible to determine the ratio between the payroll and the number of employees. This ratio (payroll to number of employees) can then be applied to the number of employees on the questionnaire requiring imputation to determine a value for the payroll.

The assumption made here is that the ratio or regression model fit to the questionnaires with valid data (i.e., which passed all edits) in the imputation class applies equally well to the questionnaires that failed edits in the imputation class. If this is not true, serious bias can be introduced.

The accuracy of the imputed values depends to a large extent on the existence of variables closely related to the variable being imputed, the degree of sophistication used in the mathematical calculations and whether or not the calculation is restricted to an imputation class or the whole dataset. One advantage of this method is that it may preserve relationships between variables. Also, ratio and regression estimators are likely to generate more stable imputed values than simple averages. However, this method of imputation can artificially induce relationships at the data analysis stage. And, like most other imputation methods (with the exception of deductive imputation), it lowers the estimated sampling variance of the final estimates if conventional variance formulas are used.

Previous value imputation, also called carry-over or carry-forward imputation, is a special case of ratio/regression imputation where the value for the current occasion is imputed by adjusting the previous occasion's value for growth. It is frequently used for quantitative variables in business survey applications.

Ratio and regression estimation are explained in more detail in **Chapter 11 - Data Analysis**.

10.4.1.4 Hot-Deck Imputation

Hot-deck imputation uses information from a donor record that has usually passed all edits to replace missing or inconsistent values for a recipient record. In order to find a donor record that is similar to the recipient record, variables that are related to those requiring imputation are identified to create imputation classes. The set of records in the imputation class which have passed all the edits is the donor pool for records in the imputation class requiring imputation. Hot-deck imputation can be used to impute quantitative or qualitative data, but generally uses qualitative variables to create the imputation classes. The two main types of hot-deck imputation are *sequential* and *random* hot-deck imputation.

With sequential hot-deck, the data are processed sequentially within the imputation class, one record at a time (i.e., sorted in some order). Imputation is performed by replacing the missing item on a questionnaire with the corresponding value from the previous clean responding donor in the imputation class on the data file. Sequential hot-deck is a deterministic imputation method if the same method of sorting is used each time. With random hot-deck imputation, donors are selected at random within the imputation class. Random hot-deck is a stochastic method of imputation.

To illustrate hot-deck imputation, consider the example of imputing the smoking status of a respondent. Suppose that there are two possible responses: smoker and non-smoker. To find a donor record, imputation classes are created based on age group and sex since these variables are related to a person's smoking status. Suppose that the record requiring imputation is for a female in the 15-24 age category. The set of donors is all respondent females aged 15-24 who reported their smoking status. A donor could be selected either randomly (i.e., random hot-deck) or sequentially, by sorting the list of donors and selecting one (i.e., sequential hot-deck).

The advantage of donor imputation methods (hot deck imputation and nearest neighbour, see section

10.4.1.6) is that since similar donors (i.e., companies, households, etc.) should have similar characteristics, the imputed value should be fairly close to the actual value. And with donor imputation, the multivariate distribution of the data can usually be preserved.

There are, however, some disadvantages. One disadvantage of sequential hot-deck is that it often leads to multiple use of the same donor. If one donor is used repeatedly, this can distort the distribution of the data and artificially lower the estimated sampling variance. Another disadvantage is that good auxiliary information and at least a partial response (for example, household income, age, sex, etc.) is needed to create the imputation classes, and these are not always available for the records requiring imputation. Also, care must be taken if the imputation class is small or the nonresponse rate in the imputation class is high as this may lead to no donor being found. (This is true for all methods of imputation that use imputation classes.)

In order to ensure that it is always possible to find a donor record, *hierarchical* hot-deck imputation can be used. Hierarchical imputation uses more than one level of imputation class. When a donor cannot be found for the initial most detailed imputation class, imputation classes are collapsed in a hierarchical fashion until a level is reached where a donor can be found.

For more details on donor imputation, see section 10.4.3.

10.4.1.5 Cold-Deck Imputation

Cold-deck imputation is similar to hot-deck imputation, the difference is that hot-deck imputation uses donors from the current survey, while cold-deck imputation uses donors from another source. Often cold-deck imputation uses historical data from an earlier occasion of the same survey or from a census. If the donors are selected in a random manner, then imputation is stochastic, otherwise it is deterministic.

10.4.1.6 Nearest-Neighbour Imputation

For surveys with largely quantitative data (e.g., business surveys with reported sales and inventory), it may be necessary or preferable to find a donor record by matching on quantitative data. Nearest-neighbour imputation selects a donor record based on matching variables. With this method of imputation, the goal is not necessarily to find a donor record that matches the recipient exactly on the matching variables. Instead, the goal is to find the donor that is closest to the recipient in terms of the matching variables within the imputation class – i.e., to find the nearest neighbour. This closeness is defined by a distance measure between two observations calculated using matching variables (e.g., to impute missing inventory, find the nearest-neighbour with respect to reported sales in the imputation class).

Caution must be exercised when implementing nearest neighbour methods in cases where the scale of the matching variables is quite different (e.g., currency and land areas). In most instances some form of transformation of the variables should be done in order to standardise the scale.

10.4.1.7 Deterministic Imputation with Random Residuals

Deterministic methods for quantitative data can be made stochastic by adding random residuals, for example, by imputing the mean value and adding a random residual:

$$\widetilde{y}_i = \overline{y} + e_i{}^*$$

where

$\widetilde{y}_i$ is the imputed value for variable y for record i,

$\overline{y}$ is the mean for the imputation class,

$e_i{}^*$ is a random model residual selected from the respondents or drawn from a distribution.

One way to select $e_i{}^*$ is as follows. For the set of respondents in an imputation class, calculate residuals as follows:

$$e_{i(r)} = y_{i(r)} - \overline{y}_r$$

where

$y_{i(r)}$ is the reported y-value for the ith respondent,

$\overline{y}_r$ is the average reported y-value for the imputation class.

Then, one can set $e_i{}^*$ by randomly selecting from all values of $e_{i(r)}$ in the imputation class.

See Kalton and Kasprzyk (1986) for a discussion of approaches to stochastic imputation.

10.4.2 Determining which Values to Impute

Fields that fail an edit rule due to nonresponse or invalid data that are not resolved through respondent follow-up should be imputed. For all other edit failures, since it is best to preserve as much of the respondent data as possible, imputing all edit failures is not recommended. Instead, it is best to impute a minimum set of fields for a record. The Fellegi/Holt framework (Fellegi and Holt, 1976) is one such method of identifying the fields that require imputation. Three criteria are used to determine which fields should be imputed:
-   the data in each record should be made to satisfy all edits by changing the fewest possible items of data (fields);
-   as much as possible, the frequency structure of the data file should be maintained;
-   imputation rules should be derived from the corresponding edit rules without explicit specification.

A key feature of the Fellegi/Holt editing approach is that the edit rules are not specific to a particular imputation method. For each failed edit record, it first proceeds through a step of error localisation in which it determines the minimal set of variables (fields) to impute, as well as the acceptable ranges(s) of values to impute. In most implementations, a single donor is selected from passed edit records by matching on the basis of other variables involved in the edits but not requiring imputation. The method searches for a single exact match and can be extended to take account of other variables not explicitly involved in the edits. Occasionally, no suitable donor can be found and a default imputation method must be available.

For example, consider that a survey has an age/marital status edit to identify people who are married and under the age of 16; and an age/level of education edit to identify people who have a university education and are under the age of 18. Suppose that the survey data have a record that fails both of these edits: there is a ten-year old married woman with a university education. In order for this record to pass both edits, both the individual's marital status and level of education could be changed, or simply the age could be changed. The Fellegi/Holt framework recommends the latter.

10.4.3 Donor Imputation Issues

The following issues require consideration when developing a donor imputation system (i.e., hot-deck, cold-deck or nearest neighbour imputation):

i.   How will a donor record be found for the recipient?

The goal is to find a donor record for each recipient that is similar to the recipient. Serious thought needs to be given to the imputation classes or matching variables used – it is important that there be a strong relationship between the variables requiring imputation and those used to select donors. For methods that require the formation of imputation classes, it is important that imputation classes be large enough that a sufficient number of potential donors are available, but not so large that the records within a donor pool are dissimilar.

ii.   Should all fields on a recipient record be imputed from a single donor?

This is desirable because taking all fields from one record preserves joint distributions between variables. For example, in a labour force survey, if both occupation and personal income are flagged for imputation, there is an obvious advantage to imputing both of these variables using the same donor record, since this will preserve the interrelationship between income and occupation. Another advantage of single donor imputation is that since the donor must have passed all edits, it can be used to impute all missing values (i.e., facilitating imputation).

One problem with donor imputation is that if too many matching variables are used (i.e., variables used to create imputation classes in the case of hot-deck and cold-deck), there is the risk that no suitable donor may be found. Another problem is that the matching variables used to impute one field may not be suitable for another, particularly if the variables requiring imputation are not related. Consider a multi-purpose health survey in which a person's height and the number of cigarettes smoked daily are flagged for imputation. In this case, a different set of matching fields might be appropriate for each field requiring imputation.

Often with donor procedures, the imputation is broken down into several stages with certain sets of fields being imputed at each stage. As a result, several donors may be involved in completing a single deficient record. If this is of concern, certain key imputed fields can be used to create imputation classes in succeeding stages to preserve internal integrity.

iii.   Can a donor record be used to impute more than one recipient?

If several recipient records are imputed by the same donor, the impact on the final survey estimates can be significant. Limiting the number of times a record is used as a donor has the effect of spreading the donor usage around and avoiding over-use of a particular donor. If the response rate in a particular imputation class is very low, limiting the number of times a donor is used may result in some matches not being very good (i.e., the donor may not be very similar to the recipient record) and may result in some recipients not finding a donor. At the same time, over-use of a donor (especially if the donor has unique characteristics making it quite different from others in the population) can have a substantial effect on survey estimates. If there is no limit placed on the number of times that a record can be used as a donor, there should be a method of identifying records which are used often as donors. If any of these records have suspicious or outlying fields, some investigation may be warranted to see if the final survey results were distorted by the imputation process.

iv.   What is done for recipients for whom a suitable donor cannot be found?

There are some recipients for whom a donor record cannot be found. Usually a back-up procedure is used for such recipients (e.g., hierarchical hot-deck or cold-deck imputation or mean value imputation).

v.   Does the survey deal with quantitative or qualitative data?

Some imputation methods are more appropriate for qualitative variables while others are more appropriate for quantitative variables. Hot-deck methods were developed in order to treat qualitative data while nearest neighbour imputation was developed for quantitative data. Nowadays, both methods have found their use in both situations, including mixed problems.

10.4.4 Variance Estimation for Imputed Data

All of the imputation methods presented produce a single imputed value for each missing or inconsistent value. All distort, to some extent, the original distribution of values for a variable and can lead to inappropriate variance estimates when standard variance estimators are used. This can lead to confidence intervals that are too narrow and spurious declarations of significance. The extent of the distortion varies considerably depending on the amount of imputation done and the method used.

When imputation is carried out – assuming there are no other nonsampling errors – the variance of an estimate has two components: one due to sampling (the sampling variance) and one due to imputation (the imputation variance). The sampling variance component is usually underestimated in the presence of imputed data since traditional formulas assume a 100% response rate. One benefit of stochastic imputation methods is that they add some noise to the completed dataset. As a result, when stochastic imputation is used, the sampling variance of an estimate can be, most of the time, correctly estimated using traditional methods. However, to determine the total variance of the estimate, the imputation variance must still be estimated.

It is important to estimate both the sampling and the imputation components of the total variance not only to draw correct inferences, but also to know the relative importance of the sampling variance and imputation variance. This can help inform users of data quality and help allocate survey resources between sample size and edit/imputation processes.

Multiple imputation is a method, proposed by Rubin (1987), which addresses this problem by properly imputing several, say m, times, each value requiring imputation (for a definition of proper imputation, see Rubin, 1987 or Binder and Weiman, 1996). From the completed dataset, m estimates can be produced for the item. From these, a single combined estimate is produced along with a pooled variance estimate that expresses the uncertainty about which value to impute. However, multiple imputation requires more work for data processing, storage and computation of estimates.

In the case of single imputation, the important variance estimation methods have been extended to the case of data files containing imputed data. The approaches are described in Särndal (1992), Rao and Shao (1992), Rao and Sitter (1995) and Gagnon et al. (1996). A comparison of the methods is presented in Lee, Rancourt and Särndal (1994, 2001).

10.4.5 Guidelines for Imputation

Although imputation can improve the quality of the final data, care should be taken when choosing an appropriate imputation methodology. One risk with imputation is that it can destroy reported data to create records that fit preconceived models that may later turn out to be incorrect. The suitability of the imputation method depends upon the survey, its objectives, available auxiliary information and the nature of the error.

The following are some guidelines for imputation:

i.   Imputed records should closely resemble the failed edit record. This is usually achieved by imputing the minimum number of variables, thereby preserving as much respondent data as possible. The underlying assumption (which is not always true in practice) is that a respondent is more likely to make only one or two errors than several.

ii.   Good imputation has an audit trail for evaluation purposes. Imputed values should be flagged and the methods and sources of imputation clearly identified. The unimputed and imputed values of the record's fields should be retained so that the degree and effects of imputation can be evaluated.

iii.   Imputed records should satisfy all edits.

iv.   The imputation methods should be chosen carefully, considering the type of data to be imputed.

v.   The imputation method should aim to reduce the nonresponse bias and preserve relationships between items as much as possible (i.e., the fit of the model underlying the imputation method should be assessed).

vi.   The imputation system should be thought out, specified, programmed and tested in advance.

vii.   The process should be automated, objective, reproducible and efficient.

viii.   The imputation system should be able to handle any pattern of missing or inconsistent fields.

ix.   For donor imputation methods, the imputed record should closely resemble the donors selected. This will tend to ensure that the combination of imputed and unimputed responses for the imputed record not only satisfy the edits but are also plausible.

10.4.6 Evaluation of Imputation Procedures

The size of the survey and its budget influence how much work can be carried out to measure imputation effects. However, users of survey data should always have at least some basic information about the degree to which survey data were modelled or estimated by imputation. In evaluating the imputation procedure, the most relevant concerns are bias and the imputation variance of the survey estimates.

If the survey budget is large, one option is to do a complete study of the effect of imputation, looking at the survey estimates with and without imputation. Cases in which discrepancies are large can be investigated and an attempt can be made to discover any bias that may exist due to imputation.

If this is not possible, at the very least, imputation should be monitored so users can be told how much

imputation was done and where. At the end of imputation, it may be useful to produce the following (some are specific to a particular method):
-    the number of records which were imputed (i.e., the number of recipient records);
-    the number of times each field was imputed and by what method;
-    the number of records eligible to be used as donors;
-    the number of records actually used as donors and the number of recipients each of these donor records imputed;
-    a list (or file) indicating which donors were used for each recipient (to trace the sources of unusual imputed records);
-    a list of all records for which imputation failed (e.g., because no donor was found).

It should be noted that the above information is useful for the redesign of a survey or the implementation of a similar survey. This information could be instrumental in improving the edit and imputation system, the survey questionnaire and the collection procedures. For example, if the answer to a question has a high imputation rate, this could indicate a poorly worded question (and poor data quality).

10.5   Identification and Treatment of Outliers

The identification of outliers can be viewed as a type of editing whereby suspicious records are identified. In **Chapter 7 - Estimation**, *an outlier was defined as an observation or subset of observations that appears to be inconsistent with the remainder of the dataset*. The distinction should also be made between extreme and influential observations. An observation is influential if the combination of the reported value and the final survey weight have a large influence on the estimate. However, an extreme value need not be influential, and vice versa.

It is possible to make the distinction between univariate outliers and multivariate outliers. An observation is a univariate outlier if it is an outlier with respect to one variable. An observation is a multivariate outlier if it is an outlier with respect to two or more variables. For example, it might not be unusual to find a person with a height of 2 metres *or* a person weighing 45 kg. But someone who is *both* 2 metres high and only weighs 45 kg is an example of a multivariate outlier.

Outliers are found in every survey for almost every variable of interest. There are many reasons why outliers exist:

i.   There are errors in the data (e.g., data capture errors).

ii.   The outliers can be thought of as arising from another model or distribution. For example, most of the data might be considered to arise from a normal distribution, but the outliers might be thought of as arising from an exponential distribution.

iii.   The outlier may be due to inherent variability of the data. What appears to be a suspicious value may simply arise from the inherent variability of the dataset – in other words, it may be a legitimate but extreme observation from the distribution. This can occur when the population is skewed, which is common for business surveys. For example, the distribution of the sales by the size of the company is typically skewed – a few very large companies often contribute to a large portion of the overall sales.

10.5.1 Identification of Outliers

The most popular outlier detection methods are univariate methods because they are simpler than multivariate methods. Traditionally, outliers are detected by measuring their relative distances from the centre of the data. For example, if $y_1, y_2, ..., y_n$ are the observed sample data and m and s are measures of the central tendency and spread of the data, respectively, then the relative distance, d_i, of y_i from the centre of the data can be defined by:

$$d_i = \frac{|y_i - m|}{s}$$

If d_i exceeds a predetermined cut-off value, then the observation is considered to be an outlier.

Alternatively, a tolerance interval can be given by:

$$(m - c_L s, m + c_U s)$$

where c_L and c_U are predetermined lower and upper bound values. If the population is skewed, unequal values of c_L and c_U are used. Observations falling outside of this interval are declared to be outliers.

The sample mean and variance are the statistics most frequently used to estimate the centre of the data and the spread of the data. However, since they are sensitive to outliers, they are a poor choice for the purpose of outlier detection. For example, the sample mean is shifted towards outliers if they are clustered on one side and the sample variance is greatly inflated by outliers. Therefore, the relative distance values of some outliers may appear rather small and the procedure may fail to detect them. This problem is referred to as the *masking effect*.

For this reason, one of the most popular methods of outlier detection is the *quartile method* which uses the median to estimate the centre and quartile ranges to estimate the spread of the weighted data, since these statistics are more robust (i.e., insensitive) to outliers. Quartiles divide the data into four parts: 25% of the data points are less than the first quartile, $q_{.25}$, 50% of the data points are less than the second quartile (or the median), $q_{.5}$, and 75% of the data points are less than the third quartile, $q_{.75}$. (The median and quartile ranges are discussed further in **Chapter 11 - Data Analysis**).

The lower and upper quartile ranges, h_L and h_U, are defined as:

$$h_L = q_{.5} - q_{.25}$$
$$h_U = q_{.75} - q_{.5}$$

The tolerance interval then becomes:

$$(q_{.5} - c_L h_L, q_{.5} + c_U h_U)$$

with some predetermined values for c_L and c_U which can be chosen by examining past data or based on past experience. Any observation falling outside of this interval is considered to be an outlier.

For more information on outlier detection methods, see Barnett and Lewis (1995).

10.5.2 Treatment of Outliers

Outliers detected at the editing stage of the survey process can be treated in various ways. In a manual editing system, the potential outliers are examined or followed-up and changed if they are in fact errors. In an automated editing system, outliers are often imputed. In some cases, no special treatment of outliers is performed if it is believed that they are not influential.

Outliers that are not treated in editing can be dealt with at estimation. Simply ignoring untreated outliers can result in poor estimates and an increase in the sampling variance of the estimates. Assigning the outlier a weight of one (to reduce its effect on estimates) can bias the results. The goal of outlier treatment is to decrease the impact that the outlier has on the sampling variance of the estimate without introducing too much bias.

The following approaches can be used to treat outliers during estimation:
- change the value;
- change the weight;
- use robust estimation.

i.   Change the value

One example of treatment of an extreme value is Winsorization. Winsorization consists of recoding the top k values.

Recall that in simple random sampling (assuming a 100% response), the usual unbiased estimator of the population total Y is given by:

$$\hat{Y} = \frac{N}{n} \sum_{i=1}^{n} y_i$$

where i is the ith unit in a sample of size n.

Assuming that y_i, $i=1,2, \ldots, n$ are ordered values of y_i in a sample of size n from a population of size N and the k largest values are considered to be outliers, the one-sided k-times-Winsorized estimator is defined by replacing these outlier values by the $n\text{-}k^{th}$ largest value, $y_{n\text{-}k}$. That is:

$$\hat{Y}_W = \frac{N}{n} (\sum_{i=1}^{n-k} y_i + k y_{n-k})$$

Note that Winsorization tends to be used for one-variable situations, so it is rarely used in the multivariate sample survey situation.

ii.   Change the weight

Another option is to reduce the weights of outliers so that they have a smaller impact. An example is to set the weight of the outlier to one or zero. This is seldom done because of its dramatic effect on estimates, especially for skewed populations. It can lead to serious bias – usually underestimation. For example, if two large companies contribute to the majority of retail sales, and one is identified as an outlier, eliminating this company from the estimates will seriously underestimate the total retail sales. Several estimators with reduced weights for outliers have been proposed, see Rao (1970), Hidiroglou and Srinath (1981).

iii.   Robust Estimators

In classical estimation theory, the estimator of a population parameter is based on an assumption of some distribution. Typically, it is assumed that the estimator has a normal sampling distribution (see **Chapter 7 - Estimation** for the definition of a sampling distribution). The usual sample mean and variance estimators are optimal under normality. However, these estimators are extremely sensitive to outliers. Robust estimators are estimators that are less sensitive to distributional assumptions. For example, the median is more robust than the mean; interquartile ranges are more robust than the usual variance estimator. Many complex robust estimators have been proposed over the years, including Huber's M-estimators, Huber (1964).

For more information on robust estimators and outlier detection in general, see Kish (1965), Barnett and Lewis (1995), Rousseeuw and Leroy (1987), Lee et al. (1992), or Lee (1995). For more information on the mean versus the median, see **Chapter 11 - Data Analysis**.

10.6   Generating Results/ Creating a Database

After coding, data capture, edit and imputation and the detection of outliers, the data are almost ready for estimation, analysis, and publication. Before proceeding however, the format for storing the data must be established. The two main choices are a database or a flat file. A flat file is a computerised 2-dimensional arrangement of records and their corresponding values. It is easily transferable between platforms and can be read using spreadsheet software or statistical software. The main drawback to a flat file is that most statistical software must have data stored in a special format to facilitate speedy processing. When using a flat file, this special format is continually being recreated, an unnecessary inefficiency. If the data are stored in an appropriate database format, it is possible to use certain statistical and database software without needing to recreate the file. Queries can be run directly on the database. However the choice of database format may restrict the choice of statistical and database software that can be used for tabulation and analysis. It may be best to create a flat file as well as several different database files with the survey results.

Once the format for storing the data has been selected, the final (estimation) weights are calculated and the planned tabulations are produced (see **Chapter 7 - Estimation** for a description of how to calculate final weights). Usually, computer programs are written to calculate the weights and produce the tabulations. More sophisticated data analysis may also be performed. Before releasing the data, they must be examined to ensure that the confidentiality of respondents is not violated. This process, called disclosure control, may result in the suppression of some survey data. For more information on data analysis and disclosure control, see **Chapter 12 - Data Dissemination**.

10.7   Automated versus Manual Processing

In the past, almost all aspects of survey processing were done manually. However, computers now make it possible to process the data in an automated manner.

The benefits of automating coding and data capture, optical scanners, computer-assisted data collection methods and pre-coding the questionnaire have already been discussed. The arguments for using computers at collection apply to using computers for processing. Experience has shown that, in general, computers are much better at processing large volumes of information than are people. Automation can improve all aspects of data quality, in particular timeliness – it can produce results faster with fewer

resources. It also ensures that procedures (for example, editing and imputation) are implemented in a consistent manner, thereby reducing nonsampling errors. Also, it is possible to use more complex methods (for example for editing, imputation, coding, quality control, etc.) and it is possible to track processing – produce reports on each processing step (e.g., number of edits and imputations performed). Automation also makes it easier to monitor and control the quality of the processing.

However, there are some drawbacks to automation, including:
- specifications must be written for each system that is to be automated. Developing a computer program for each procedure (e.g., imputation) can be time-consuming;
- operators must be trained on the software;
- automated coding, editing and imputation does not take into account any additional knowledge held by the operator.

Despite these drawbacks, it is wise to automate procedures as much as possible. The additional time required at the outset is more than offset by the time saved later in the survey process (particularly if the survey is to be repeated). As a minimum data should always be captured and then weighted and estimation performed by computer. The consistency that results from automation is important to attaining accurate and measurable results. It is also wise to take advantage of existing systems and processes, automated systems for coding, etc.

10.8 Summary

Processing is an important survey activity that converts questionnaire responses into a format suitable for tabulation and data analysis. Processing is costly, time-consuming, resource-intensive and has an impact on the final quality of the data. Automation can make it more efficient and improve the final quality of the data.

Processing usually begins with a preliminary clean-up of the questionnaire, followed by coding and data capture. This is usually followed by more detailed editing to identify missing or inconsistent data, and imputation to provide plausible substitutes for these values. Outlier detection may also be performed to identify suspicious values. Once the data are complete, consistent and valid, they are typically stored in a database.

Bibliography

Bankier, M., M. Lachance, and P. Poirier. 1999. A Generic Implementation of the Nearest neighbour imputation method. *Proceedings of the Survey Research Methods Section*. American Statistical Association. 548-553.

Barnett, V., and T. Lewis. 1995. *Outliers in Statistical Data*. John Wiley and Sons, Chichester.

Latouche, M. and J.-M. Berthelot. 1992. Use of a Score Function to Prioritize and Limit Recontacts in Editing Business Surveys. *Journal of Official Statistics,* 8(3): 389-400.

Binder, D., and S. Weimin. 1996. Frequency Valid Multiple Imputation for Surveys with a Complex Design. *Proceedings for the Section on Survey Research Methods of the American Statistical Association,* 1: 281-286.

Brick, J.M. and G. Kalton. 1996. Handling Missing Data in Survey Research. *Statistical Mathematics in Medical Research,* 5: 215-238.

Boucher, L, J.-P. S. Simard and J.-F. Gosselin. 1993. Macro-Editing, a Case Study: Selective Editing for the Annual Survey of Manufacturers Conducted by Statistics Canada, *Proceedings of the International Conference on Establishment Surveys.* American Statistical Association. Virginia.

Chambers, R.L. 1986. Outlier Robust Finite Population Estimation. *Journal of the American Statistical Association,* 81: 1063-1069.

Cox, B.G., D.A. Binder, B.N. Chinnappa, A. Christianson, M.J. Colledge and P.S. Kott, eds. 1995. *Business Survey Methods.* John Wiley and Sons, New York.

Dielman, L. and M.P. Couper. 1995. Data Quality in a CAPI Survey: Keying Errors. *Journal of Official Statistics,* 11(2): 141-146.

Dolson, D. 1999. *Imputation Methods.* Statistics Canada.

Fay, R.E. 1996. Alternative Paradigms for the Analysis of Imputed Survey Data. *Journal of the American Statistical Association,* 91: 490-498.

Fellegi, I.P. and D. Holt. 1976. A Systematic Approach to Automatic Edit and Imputation. *Journal of the American Statistical Association,* 71: 17-35.

Gagnon, F., H. Lee, E. Rancourt and C.E. Särndal. 1996. Estimating the Variance of the Generalized Regression Estimation in the Presence of Imputation for the Generalized Estimation System. *Proceedings of the Survey Methods Section.* Statistical Society of Canada. 151-156.

Granquist, L. 1984. On the Role of Editing. *Statistisk tidskrift,* 2: 105-118.

Granquist, L. and J. Kovar. 1997. Editing of Survey Data: How Much is Enough? In Lyberg, L., P. Biemer, M. Collins, E. de Leeuw, C. Dippo, N. Schwarz and D. Trewin, eds. 1997. *Survey Measurement and Process Quality.* John Wiley and Sons, New York.

Hidiroglou, M.A. 1999. Course notes for *Methods for Designing Business Survey.* Sponsored by the IASS: 52nd session of the ISI. University of Jyvaskylä, Finland.

Hidiroglou, M.A. and J.-M. Berthelot. 1986. Statistical Edit and Imputation for Periodic Surveys. *Survey Methodology,* 12(1): 73-84.

Hidiroglou, M.A. and K.P. Srinath. 1981. Some Estimators of a Population Total Containing Large Units. *Journal of the American Statistical Association,* 78: 690-695.

Huber, P.J. 1964. Robust Estimation of a Location Parameter. *Annals of Mathematical Statistics,* 35: 73-101.

Kalton, G. and D. Kasprzyk. 1982. Imputation for Missing Survey Responses. *Proceedings of the Section on Survey Research Methods.* American Statistical Association. 23-31.

Kalton, G. and D. Kasprzyk, D. 1986. The Treatment of Missing Survey Data. *Survey Methodology,* 12(1): 1-16.

Kish, L. 1965. *Survey Sampling*. John Wiley and Sons, New York.

Kovar, J.G., J. MacMillan and P. Whitridge. 1988. *Overview and Strategy for the Generalized Edit and Imputation System. (Updated February 1991)*. Statistics Canada. BSMD-88-007E/F.

Latouche, M. et J.-M. Berthelot. 1992. Use of a Score Function to Prioritize and Limit Recontacts in Editing Business Surveys. *Journal of Official Statistics*, 8(3): 389-400.

Lee, H., E. Rancourt and C.E. Särndal. 1994. Experiments with Variance Estimation from Survey Data with Imputed Values. *Journal of Official Statistics,* 10(3): 231-243.

Lee, H., E. Rancourt and C.E. Särndal. 2001. Variance Estimation from Survey Data under Single Value Imputation. *Survey Nonresponse*. John Wiley and Sons, New York.

Lee, H. 1995. Outliers in Business Surveys. In *Business Survey Methods.* Cox, B.G., D. A. Binder, B.N. Chinnappa, A. Christianson, M.J. Colledge and P.S. Kott, eds. John Wiley and Sons. New York. 503-526.

Lyberg, L. and P. Dean. 1992. *Automated Coding of Survey Responses: An International Review*. Presented at the Conference of European Statisticians. Washington, D.C.

Moser, C.A. and G. Kalton. 1971. *Survey Methods in Social Investigation*. Heinemann Educational Books Limited, London.

Raj, D. 1972. *The Design of Sample Surveys*. McGraw-Hill Series in Probability and Statistics, New York.

Rancourt, E., H. Lee and C.E. Särndal. 1993. *Variance Estimation Under More than One Imputation Method*. Proceedings of the International Conference on Establishment Surveys, American Statistical Association, 374-379.

Rao, C.R. 1970. Estimation of Heteroscedastic Variances in Linear Models. *Journal of the American Statistical Association,* 65: 161-172.

Rao, J.N.K. and J. Shao. 1992. Jackknife Variance Estimation with Survey Data under Hot-deck Imputation. *Biometrika,* 79: 811-822.

Rao, J.N.K. and R.R. Sitter. 1995. Variance Estimation under Two-Phase Sampling with Application to Imputation for Missing Data. *Biometrika,* 82: 453-460.

Rao, J.N.K. 1996. On Variance Estimation with Imputed Survey Data. *Journal of the American Statistical Association,* 91: 499-506.

Rousseeuw, P.J. and A.M. Leroy. 1987. *Robust Regression and Outlier Detection*. John Wiley and Sons, New York.

Rubin, D.B. 1987. *Multiple Imputation for Nonresponse in Surveys*. John Wiley and Sons, New York.

Rubin, D.B. 1996. Multiple Imputation after 18+ Years. *Journal of the American Statistical Association,* 91: 473-489.

Sande, I.G. 1979. A Personal View of Hot-deck Imputation Procedures. *Survey Methodology*, 5(2): 238-258.

Sande, I.G. 1982. Imputation in Surveys: Coping with Reality. *The American Statistician,* 36(3). Part 1: 145-152.

Särndal, C.E. 1992. Methods for Estimating the Precision of Survey Estimates when Imputation has Been Used. *Survey Methodology,* 18(2): 242-253.

Särndal, C.E., B. Swensson and J. Wretman. 1992. *Model Assisted Survey Sampling*. Springer Verlag, New York.

Shao, J. and R.R. Sitter. 1996. Bootstrap for Imputed Survey Data. *Journal of the American Statistical Association,* 94: 254-265.

Statistics Canada. 1987. *Quality Guidelines*. Second Edition.

Statistics Canada. 1990. Course notes for *Survey Skills Development Course*.

Statistics Canada. 1998. *Statistics Canada Quality Guidelines*. Third Edition.12-539-X1E.

Statistics Canada. 1998. Course notes for *Surveys from Start to Finish*. Course code 416.

Wenzowski, M.J. 1988. Advances in Automated Coding and Computer-Assisted Coding Software at Statistics Canada. Proceedings of the 1996 Annual Research of the U.S. Census Bureau.

Yung, W. and J.N.K. Rao. 2000. Jackknife Variance Estimation under Imputation for Estimators using Poststratification Information. *Journal of the American Statistical Association,* 95: 903-915.

Chapter 11 - Analysis of Survey Data

11.0 Introduction

Data analysis involves summarising the data and interpreting their meaning in a way that provides clear answers to questions that initiated the survey. Often, it consists of interpreting tables and various summary measures, such as frequency distributions, means and ranges, or more sophisticated analyses may be performed. The analyst may just want to describe the observed units, in which case all tools from elementary and intermediate statistics are available (tables, diagrams and charts, elementary measures of location and spread, basic modelling, classification models, etc.). Or – more commonly – the analyst wants to describe the population and test hypotheses about it, in which the sample design must be properly accounted for during analysis.

The purpose of this chapter is to discuss the analysis of summary statistics (frequency distributions, measures of central tendency and measures of spread) and introduce more analytic methods involving inferential analysis for probability samples and how these apply to simple and complex sample designs.

This chapter begins with the analysis of simple survey data – no stratification, clustering, weight adjustments, etc. Data analysis for more complex survey data rapidly gets complicated and a specialist should be consulted. The more advanced material in this chapter requires undergraduate courses in statistics to thoroughly understand and begins with section 11.3.2.2.1 Confidence Intervals in the Presence of Bias.

11.1 Parameters, Estimates, Sampling Error

Before proceeding, recall some definitions presented in **Chapter 6 - Sample Designs**. *A parameter is a population characteristic that the client or data user is interested in estimating*, for example the population *average* or *mean*, $\overline{Y}$. *An estimator is a formula by which an estimate of the parameter is calculated from the sample and an estimate is the value of the estimator using the data from the realised sample.* Estimates calculated from different samples differ from one another. *The sampling distribution of an estimator is the distribution of all the different values that the estimator can have for all possible samples from the same design from the population.* This distribution depends on the estimator and the sample design. One desirable property of an estimator is that it be unbiased or approximately unbiased, another is that the sampling distribution be concentrated as closely as possible about the mean (i.e., that the sampling error be small). For probability samples, this error can be measured, usually by estimating the sampling variance, standard error, coefficient of variation or margin of error.

11.2 Types of Data

A range of characteristics, or variables, are collected by a survey. Recall from **Chapter 7 - Estimation**, that a single survey may have both qualitative and quantitative variables. Qualitative variables are categorical in nature while quantitative variables indicate an amount. Further decompositions can be made: qualitative variables may be nominal or ordinal and quantitative variables may be discrete or continuous.

i.   Nominal variables

A nominal variable consists of categories that are simply labels or names with no mathematical relationships between the names. It cannot be said that a particular category is greater than, equal to, or less than another; for example, if type of sport is the nominal variable, cricket < soccer has no meaning.

ii.   Ordinal variables

An ordinal variable consists of categories that are ordered or ranked according to some scale or continuum; a particular category can be said to come before or after another. The differences between categories are not necessarily equal. Numbers may be assigned to ordinal variables but only the order matters, adding them together or performing other arithmetic operations is inappropriate. An example of ordinal data is: strongly agree, agree, neutral, disagree, strongly disagree. Other examples are: age collected using a closed question, as in less than 15 years old, 15 to 34 years old, …, 75 years or older; or blood pressure reported as low, normal, high.

iii.   Discrete variables

A discrete variable is a quantitative variable with countable values. An example of such a variable is one where possible values are integers and there can be no intermediate value between any two integers. For example, household size can be 1, 2, 3; values such as 1.5 or 4.75 are impossible. Discrete variables need not be integers, however: another example of a discrete variable is shoe size, where size 6, 6.5, 7, 7.5, etc. are possible, but 6.75 is impossible.

iv.   Continuous variables

A continuous variable is a quantitative variable where any value in a certain range is possible (as opposed to discrete where only particular values are possible). Thus height and weight are continuous variables whereas the number of goals scored by a hockey team is a discrete variable. It is possible for a person to have any height – within a reasonable range – such as 1.68 metres, but a hockey team cannot score 2.3 goals since the number of goals must be a discrete and integer value. Note that continuous variables can be made categorical, for example, blood pressure measurements can be categorised as low, normal or high.

The types of analytical procedures that can be used depend on the type of data, as explained in the following sections.

11.3   Summary Measures

In the *Analysis of Complex Surveys* (1989), Skinner, Holt and Smith state that data from a sample survey can be used for descriptive or analytic purposes. Descriptive uses are directed at the estimation of summary measures of the population, such as means and frequencies, while analytic uses go beyond the summary measures and into the explanation of the processes that underlie the descriptive measures.

This section presents the following summary measures:
-    frequency distributions (in table or chart form);
-    measures of location (i.e., the mean, median or mode);
-    measures of the spread of the distribution (e.g., variance, range).

When analysing the population, it is important to properly account for the sample design. This chapter first presents the case of simple data in section 11.3.1, along with guidelines to display survey results in chart form. Then measures of location and spread for more complex data are presented in section 11.3.2.

11.3.1 Simple Survey Data

Summary statistics for simple survey data (e.g., a census, Simple Random Sample, SRS, or Systematic Sample, SYS, with no weight adjustments) are covered in undergraduate statistics classes and briefly presented here. There are many textbooks that the interested reader can turn to for more information (e.g., Lohr, 1999, Cochran, 1977).

11.3.1.1 Estimation and Presentation of Frequency Distributions

The simplest display of a variable is a *frequency distribution*. Frequency distributions of a qualitative variable show the frequency of each category – the number of observations falling into each category – and can be presented in table or chart form (e.g., a bar chart). Frequency distributions for quantitative variables are usually presented in charts since a table with the frequency of each value of the variable can be unwieldy.

Chapter 7 - Estimation presented estimators using sampling weights which apply to both simple and complex data. To estimate frequencies, domain estimators are used, where the domain is a category (for a qualitative data) or a value (for quantitative data).

For example, for qualitative data the usual estimator for the size of the population for a domain of interest is:

$$\hat{N}_{domain} = \sum_{i \in S_r \cap domain} w_i$$

where w_i is the final adjusted weight of the ith respondent and S_r is the set of responding units.

For quantitative data, the usual estimator of a domain total is:

$$\hat{Y}_{domain} = \sum_{i \in S_r \cap domain} w_i y_i$$

To illustrate the estimation of frequency distributions from a sample survey, consider an SRS of 100 male employees selected from a population of 1,000 men. One of the survey variables is the nominal variable type of work which has two categories: manual and office workers. Another survey variable is the continuous variable systolic blood pressure which was directly measured by a trained nurse and reported in millimetres of mercury (mm Hg). After the survey, the blood pressure readings were also categorised into three groups: low, medium or high.

The weighted frequency distribution of the qualitative variable type of worker can be shown in tabular form as:

Table 1: Estimated Number of Men by Type of Worker

Type of Worker	Estimated Number of Men $\hat{N}$
Manual	550
Office	450
Total	**1,000**

Source: Fictitious Survey of Working Men, Canada, 2002.

(Note that each of the estimates in these tables should also be accompanied by an estimate of sampling error.)

The weighted frequency distribution of the qualitative variable blood pressure is:

Table 2: Estimated Number of Men by Blood Pressure

Blood Pressure	Estimated Number of Men $\hat{N}$
Low	320
Normal	630
High	50
Total	**1,000**

Source: Fictitious Survey of Working Men, Canada, 2002.

Joint distributions are useful for identifying unusual combinations. The weighted joint distribution of type of worker and blood pressure below indicates no incidence of high blood pressure amongst manual workers (for the population surveyed):

Table 3: Estimated Number of Men by Type of Worker and Blood Pressure

Type of Worker	Blood Pressure			Estimated Number of Men $\hat{N}$
	Low	**Normal**	**High**	
Manual	240	310	0	550
Office	80	320	50	450
Total	**320**	**630**	**50**	**1,000**

Source: Fictitious Survey of Working Men, Canada, 2002.

(Tables of joint distributions are often analysed before data are disseminated to the public in order to ensure that confidential data are not released, i.e., tables that reveal unique individuals are suppressed. For more information on disclosure control methods, see **Chapter 12 - Data Dissemination**.)

Frequency distributions can also be displayed using graphs or charts. In fact, data analysis should begin with a visual analysis of the data. Graphical displays are important for many reasons, some of which are:
- graphical representations of the data are superior to purely numerical representations for discovering the characteristic shape of the distribution;
- the shape of the distribution is at least as important as the spread and centre of the distribution;
- the shape of the distribution should determine the choice of parameter (e.g., mean, median or mode) used to describe the data for a single variable.

The following types of charts might be included in a report presenting survey results:
- pie chart;
- column chart;
- bar chart;
- line chart;
- box plot.

These will be reviewed in the next section.

11.3.1.1.1 Charts and Diagrams

The type of chart used depends on the data that are to be represented and what the chart is intended to stress: magnitude, size or trend.

i.   Pie charts

A pie chart is a circle divided into slices like a pie, used to display the percentage of the population falling into different categories of a qualitative variable. For a chart to be useful, the population needs to be divisible into separate groups (e.g., mother tongue is French or English) and preferably only a few units fall into an *other* or *not applicable* category. Pie charts are used to answer questions about relative proportions of mutually exclusive components.

When preparing a pie chart, sectors (slices) should be arranged according to size, placing the largest slice at 12:00 and continuing clockwise with progressively smaller portions. In general, the number of sectors should be limited to five or six. If there are many small sectors, it may be worth collapsing them. Labels should be placed outside the slices; arrows and legends should be avoided. A good example of a pie chart showing household expenditures is illustrated below:

Distribution of Household Expenditures
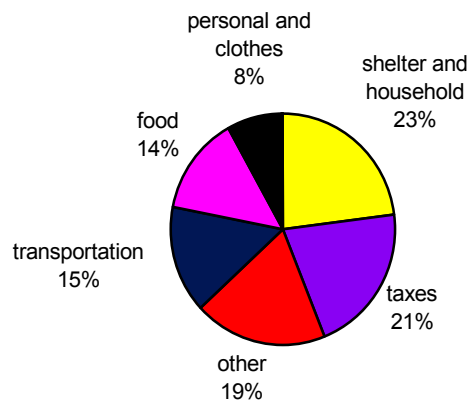
Source: Fictitious Survey on Household Income and Expenditures, Canada, 2002

Three-dimensional presentations of pie charts (see below) can be confusing since they distort areas and therefore should be avoided.

Distribution of Household Expenditures
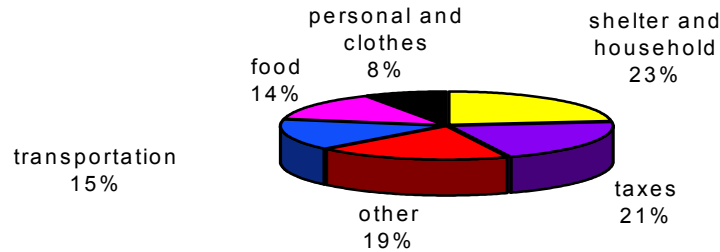
Source : Fictitious Survey on Household Income and Expenditures, Canada, 2002

ii.   Column charts

A column chart is a series of columns whose heights represent magnitudes (e.g., totals, means or proportions). Column charts can be used for qualitative or quantitative variables. Column charts should only be used for a few points and the columns should all have identical widths.

For example, the distribution of systolic blood pressures (a quantitative variable) in the population can be estimated using weighted sample survey data and can be presented in the following column chart:

Distribution of Systolic Blood Pressure, Canada 2002
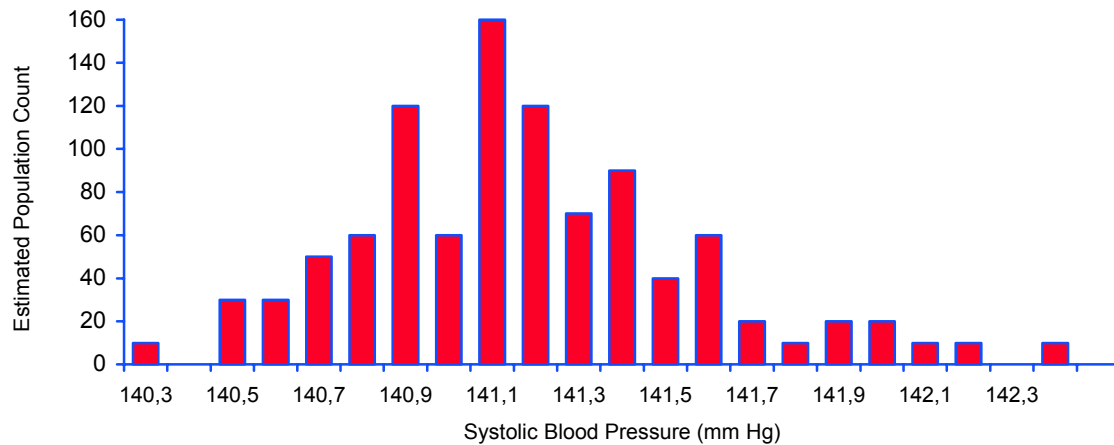
Source:Fictitious Survey of Working Men, Canada, 2002

There are a number of variations of the column chart. A grouped column chart has several variables grouped in bars side by side. There should be no more than three bars in a group. For example, the analyst might want to compare total revenue, total sales and net income over a period of time. The following is an example of a grouped column chart, where the side by side columns represent consecutive years and each group of columns represents the number of passengers visiting a given region by city of passengers' origin.

Distribution of Passengers' Origin
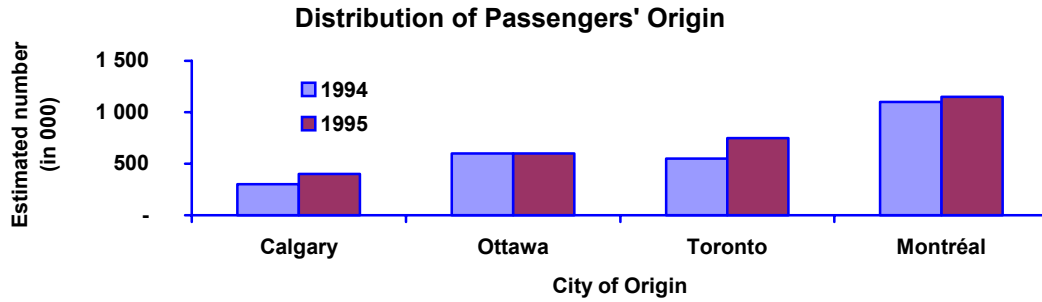
Source: Fictitious Survey on Domestic Tourism, Canada 1995,1996

A 100% (or stacked) column chart shows the proportion of the population falling into each category of a qualitative variable, where each column represents a different domain. The columns are all the same height and the proportion of most interest should be next to the baseline to facilitate easy comparison. The variable being compared across different domains should have no more than three categories – too many can make the stacked column chart almost unreadable. For this reason, in the following example, the variable satisfaction, which originally had five categories (very satisfied, satisfied, neutral, dissatisfied and very dissatisfied) was collapsed into three (satisfied, neutral and dissatisfied) and compared for five domains of interest (hours, staff, delivery, warranty, service):

Client Satisfaction, by Reason for Satisfaction
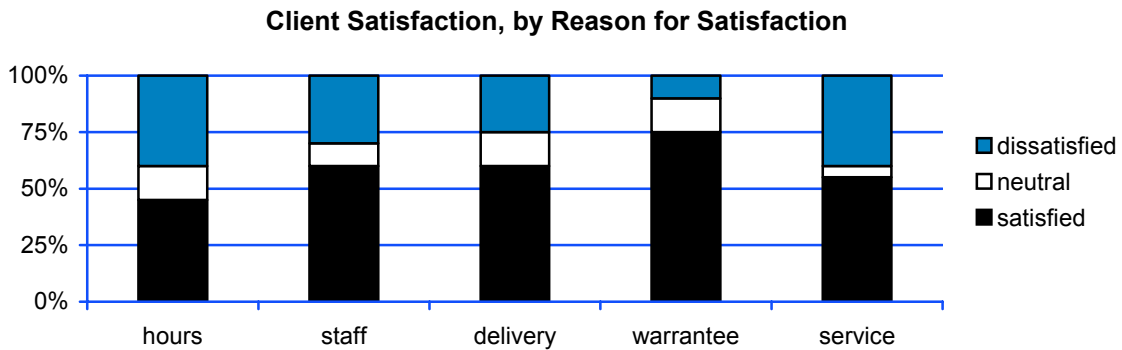
Source: Fictitious Client Satisfaction Survey, Place, Year

In general, column charts are used only for positive values (e.g., population counts, proportions, etc.). However, a deviation column chart portrays positive and negative values over a period of time. A negative value simply points down from the baseline instead of pointing up.

iii.   Bar charts

A bar chart is a sideways column chart. When preparing a bar chart, bars should be arranged in order of length (from the longest to the shortest, or vice versa).

If exact values are shown, the chart should be annotated (i.e., the exact value should be placed at the end of each bar). If these stub headings are lengthy, a bar chart may be easier to read and appear less cluttered than a column chart. There are many variations on the basic bar chart, corresponding to the different types of column charts (e.g., stacked, grouped, etc.).

The following is an example of a grouped bar chart:

Distribution of Passengers' Origin
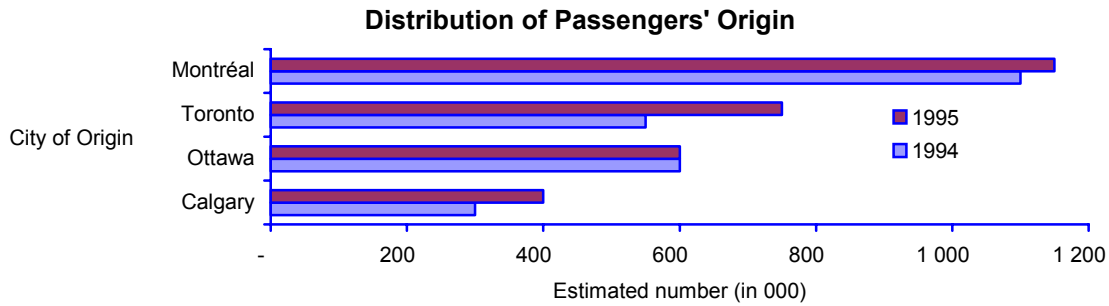
Source: Fictitious Survey on Domestic Tourism, Canada 1995,1996

iv.   Line charts

A line chart shows variation in the magnitude of a variable over a period of time (e.g., totals, means or proportions over time). Time (the explanatory variable) is placed on the horizontal axis. The range of values of the variable of interest is placed on the vertical axis. A point (i.e., a measure of magnitude) is plotted for this variable for each unit of time, and the points are connected in sequence. The lines can either be straight lines from point to point, or smooth curves. The following are examples of line charts:

Distribution of Systolic Blood Pressure, Canada 2002

Source:Fictitious Survey of Working Men, Canada, 2002

Consumer Price Index: All Items and Private Transportation
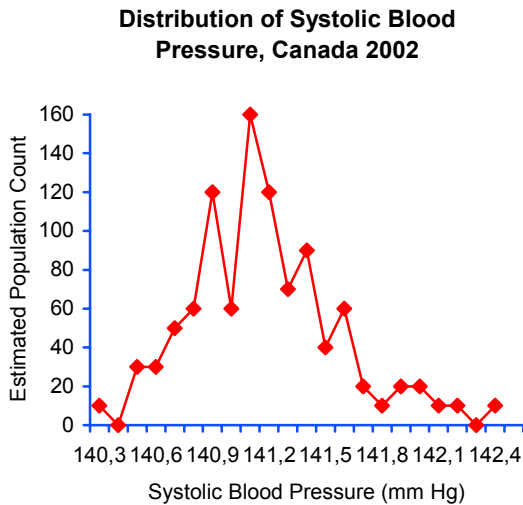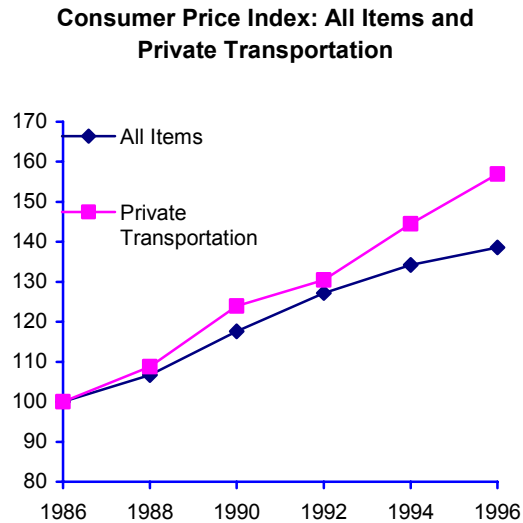
Line charts should be used to demonstrate trends or movement. For time series with a large number of points, line charts are preferable to column charts. For comparing several data series, line charts are the best way to highlight differences or similarities between groups. If there are obvious trends in the data, line charts give the user some predictive ability. Steady upward or downward trends, or obvious periodicity, allow the viewer to interpolate or extrapolate data.

Use consistent intervals for line charts. For example, do not use 1, 2, 5, 8 even if there are no data points for the other values. Instead use 1, 2, 3, 4, 5, 6, 7, 8. Also, when starting with a large number, or when there is a gap in the values of one of the axes, use a symbol to indicate the gap.

It is best not to compare too many series at once, since this can be confusing. The following is an example of a poor line chart:

Therapeutic Abortions, per 10,000 Child-bearing Aged Women, Canada and Provinces, 1981, 1993
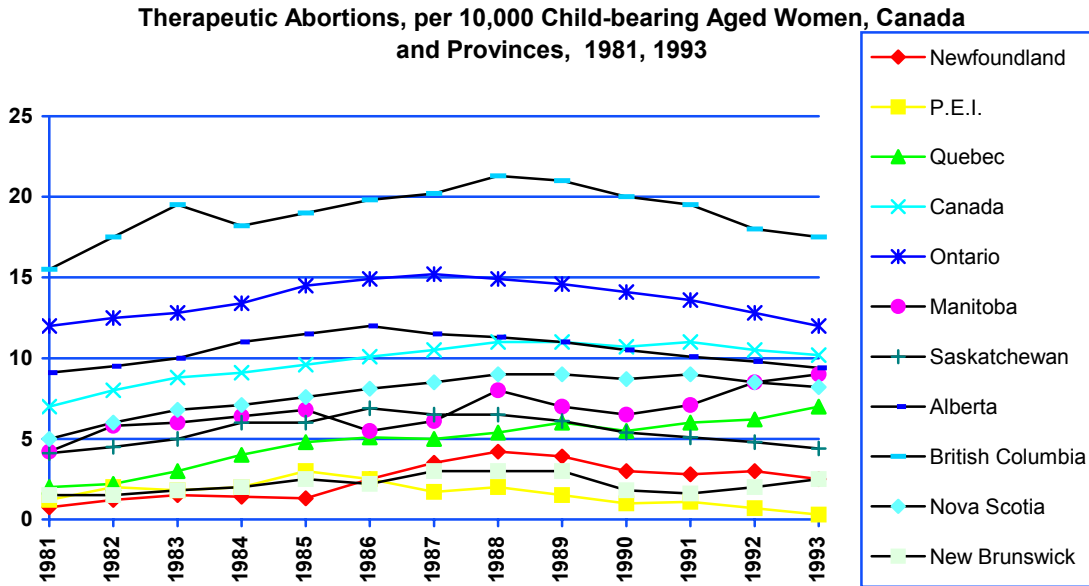
v.   Box plots

Summary statistics can also be depicted in a single summary graph: the box plot. A box-plot is used to study the distribution and the spread of the data. The box itself extends from the first quartile (i.e., the 25th percentile) to the third quartile (i.e., the 75th percentile) with a line at the median (i.e., the 50th percentile). The 'whiskers' or the endpoints of the lines attached to the box represent the minimum and maximum values. Some statistical packages will also display the mean and standard error of the mean (assuming SRS) on the box plot; neither one are displayed here.

Distribution of Sales Prices for Houses, June 2002
(Prices in 1,000's of Dollars)
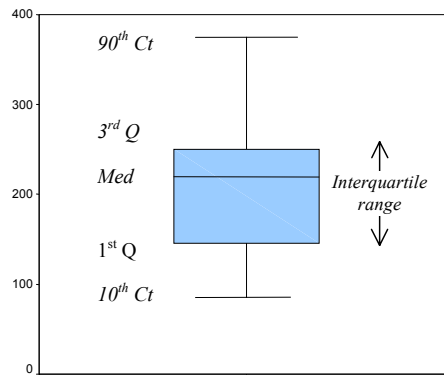
Source: Fictitious survey of houses sold in June 2002.

For a definition of the median, first quartile, third quartile and 10th and 90th percentile and how they are calculated, see Example 11.1 in the following section for simple data and sections 11.3.2.1 and 11.3.2.2 for complex data. For more information on box plots, see Tukey (1977).

11.3.1.2 Location: the Mean, the Median and the Mode

There are three common measures of location: the mean, the median and the mode. For statistical analysis, the mean is by far the most commonly used for quantitative data. *For quantitative data, the population mean for a census is simply the arithmetic average: the sum of all the values of a variable divided by the number of values.* To estimate the population mean from a simple random sample with 100% response rate, the usual estimator is:

$$\hat{\bar{Y}} = \frac{\sum_{i \in S_r} y_i}{n_r}$$

where y_i is the reported value for the ith responding unit, and n_r is the sample size.

The mean has several advantages compared to other measures of location. The first is that it is easy to calculate and understand. For many probability sample designs and for large samples in general, it has the desirable feature of being an unbiased estimator of the population mean. However, there are several disadvantages to using the mean. When considering integer values, such as the number of children per household, the mean may be a fraction. For example, the mean number of children per household may be 1.8. Also, the mean cannot be used as a measure of location for qualitative variables. Another disadvantage of the mean is that it can be strongly affected by extreme values (it moves in the direction of the extreme values). For example, in a survey of incomes, if a few members of the population have extremely high incomes, the population mean will be inflated by these individuals. So, if the user wants an estimate of the central value, he or she may prefer a measure of location that is less sensitive to skewed distributions or extreme values.

Another measure of location is the median. *The median is the middle value of a set of data arranged in numerical order (listed either from lowest to highest or highest to lowest).* When there are an even number of data points, the median is the mean of the middle two values. The median can be used for both quantitative and numerical ordinal data and is the best measure of central tendency for ordinal data.

The main advantage of the median is that it is less affected than the mean by extreme values. For example, in a survey of incomes, the median will be less affected by the presence of a few members with extremely high incomes. In fact, the median would be unchanged whether the highest income earner is a millionaire or a billionaire. In the case of sample survey data, the main disadvantage of the median is that it is usually more difficult to calculate its sampling variance and thus use it for inferential analysis.

The third measure of location is the mode. *The mode is the data value that occurs most frequently*. It is the most general of the three measures of central tendency. It can be applied to all types of data but is most appropriate for qualitative data and is the only measure of central tendency that is meaningful for nominal data. For example, if an agricultural census asks farmers to list the crop that occupies most of the land, and if 38 out of the 50 farmers in the population state that this crop is wheat, then wheat is the mode.

The main advantage of the mode is its simplicity – it can be determined from a table or graph of the frequency distribution of the data. However, the mode has a number of disadvantages. First, it may not be very descriptive of the data, since the most common category may not occur very often. This problem usually arises when there are many possible data values. For example, a census on inter-city migration may collect nominal data asking 2,000 people what city they moved from, and get 1,999 different answers, with two people sharing a common origin. This common city would be the mode, but it would not be very meaningful. This is why the mode is infrequently applied to quantitative data, where there are

usually many possible values. Also, unlike the median and the mean, the mode is not necessarily unique. It is possible for several categories to be tied for the most common ranking.

The natural question is 'Which measure should I use?' What is important is that the measure be meaningful, appropriate and meet the user's needs. In general, the mode should be used for nominal data, the median for numerical ordinal and skewed (i.e., not symmetrical about the mean) quantitative data, and the mean for quantitative, symmetrically distributed data. When dealing with quantitative data, the choice should depend on the distribution of the values of the variable. If the distribution is symmetric with just one peak (e.g., normally distributed) then the mode, median and mean are all the same. The choice in this case does not matter, but knowing that they are all the same informs the analyst that the data are symmetric. In the case of a skewed distribution, an estimate of all three measures provides an indicator of the amount of skewness.

Other measures of location are sometimes used in descriptive statistical analysis. *Quartiles are measures of position that, like the median, require ordering the data values first, but instead of separating the distribution into two parts (like the median), quartiles define four parts, each containing 25% of the ordered distribution. Percentiles also order data values, but divide the distribution into 100 even pieces.* The 10th, the 50th (the median) and the 90th percentiles are commonly used statistics.

Example 11.1: Measures of Location for a Census of Home Sales

Suppose that a survey conducts a census of all of the homes sold in the month of June in a particular city and obtains the following sales figures: (in thousands of dollars): 85, 235, 146, 295, 96, 250, 235, 205, 195 and 375. Sorted in order: 85, 96, 146, 195, 205, 235, 235, 250, 295 and 375.

Table 4: Estimated Measures of Location for Census of Home Sales

Measure of Location	Estimate
Mean	$211,700
Median	$220,000 (i.e., mean of $205,000 and $235,000)
Mode	$235,000
1st quartile (25th percentile)	$146,000 (i.e., smallest value greater than first 25% of values)
3rd quartile (75th quartile)	$250,000 (i.e., smallest value greater than first 75% of values)
90th percentile	$375,000 (i.e., smallest value greater than the first 90% of values)

11.3.1.3 The Spread

Spread refers to the variability or the dispersion of the data. **Chapter 7 - Estimation** presented one measure of spread: the variance, which is calculated as squared differences about the mean value. The variance of two different distributions were discussed: the population's and the estimator's. The population variance measures the spread of the distribution of all y_i in the population (where y is a variable of interest and y_i is the value for the ith unit). The sampling variance measures the spread of the distribution of estimates from different samples using the same sample design and estimator. In order to provide users with information on the quality of the sample survey, all sample estimates should be accompanied by some measure of sampling error (sampling variance, standard error, coefficient of variation or margin of error).

Besides the population variance, other measures of population spread include the range and interquartile range. The range is the difference between the largest and smallest values. Since this measure uses only two values of the distribution, it gives only a rough idea of the spread and is strongly affected by extreme values.

The *interquartile range* gives the range of the middle 50% of the data. It is the difference between the third and first quartile (or the 75th and 25th percentile). This measure is less sensitive to extreme values, thus; it gives a more useful measure of the spread than the simple range. The interquartile range can be used for all quantitative data.

Example 11.1 (continued): Range and Interquartile Range for a Census of Home Sales

For the census of home sales, the estimated range is $290,000 (i.e., $375,000 - $85,000) and the estimated interquartile range is $104,000 (i.e., $250,000 - $146,000).

To understand the importance of combining information about the spread with information of location, consider the following hypothetical case. An employee of a bank selling financial products for retirement is trying to identify the best location to open a new office. The target market has been identified to be workers around 45 years old, as they are not too far from retirement but are unlikely to have already started planning, and they have money available. There are two potential cities in which to open an office. A statistical report on a census of the cities shows that the mean age of workers is 45 years old in both. Without other information, the employee may want to open an office in both cities. But looking at the spread of the data shows that city A workers are all between 40 and 50 years old, and city B workers are between 15 and 65 years old, with two modal values at 20 and 60 years old. The picture is now quite different and it may be more beneficial for the bank to build an office in city A (more information would still be required, for instance knowing how many residents aged 40 to 50 live in each city).

11.3.2 Complex Survey Data

The same domain estimators as presented in **Chapter 7 - Estimation** and section 11.3.1 above can be used to estimate frequency distributions, means, totals and proportions for surveys with complex data. Estimates for order statistics such as the median and interquartile range are more complicated.

11.3.2.1 The Median

The population median is the value of the variable of interest below which half of the population distribution is found. For complex designs, estimating the population median is more complicated than for simple designs. For ordinal variables, estimated class sizes are needed. For continuous variables, data values are sorted in increasing order and estimation weights added until the sum reaches 50% of the estimated population size. The following example illustrates how to estimate the population median by estimating the population distribution using weighted counts.

Example 11.2: Estimated Median for a Stratified SRS (see example 7.6 from **Chapter 7 - Estimation**)

Recall that in this example, the sample has ten observations and two strata. The (sorted) sample data points are:

Table 5: Estimated Population Distribution of Incomes from a Stratified SRS

Stratum	Unit Id	Final Weight	Cumulative Weight	Cumulative relative weight	Type of Farm	Reported Income ($)
2	8	16.5	16.5	0.16	1	14,000
1	2	5.67	22.17	0.22	2	15,000
2	10	16.5	38.67	0.38	1	22,000
2	7	16.5	55.17	0.55	1	30,000
1	6	5.67	60.84	0.60	1	40,000
2	9	16.5	77.34	0.77	2	48,000
1	4	5.67	83.01	0.83	1	67,000
1	1	5.67	88.68	0.88	1	75,000
1	5	5.67	94.35	0.94	2	80,000
1	3	5.67	100.02	1.0	1	125,000

Type of Farm
1=Crop $(N_1=34, n_1=6)$
2=Livestock $(N_2=66, n_2=4)$

The estimated mean income for the entire population of farms is:

$$\hat{\bar{Y}} = \frac{\sum_{i \in S_r} w_i y_i}{\sum_{i \in S_r} w_i} = \frac{4,160,340}{100.02} = 41,595.1$$

Estimating the Median from the Estimated Distribution
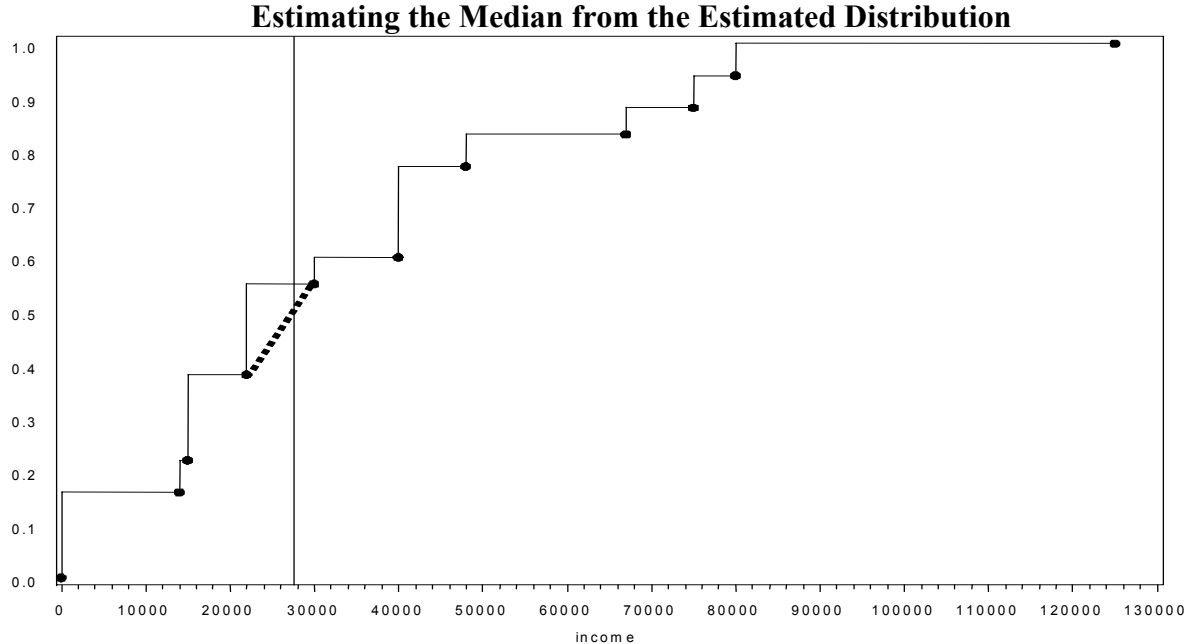
The estimated median is between $22,000 and $30,000 since the cumulated weights go from 0.38 to 0.55 for these 2 figures; to obtain a single value, a common practice is to do a linear interpolation between the points ($22 000, 0.38) and ($30 000, 0.55) to obtain the co-ordinates of the median point (Med, 0.50); this is illustrated above (the unweighted estimate of the median is $44,000).

$$M\hat{e}d = 22{,}000 + \frac{30{,}000 - 22{,}000}{0.55 - 0.38}(0.50 - 0.38) = 27{,}647 \; .$$

11.3.2.2 The Spread

To illustrate the concept of sampling variance, it is easiest to present the case of survey data from an SRS or stratified SRS without weight adjustments, as presented in **Chapter 7 - Estimation**. In practice, however, virtually all surveys have more complex data; even if the sample design is SRS or Systematic (SYS), a weight adjustment for nonresponse is usually applied, so the SRS or stratified SRS formulas do not apply.

The correct variance formula depends on the sample design and the point estimator (i.e., the estimator for the sampling variance of a mean depends on the estimator of the mean). Variance estimation for complex data rapidly becomes complicated. In order to correctly estimate the sampling error for a survey with complex data, a survey statistician familiar with this type of problem should be consulted. Simply running software – even statistical software – is not recommended, since oftentimes the software assumes SRS with no weight adjustments.

In order to estimate interquartile ranges for complex data, use the approach explained above for the median to estimate the 25th and 75th percentile.

11.3.2.2.1 Confidence Intervals in the Presence of Bias

So far, the discussion of estimation and analysis of survey data has assumed that there is no bias. **Chapter 3 - Introduction to Survey Design** listed the four sources of nonsampling error which can cause bias: coverage, measurement, nonresponse, processing errors. Bias can also be caused by the estimator: the analyst may prefer to use an estimator with small bias but good precision rather than an alternative unbiased estimator with poorer precision.

The total variation about the true value of a parameter, θ, is called the *Mean Square Error*:

$$MSE(t) = E(t - \theta)^2$$
$$= E(t - E(t))^2 + (E(t) - \theta)^2$$
$$= Var(t) + \big(Bias(t)\big)^2 .$$

Where t is the estimate of θ for a realised sample, $E(t)$ is the expected value, or the average estimate over all possible samples, and $Var(t)$ is the sampling variance of t.

When bias is present, $E(t) = \theta + B$. When there is no bias, $E(t) = \theta$, and the total variation about the true value, θ, is simply the sampling variance:

$$MSE(t) = E(t - \theta)^2$$
$$= E(t - E(t))^2 + (E(t) - \theta)^2$$
$$= Var(t).$$

Confidence intervals (previously discussed in **Chapter 7 - Estimation** and **Chapter 8 - Sample Size Determination and Allocation**) are commonly used to present results from probability surveys. Given an estimate t and its estimated standard error, $S\hat{E}(t) = \sqrt{V\hat{a}r(t)}$, a confidence interval can be constructed as follows:

$$(t - z \times S\hat{E}(t), \quad t + z \times S\hat{E}(t))$$

where z is a value corresponding to the level of confidence (e.g., z=1.96 for a 95% confidence interval) from a standard normal distribution table. This is the standard theory that is taught in undergraduate statistics classes. It applies to means, proportions, regression parameters, and many other statistics. Its theoretical foundation is the Central Limit Theorem in infinite populations; its practical limitation is that it requires a large enough sample for the asymptotic theory to apply.

An example of a 95% confidence interval is:

> *According to a recent survey, 15% of Ottawa residents attend religious services every week. The results, based on a sample of 1,345 residents, are considered accurate within plus or minus three percentage points 19 times out of 20.*

For unbiased estimators that have normal, or approximately normal, sampling distributions, a 95% confidence interval means that if the survey were repeated many times, about 19 times out of 20 (or 95% of the time), the confidence interval would cover the true population value.

Distribution of an Estimator, t, with and without Bias
B/SE(t)=1
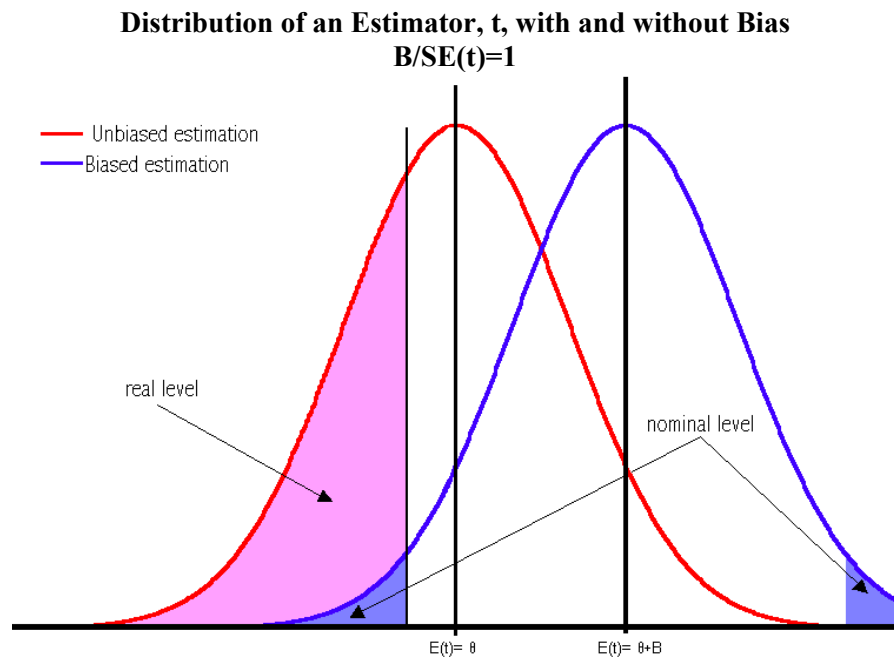
When bias is present there is usually no measure of *Bias(t)* – if there were, then $t + Bi\hat{a}s(t)$ would be an unbiased estimate of θ and a confidence interval could be constructed about this value – instead, a confidence interval is constructed about t using $S\hat{E}(t) = \sqrt{V\hat{a}r(t)}$ instead of $\sqrt{M\hat{S}E(t)}$.

The impact of bias on the confidence interval is especially felt in the coverage probability ('is this really 95%?'). In the presence of bias, if the usual estimator for a confidence interval is used then the confidence interval will be constructed about $E(t) = \theta+B$, yielding the blue curve on the right (the coverage probability is the white area under the blue curve). If the analyst is unaware that bias exists and thinks that he or she is estimating the red curve on the left, then the coverage probability for the confidence interval about θ (the white space under the red curve) is much less than expected and the confidence interval is asymmetric.

Särndal *et al*. (1992) give the following table of the effective coverage probability as a function of the relative bias, that is the ratio $B/\sqrt{Var(t)}$.

Table 6: Coverage Probability given $B/\sqrt{Var(t)}$.

Bias Ratio	Coverage probability
0.00	0.9500
0.05	0.9497
0.10	0.9489
0.30	0.9396
0.50	0.9210
1.00	0.8300

As stated already, in practice, *B* is unknown but the survey designer and the survey user must be aware of its existence and its detrimental effect.

Often the survey report or data analysis report includes tables of estimated standard errors or coefficients of variation, that is the ratio of the sampling error to the estimate (in percent), so that users can calculate their own confidence intervals and perform their own hypothesis tests. These tables should be accompanied by an explanation of how they can be used to perform analytical tests. Information on bias and its implications should also be presented.

11.4   Testing Hypotheses About a Population: Continuous Variables

Recall that sample surveys are typically conducted in order to study the characteristics of a population, build a database for analytical purposes or test a hypothesis. Most of the theory and methods that have been covered in this manual, so far, pertain to describing the population and its characteristics: How many men and women are there in the population? How many are smokers? What proportion of the population are low income families? What is the median household income?

This section focuses on testing hypotheses about the population: is the proportion of male smokers different from the proportion of female smokers? Is the proportion of low income families the same across all provinces? Does life expectancy vary by province?

11.4.1 Introduction: The Elements of a Test

Hypothesis testing is a procedure to verify whether or not the sample data support statements made about the population. A hypothesis is a statement, or theory, about the true population value of a characteristic. Hypothesis testing involves testing a *null hypothesis, H_o,* against an *alternative hypothesis, H_1*. For

example, in an experiment where a coin is tossed repeatedly, the null hypothesis might be H_o : *the coin is unbiased* and the alternative hypothesis is H_1 : *the coin is biased*.

Using data from a sample, the probability that the observed values are the chance result of sampling, assuming the null hypothesis is true, is calculated. If this probability turns out to be smaller than the *significance level* of the test, the null hypothesis is rejected.

There are four components to a hypothesis test: the *null* and *alternative hypotheses*, the *test statistic*, and the *significance level*. One could add a fifth element: a *conclusion*.

i.   The null hypothesis

The null hypothesis is a statement about a population parameter that the analyst wants to test and is denoted by H_o. Examples of null hypotheses might be:
-    there is no difference in the mean incomes from the two provinces, $H_O : \overline{Y}_1 = \overline{Y}_2$;

-    the proportion of smokers in the population is 40%, $H_O : P = .4$;

-    the mean age of the population is 38, $H_O : \overline{Y} = 38$.

ii.   The alternative hypothesis

This is the hypothesis against which the null hypothesis is tested and is often denoted by H_1 or H_A. The alternative hypothesis is often a statement about the population that is expected to be true. The alternative hypothesis can only be accepted if the null hypothesis cannot be supported by the data for a given level of significance. For example, alternative hypotheses to the null hypotheses above might be:
-    the mean incomes from the two provinces are different, $H_1 : \overline{Y}_1 \neq \overline{Y}_2$;

-    the proportion of smokers in the population is greater than 40%, $H_1 : P > .4$;

-    the mean age of the population is less than 38, $H_1 : \overline{Y} < 38$.

iii.   The test statistic

The test statistic is a value calculated from a sample (or samples) in order to test a hypothesis about the population from which the sample was drawn. The value of the test statistic depends on the data, the hypothesis being tested, the significance level and the estimator being used to estimate the parameter. Typically, the test statistic requires that the estimator be unbiased (or approximately unbiased) and the sampling distribution of the estimator be known. For example, a *z*-statistic is normally distributed, a chi-squared statistic has a chi-squared distribution and an *F*-statistic has a Fisher-Snedecor *F*-distribution.

iv.   The significance level

The only possible outcomes of a hypothesis test are *reject the null hypothesis* or *do not reject the null hypothesis*. Rejecting the null hypothesis does not always mean that it is false, just as failing to reject the null hypothesis does not mean that the null hypothesis is necessarily true. There are actually two types of false conclusions: concluding that the null hypothesis is false when it is actually true and concluding that the null hypothesis is true when it is actually false.

Table 7: Types of Error

		The null hypothesis is, in fact:	
		TRUE	FALSE
The test concludes that	TRUE		II
the null hypothesis is:	FALSE	I	

These two types of false conclusions are known as Type I errors and Type II errors, respectively. The significance level of a test, denoted by α, is the accepted risk of committing a Type I error, in other words, rejecting a true null hypothesis. For example, $\alpha = .05$ is commonly used. If less risk is acceptable, α can be set lower, say $\alpha = .01$. If more risk is allowable, $\alpha = .10$ may be used.

The Cambridge Dictionary of Statistics (Everitt, 1998) illustrates significance levels as follows: Suppose a coin is tossed 100 times and comes down heads every time. There is strong reason to suspect the coin of being biased, but there is the remote possibility that it is unbiased and just happened to fall that way. What is known is that the probability of a fair coin landing the same way 100 times out of 100 is very small: $2 \times (\frac{1}{2})^{100}$, or 1.6×10^{-30} (this is the value of the test statistic). Based on this evidence, the analyst can confidently reject the null hypothesis, *H_o: the coin is unbiased* in favour of the alternative hypothesis, *H_1: the coin is biased*, knowing that there is only a tiny probability that our conclusion is incorrect. Suppose, however, that the coin was only tossed 6 times and it came down heads every time. The probability of a fair coin landing this way is: $2 \times (\frac{1}{2})^{6}$, which is .031. While this is unlikely, it is not impossible. With a significance level of $\alpha = .05$, the analyst would reject the null hypothesis; but with a stricter significance level of $\alpha = .01$, the analyst would accept the null hypothesis.

There are two types of hypothesis tests: one-tailed and two-tailed tests. A test is one-tailed when the rejection region for the null hypothesis, expressed graphically, consists of one tail of the estimator's sampling distribution. (The rejection region is the range of values of the test statistic that would lead to rejecting the null hypothesis.) With a two-tailed test, the rejection region consists of both tails of the distribution. Usually two-tailed tests refer to normally distributed estimators. For example, the above alternative hypothesis that the mean incomes from the two provinces are different (e.g., $H_1 : \overline{Y}_1 \neq \overline{Y}_2$) would use a two-tailed test while the other two alternative hypotheses would use one-tailed tests.

11.4.2 Simple Survey Data

The material covered in this section is usually the topic of undergraduate statistics courses; most of the details and complications will be skipped on purpose. The interested reader is referred to any elementary textbook (e.g., Snedecor and Cochran, 1989, Wonnacott and Wonnacott, 1977).

11.4.2.1 Testing for a Single Mean

Given a data set that has been obtained by a simple random sample scheme from a population, the estimated population mean, $\hat{\overline{Y}}$, is unbiased and (with a large enough sample) almost normally distributed with mean, $\overline{Y}$, and estimated standard error, $S\hat{E}(\hat{\overline{Y}})$. If an analyst wishes to test the hypothesis that the value of $\overline{Y}$ is k (i.e., $H_O : \overline{Y} = k$), the following test statistic can be used:

$$z = \frac{\hat{\bar{Y}} - k}{S\hat{E}(\hat{\bar{Y}})}$$

This test statistic is called a z-statistic since if H_o is true, then z has an approximately standard normal distribution with mean equal to 0 and standard error equal to 1. Note that this is the same z-statistic that is used to construct confidence intervals about the mean (see section 7.3.2.2).

To choose the level of significance for the test, the analyst uses the known probability of z lying within a certain number of standard errors of its mean. For example, it is known that 5% of the z-values are larger in magnitude than 1.96. So, to construct a two-tailed test (e.g., $H_1 : \bar{Y} \neq k$) using a z-statistic with $\alpha = 0.05$, the rejection region would be values of z that are less than -1.96 or greater than 1.96. In the case of a one-tailed test (e.g., $H_1 : \bar{Y} > k$) to construct a test with $\alpha = 0.05$, the rejection region would be values of z that are greater than 1.65.

Note that for large samples it is often reasonable to assume that $\hat{\bar{Y}}$ follows a normal distribution. This is because of the Central Limit Theorem which states that, under certain conditions, the distribution of a sample mean approaches the normal distribution as the sample size increases.

Example 11.3: Testing a Single Mean from an SRS

Suppose a statistical agency conducts a health survey and collects the data using a probability sample. The agency wishes to test the hypothesis that the population is overweight, which is defined as the mean weight of the population being greater than 100 kg. The usual estimator for the population mean is known to be unbiased and normally distributed, so a z-statistic is used with a significance level of $\alpha = 5\%$. Since a one-tailed test is appropriate, in order to be 95% certain when rejecting the null hypothesis, the rejection region consists of all z-values that are greater than 1.65.

The hypothesis test is:

$$\begin{cases} H_0 : \bar{Y} \leq 100kg \\ H_1 : \bar{Y} > 100kg \end{cases}$$

The test statistic is:

$$z = \frac{\hat{\bar{Y}} - 100}{S\hat{E}(\hat{\bar{Y}})}$$

If the survey estimates are $\hat{\bar{Y}} = 102.1$ and $S\hat{E}(\hat{\bar{Y}}) = 1.5$, then:

$$z = \frac{102.1 - 100}{1.5} = \frac{2.1}{1.5} = 1.4 .$$

Since 1.4 is less than 1.645, it does not lie in the rejection region. Therefore, there is not enough evidence to reject the null hypothesis.

11.4.2.2 Comparing Two (Sub-)population Means

The approach to the test on one mean can readily be extended to two means: the difference between two groups is of interest, or perhaps, the same group measured at two points in time. Now, it is assumed that a sample was drawn from each group, that the samples are independent and that each sample is large enough to justify the application of the Central Limit Theorem.

Now, the first group has unknown mean $\overline{Y}_1$ and the second group has unknown mean $\overline{Y}_2$; if the null hypothesis is true, these unknown means are equal. Thus, their difference is zero and their estimates should be quite close to one another. Any large observed difference between the estimates must be either because the samples are unfortunately bad (but there is no good reason for that), or because H_0 is false. Following this rationale, the test can be laid out as:

$$\begin{cases} H_0 : \overline{Y}_1 = \overline{Y}_2 \\ H_1 : \overline{Y}_1 \neq \overline{Y}_2 \end{cases}$$

with the asymptotically normal test statistic:

$$z = \frac{\hat{\overline{Y}}_1 - \hat{\overline{Y}}_2}{\sqrt{V\hat{a}r(\hat{\overline{Y}}_1) + V\hat{a}r(\hat{\overline{Y}}_2)}} .$$

The level of the test is decided in advance, usually 5%. Since this is a two-tailed test, this corresponds to rejecting the null hypothesis if the test statistic lies outside (−1.96, 1.96). (Note that this test statistic is only correct if the two samples are independent.)

Example 11.4: Testing Two Means from an SRS

Suppose an analyst is interested in determining whether the people in one province weigh more, on average, than the people another province. A simple random sample was drawn in each province and the results are $\hat{\overline{Y}}_1 = 95$, $\hat{\overline{Y}}_2 = 105$, $S\hat{E}(\hat{\overline{Y}}_1) = 1.4$, $S\hat{E}(\hat{\overline{Y}}_2) = 2.2$. Then the test statistic is:

$$z = \frac{95 - 105}{\sqrt{1.4^2 + 2.2^2}} = \frac{-10}{\sqrt{6.80}} = -3.83$$

and the two groups are declared to be significantly different.

11.4.2.3 Comparing Many (sub-)population Means: the One-way ANOVA and Linear Regression Models

The natural extension of the above theory is to develop a test for the comparison of the means of many groups. With ANOVA (*an*alysis *of va*riance) no assumption is made about the relationship that could exist among the means; with *linear models*, a linear relationship among the means is hypothesised. *Linear models* fall in a class of statistical techniques used to determine if a response variable is linearly related to one or more explanatory variables. A key characteristic of linear models is that the effects of the various explanatory variables are additive.

11.4.2.3.1 Analysis of Variance (ANOVA)

ANOVA is used to assess the effects of one or more qualitative variables (called factors) on a continuous response variable. The differences between means are tested by investigating the variability in a set of observations to determine if the variability is random, or if it can be attributed to the factor(s).

The simplest ANOVA involves a one-way design in which a sample is drawn from each of the k different groups of a single factor (i.e., k different means are compared and the null hypothesis is that they are all equal). For example, the analyst might want to test the null hypothesis that there is no difference in mean incomes for ten provinces:

$$H_O : \overline{Y}_1 = \overline{Y}_2 = \overline{Y}_3 = \overline{Y}_4 = \overline{Y}_5 = \overline{Y}_6 = \overline{Y}_7 = \overline{Y}_8 = \overline{Y}_9 = \overline{Y}_{10}.$$

The mathematical expression for the ANOVA model has the following form:

$$y_{gi} = \gamma_0 + \gamma_g + \varepsilon_i$$

where y_{gi} is the value of the response variable, income, for the ith unit of the gth province; γ_0 is the mean income across all provinces; γ_g is the difference between province g's mean income and the national income; if all means are equal, $\Sigma\gamma_g = 0$; finally, ε_i is assumed to be a random error variable with mean 0 and variance σ^2.

The total variation in the population is divided into variation due to the differences between the k groups and variation due to differences between subjects within the same group:

$$\sum_g \sum_i (y_{gi} - \overline{\overline{Y}})^2 = \sum_g N_g (\overline{Y}_g - \overline{\overline{Y}})^2 + \sum_g \sum_i \left(y_{gi} - \overline{Y}_g\right)^2$$

where N_g is the number of units in group g, $\overline{Y}$ is the mean of group g and $\overline{\overline{Y}}$ is the overall mean.

If independent random samples have been drawn from g normally distributed populations, then this variation can be estimated as follows:

$$\sum_g \sum_{i \in S} (y_{gi} - \overline{\overline{y}})^2 = \sum_g n_g (\overline{y}_g - \overline{\overline{y}})^2 + \sum_g \sum_{i \in S} \left(y_{gi} - \overline{y}_g\right)^2$$

$$SS(total) = SS(Model) + SS(Residual)$$

where n_g is the number of sampled units in group g, $\overline{y}_g$ is the sample mean of group g, $\overline{\overline{y}}$ is the overall sample mean and SS stands for 'sums of squares'.

If the k sample means are all the same, they are also equal to the overall mean $\overline{\overline{y}}$. Then, within the limits of random variation, the between group variance, namely:

$$MS(Model) = \frac{SS(Model)}{g-1}$$

should be close to zero.

This can be assessed using an *F*-test built as follows:

$$
\begin{cases} H_0 : \gamma_g = 0, \forall g \\ H_1 : \gamma_j \neq 0, \text{for some } j \end{cases} \equiv \begin{cases} H_0 : \overline{Y}_1 = \cdots = \overline{Y}_{10} \\ H_1 : \overline{Y}_j \neq \overline{Y}_k, \text{for some } j, k \end{cases}
$$

with the test statistic

$$
F = \frac{MS(Model)}{MS(Residual)} = \frac{SS(Model)\big/(g-1)}{SS(Residual)\big/g(n_g-1)} \sim F_{g-1; g(n_g-1)}
$$

This test statistic has a Fisher-Snedecor *F*-distribution with (*g-1*) and $g(n_g\text{-}1)$ degrees of freedom. The critical values are read off '*F* tables' with the appropriate level α and degrees of freedom. The test will find a significant difference among the means if the calculated *F* statistic is large enough, that is, larger than the tabulated critical value.

The case described here is for the simplest sample design: assuming equal size samples in each group and simple random sampling in each group. This is not typical situation of large scale surveys, and need not be efficient in practical applications of experimental designs.

For more information on ANOVA, see any introductory statistics book (e.g., Lohr, 1999, Wonnacott and Wonnacott, 1977), or books on experimental designs (Box, Hunter, Hunter, 1978).

11.4.2.3.2 Linear Regression

Linear regression is probably the best known linear model. Whereas ANOVA is used to determine if one group mean is significantly different from the rest, regression is used to identify or model the relationship among the different group means. Another application of linear regression is to make predictions or forecasts of the response variable for values of the known related explanatory variables. In linear regression, the response variable is usually a continuous variable (e.g., age, weight, height) and the explanatory variables are either qualitative or quantitative. When only one explanatory variable is used, the regression is called *simple*, when several are used, the regression is called *multiple*.

For example, suppose that a survey collecting weight and height data has been conducted and the analyst is interested in how these two variables are related. From the following graph of the data, there seems to be a linear relationship between the two variables.

The mathematical model for this relationship has the following form:

$$
y_i = \beta_0 + \beta_1 x_i + \varepsilon_i
$$

where y_i is the value of the continuous response variable, weight, for the ith unit; x_i is the value of the explanatory variable, height, for the ith unit; β_0 is the y-intercept (the value of *y* when x_i=0); β_1 is the slope of the line (the change in y_i for one unit increase in x_i). ε_i is assumed to be a random error variable with mean 0 and variance σ^2. In other words, it is assumed that y_i is approximately linearly related to x_i and that observed values of y_i deviate above and below this line by a random amount, ε_i. β_0 and β_1 are unknown parameters and are estimated from the sample data. To determine whether or not the two

variables are linearly related, confidence intervals can be created for β_1 and hypothesis tests about its true value can be performed.

Weight by Height
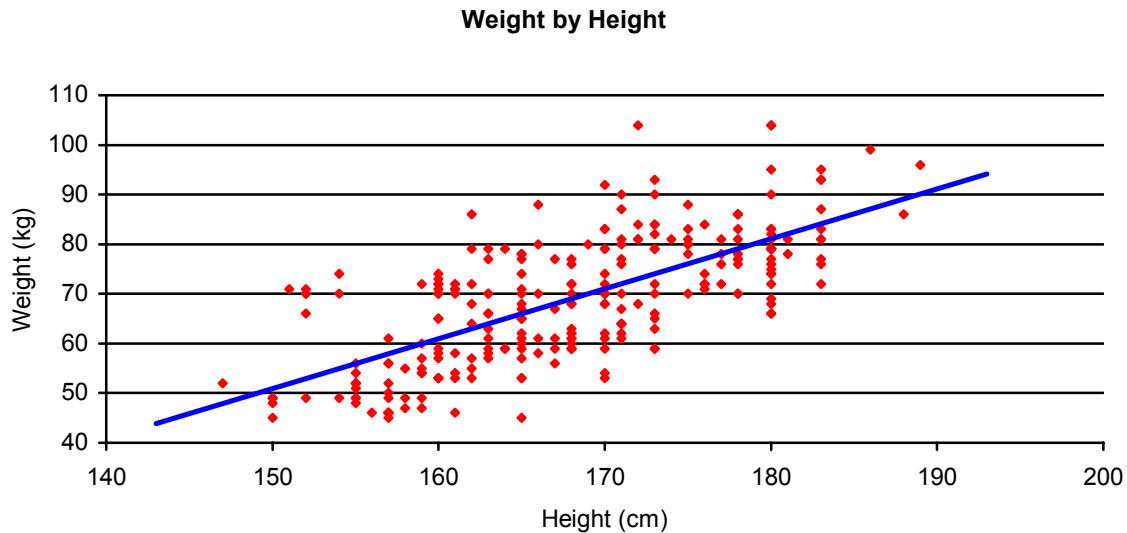
The parameter estimates can be computed from the observed data (here, assuming simple random sampling) as:

$$\hat{\beta}_1 = \frac{\sum (x_i - \bar{x})(y_i - \bar{y})}{\sum (x_i - \bar{x})^2}, \quad \hat{\beta}_0 = \bar{y} - \hat{\beta}_1 \bar{x}.$$

Of course, sampling errors for these estimates can be obtained as well. The test for the significance of the relationship is the test on β_1; the relationship is significant if the line is not horizontal, that is $\beta_1 \neq 0$. The null and alternative hypotheses are:

$$\begin{cases} H_0 : \beta_1 = 0 \\ H_1 : \beta_1 \neq 0 \end{cases}$$

the test statistic is the familiar z:

$$z = \frac{\hat{\beta}_1}{S\hat{E}(\hat{\beta}_1)}$$

which has a standard normal distribution under the usual large sample assumptions. The decision criterion is identical to that seen earlier, namely reject H_0 if values of z lie in the rejection region for the chosen level α.

Example 11.5: Linear Regression for Height and Weight Data Collected from an SRS

Suppose that the height and weight data above were collected from an SRS and that the following estimates were calculated:

<div align="center">

Table 8: Estimated Values for B_0, B_1

	Estimate	SE(Estimate)	z
$\hat{\beta}_0$	-90.88	7.66	
$\hat{\beta}_1$	0.95	0.04	21.09

</div>

The analyst would conclude that there is a significant relationship between the weight and height of people in the population.

Regression is also used by surveys during estimation or imputation to improve the quality of the estimates (see **Chapter 7 - Estimation** and **Chapter 10 - Processing**). For more information on regression analysis and how to calculate β_0 and β_1, see Draper and Smith (1981).

11.4.3 The Case of Complex Survey Data

11.4.3.1 Testing for a Single Mean

The test for a mean can be readily extended to the case of complex survey data. In effect, the large sample requirements for the test are covered by the finite population version of the Central Limit Theorem. The correct estimation of the sampling error of the estimator of the mean (that is, accounting for stratification and clustering of the data) replaces the traditional requirements that the data be independent and identically distributed of the traditional requirements.

11.4.3.2 Comparing Many Sub-population Means: Adapting the ANOVA and Regression

ANOVA and regression models can be applied to populations and inferential analyses can be made when samples with complex survey designs are drawn from those populations. Few books devote space to the estimation and testing of the parameters of ANOVA and linear regression models under complex designs, those who do regroup them under the umbrella of linear models and treat both at once.

The theoretical interest and difficulties are beyond the scope of this manual. By now, the reader should be fully aware that ordinary statistical packages will not correctly account for the eventual complexities of the design of interest, and would probably yield misleading results. More can be found in Chapter 8 of Thompson, 1992, Chapter 7 of Särndal et al., 1992, and in Chapter 8 of Lehtonen and Pahkinen, 1995.

11.5   Testing Hypotheses About a Population: Discrete Variables

The previous section 11.4 discussed testing hypotheses using continuous variables. Often, analysis is performed on categorical data (e.g., analysis of counts for different categories). For example, in the joint distribution presented in Table 3, the analyst may want to test if the proportion in the population of office workers with low blood pressure is different from the proportion of manual workers with low blood pressure.

11.5.1 Tests of Independence and Tests of Homogeneity with Simple Survey Data

The relationships among discrete variables in a population – particularly discrete variables with a small number of distinct values – are often examined and tested through the use of contingency tables of counts and proportions.

11.5.1.1 Testing for Independence

In the case of a two-way *contingency table*, it is often of interest to determine whether two characteristics defining the rows and the columns of the table are independent. Let variable *A*, with *r* different values, be the characteristic defining the rows of the table and let variable *B*, with *c* different values, be the characteristic defining the columns. The observed proportions (or counts) from the sample are displayed in an *r×c* table with the value in the ith row and the jth column being the proportion (or number) of individuals who simultaneously have value *i* for variable *A* and value *j* for variable *B*.

Table 9: Sample Counts in a Two-Way Contingency Table with r Rows and c Columns

Variable A	Variable B				Sample Sizes
	1	**2**	**…**	**C**	
1	n_{11}	n_{12}		N_{1c}	n_{1+}
2	n_{21}	n_{22}		N_{2c}	n_{2+}
3					
…					
r	n_{r1}	n_{r2}		n_{rc}	n_{r+}
	n_{+1}	n_{+2}		N_{+c}	n_{++}

Let p_{ij} represent the proportion of the population in cell (*i, j*) and p_{i+} and p_{+j} represent the proportions for the ith row and j^{th} column respectively. These may be estimated by $\hat{p}_{ij} = \dfrac{n_{ij}}{n_{++}}$, $\hat{p}_{i+} = \dfrac{n_{i+}}{n_{++}}$ and $\hat{p}_{+j} = \dfrac{n_{+j}}{n_{++}}$.

Then the hypothesis of independence to be tested can be written as:

$$\begin{cases} H_0 : p_{ij} = p_{i+}p_{+j}, & i = 1...r; j = 1...c \\ H_1 : p_{ij} \neq p_{i+}p_{+j}, & \text{for some } i \text{ and } j \end{cases}$$

Note that $\sum_i\sum_j p_{ij} = 1$, because every individual in the population under study falls into one and only one cell. For a data set that has been obtained by a simple random sample scheme from a population, common statistics for testing independence are Pearson's X^2

$$X^2 = n\sum_{i,j} \frac{\left(\hat{p}_{ij} - \hat{p}_{i+}\hat{p}_{+j}\right)^2}{\hat{p}_{i+}\hat{p}_{+j}},$$

and the likelihood ratio G^2

$$G^2 = 2n\sum_{i,j} \hat{p}_{ij} \ln\left(\frac{\hat{p}_{ij}}{\hat{p}_{i+}\hat{p}_{+j}}\right), \text{ with } \hat{p}_{ij} = \frac{n_{ij}}{n_{++}},$$

where n_{ij} is the sample count in cell (*i, j*) and $\hat{p}_{ij}$ is the corresponding sample proportion.

Under H_o and the other hypotheses about sampling, both statistics have an asymptotic chi-square distribution with $(r-1)(c-1)$ degrees of freedom. For a given level of significance α, the null hypothesis is rejected if X^2 (or G^2) is larger than the tabulated critical value $\chi^2_{(1-\alpha);(r-1)(c-1)}$.

Example 11.6: Test of Independence for Contingency Table Data from an SRS

You wish to examine whether the frequency of reading the daily paper (characteristic A, $i=1$ if *daily*, $i=2$ if *sometimes*, $i=3$ if *never*) is independent of one's political opinions (characteristic B, $j=1$ if *extreme right wing*, $j=2$ if *moderate right wing*, $j=3$ if *moderate left wing*, $j=4$ if *extreme left wing*). Suppose a simple random sample of $n=500$ is selected and the two characteristics are measured on all individuals. The survey results are:

Table 10: Survey Estimates

Reads the Paper…		Political Opinions				
		Left Wing		Right Wing		
		Extreme	Moderate	Moderate	Extreme	Total
Daily	Frequency	$n_{11} = 35$	50	36	6	127
	Proportion (%)	$\hat{p}_{11} = 7.0$	10.0	7.2	1.2	$\hat{p}_{1+} = 25.4$
Sometimes	Frequency	46	124	72	16	258
	Proportion (%)	9.2	24.8	14.40	3.2	51.6
Never	Frequency	28	50	33	4	115
	Proportion (%)	5.6	10.0	6.6	0.8	23.0
Total	Frequency	109	224	141	26	500
	Proportion (%)	$\hat{p}_{+1} = 21.8$	44.8	28.2	5.2	100.0

The results of the tests are

Table 11: Test Statistics

Statistic	Df	Value	p-value
Pearson's X^2	6	6.86	0.334
Likelihood ratio G^2	6	6.90	0.329

As the test values are well below the critical value for $\alpha=0.05$, $\chi^2_{0.95;6}= 12.59$, there is not enough statistical evidence to confirm that political opinions and frequency of reading a newspaper are linked. Alternatively, one can compare the probability of obtaining a result at least as extreme as the one obtained (for example, $\Pr(X^2 \geq 6.86) = 0.334$) to α, the level of the test (here, $\alpha = 0.05$). That probability is called a *p-value*. If the *p-value* is larger than α, then one can say, always supposing H_0 true, that what was observed was not extreme enough to reject the null hypothesis.

11.5.1.2 Testing for Homogeneity

Another simple case with discrete variables is testing for the homogeneity of proportions across populations, where an independent sample has been selected from each population. For example, the comparison across provinces of the proportion of individuals speaking neither, one, or both official languages, using a national survey with independent samples within each province would be a test of homogeneity.

In this situation, suppose that r populations are being compared. Let $p_{j|i}$ be the proportion of individuals in the ith population having the jth value of a c-category discrete variable. Since each individual in the ith population has to fall into one of the c categories, $\sum_j p_{j|i} = 1$. The hypothesis to be tested is

$$\begin{cases} H_0 : p_{j|1} = p_{j|2} = ... = p_{j|r}, & j = 1...c \\ H_1 : p_{j|i} \neq p_{j|k}, & \text{for some } i \text{ and } k \text{ and for at least one } j \end{cases}.$$

Suppose that independent simple random samples of sizes n_{i+}, $i=1, ..., r$, are chosen from each of the populations. Let n_{ij} be the number of individuals from the ith population with the jth value of the discrete variable. Obviously, $\sum_j n_{ij} = n_{i+}$, the sample size. The counts may be shown in a $r{\times}c$ table and the

proportion $p_{j|i}$ may be estimated by $\hat{p}_{j|i} = \dfrac{n_{ij}}{n_{i+}}$.

Pearson's statistic for testing homogeneity has the form:

$$X^2_{(H)} = n \sum_i^r \frac{n_{i+}}{n_{++}} \sum_j^c \frac{\left(\hat{p}_{j|i} - \hat{p}_{+j}\right)^2}{\hat{p}_{+j}}, \quad \text{where} \quad \hat{p}_{+j} = \frac{n_{+j}}{n_{++}}.$$

There is also a corresponding likelihood ratio statistic.

Straightforward calculations will show that $X^2_{(H)}$ can also be written as

$$X^2_{(H)} = n \sum_i^r \sum_j^c \frac{\left(\hat{p}_{ij} - \hat{p}_{i+}\hat{p}_{+j}\right)^2}{\hat{p}_{i+}\hat{p}_{+j}},$$

which has the same form as Pearson's X^2 statistic for testing independence. Also, under the null hypothesis of homogeneity, $X^2_{(H)}$ has an asymptotic Chi-square distribution with $(r-1)(c-1)$ degrees of freedom.

Example 11.6 (continued): Test of Homogeneity

Suppose that, in the political opinion survey examined above, instead of a simple random sample, four independent simple random samples had been taken, each from a different political opinion group. The test of homogeneity would be testing whether the frequency of reading the paper is the same for each political group.

11.5.1.3 Use of Log-Linear Models when Testing Hypotheses

Relationships among the proportions in the cells of a contingency table may often be expressed in the form of a log-linear model. For a two-way table, for example, a saturated log-linear model is in the form of a 2-factor ANOVA model with interaction:

$$\ln\left(p_{ij}\right) = \mu + \alpha_i + \beta_j + \left(\alpha\beta\right)_{ij}$$
$$\text{with} \quad \sum \alpha_i = \sum \beta_j = 0$$
$$\sum_i \left(\alpha\beta\right)_{ij} = \sum_j \left(\alpha\beta\right)_{ij} = 0$$

The earlier independence hypothesis is equivalent to testing for the absence of interaction and can be re-written as:

$$H_0 : \left(\alpha\beta\right)_{ij} = 0, \forall i, j.$$

Test statistics for many different hypotheses about parameters of log-linear models have been developed, as seen, for example, in Agresti (1996). The test statistic for testing independence (which is not given here) has an asymptotic Chi-square distribution with $(r\text{-}1)(c\text{-}1)$ degrees of freedom when the hypothesis is true.

11.5.2 Tests of Independence and Tests of Homogeneity with Complex Survey Data

Tests for properties such as independence or homogeneity of discrete variables in the population may also be carried out with data collected from a survey with a complex design. However, the tests used in the simple survey case are not applicable to the complex case without modification. First of all, a contingency table of sample counts or of simple proportions, ignoring the probabilities of selection, would not give an accurate picture of the association between the discrete variables determining the cells of the table. As well, the use, without modification, of the test statistics for independence and homogeneity given in 11.5.1.1, could lead to incorrect conclusions (since these test statistics no longer follow a central chi-square distribution when the hypothesis is true). In what follows, only the test for independence will be discussed, although similar approaches are available for the test of homogeneity.

Many different approaches have been proposed for accounting for a complex survey design when testing for independence. Thomas *et al*. (1996) describe more than 25 methods and give an extensive bibliography; they also compare the performance of these methods through a simulation study. Lohr (1999) gives a clear account of the main methods that have been included in computer software for analysis of data from complex surveys.

One class of approaches consists of adjustments to statistics similar to the Pearson and likelihood ratio statistics that were described above for data from simple survey designs. The starting step for these approaches is to modify the X^2 and G^2 test statistics defined in 11.5.1.1 by replacing $\hat{p}_{ij} = \dfrac{n_{ij}}{n_{++}}$ with

$$\hat{p}_{ij} = \frac{\sum\limits_{k \in S} w_k y_{kij}}{\sum\limits_{k \in S} w_k}$$

$$\text{where} \quad y_{kij} = \begin{cases} 1, & \text{if } y_k \text{ is in cell } (i,j) \\ 0, & \text{otherwise} \end{cases}$$

and w_k is the weight of the kth sampled individual.

This modification alone is not sufficient since, under H_0, these modified statistics, which we will denote by X^2_m and G^2_m do not follow a $\chi^2_{(r-1)(c-1)}$ distribution. Further adjustments are required, such as multiplying the X^2_m and G^2_m statistics by a constant to come up with statistics that may approximately follow a Chi-square distribution. Two well-known adjustments which have been implemented in some software packages are described below.

The first-order corrections to X^2_m and G^2_m (Rao and Scott, 1981, 1984) – often called '*first-order Rao-Scott corrections*' – consist of matching the asymptotic mean of the test statistics to the mean of a $\chi^2_{(r-1)(c-1)}$ distribution. The corrected statistics have the form $X^2_{RS} = \dfrac{X^2_m}{\hat{\delta}}$ and $G^2_{RS} = \dfrac{G^2_m}{\hat{\delta}}$, where $\hat{\delta}$ is a function of the design effects for estimating the cell proportions p_{ij} and the marginal proportions p_{i+} and p_{+j}. The correction thus requires the facility to do variance estimation for the estimated proportions involved in the formulas for X^2_m and G^2_m. X^2_{RS} and G^2_{RS} may then be compared to a $\chi^2_{(r-1)(c-1)}$ distribution.

The first-order corrections only adjust X^2_m and G^2_m so that their means are the same as that of a random variable with a $\chi^2_{(r-1)(c-1)}$ distribution. Rao and Scott (1981, 1984) have also proposed a second-order correction – often called '*Satterthwaite correction*'- that matches both the means and variance of the test statistic to the mean and variance of a χ^2 distribution. This second-order correction is somewhat more involved to compute than a first-order correction, but may perform better when the cell design effects vary considerably.

Example 11.7: Test of Independence for Data from a Stratified Cluster Sample
(Lohr, 1999, p. 332-334)

In a survey on youth and criminality (*Survey of Youth in Custody*) conducted by the U.S. Department of Justice in 1987, a sample of 2,621 juveniles and young adults residing in long-term state-operated juvenile institutions was taken. The sample is a stratified cluster sample of individuals in some 52 institutions selected with unequal probabilities. Interviews collected information on family background, criminal history, and drug and alcohol use. Using the survey data, the following table was built to investigate a possible relationship between age and whether or not the criminal offence was violent; the weighted proportions were found to be:

Table 12: Estimated Proportions (Using Weights)

		Age Class			
		≤ 15	16 or 17	≥ 18	
Violent Offence?	No	0.1698	0.2616	0.1275	0.5589
	Yes	0.1107	0.1851	0.1453	0.4411
		0.2805	0.4467	0.2728	1.0000

If the unequal selection probabilities and clustered design were ignored, the estimated proportions would be:

Table 13: Unweighted Proportions

		Age Class			
		≤ 15	16 or 17	≥ 18	
Violent Offence?	No	0.1389	0.2823	0.1328	0.5540
	Yes	0.0908	0.1969	0.1583	0.4460
		0.2297	0.4792	0.2911	1.0000

Clearly, the sample design has an effect on the estimates and cannot be dismissed or disregarded.

As well, the simple Pearson test statistic for independence defined in 11.5.1.1 would have a value of 34. Since the critical value for a $\chi^2_{(2-1)(3-1)}$ is 5.99 at the 5% level, the hypothesis of independence would be rejected. Now, clearly, young offenders are not scattered at random among the correctional facilities. In particular, all residents of Facility #31 are violent offenders. The effect of these clusterings can be seen after computing the design effects for the preceding table:

Table 14: Design Effects

		Age Class			
		≤ 15	16 or 17	≥ 18	
Violent Offence?	No	20.2	1.9	2.8	5.7
	Yes	5.3	8.4	2.4	5.7
		22.0	9.7	4.3	

The first-order adjusted test statistic has a value of $X^2_{RS} = 16.2$. The effect of the design is noticeable, although the conclusion remains the same.

11.6 Summary

Data analysis is one of the most crucial steps of a survey, since the quality of the analysis and how well it is communicated can substantially affect the usefulness of the whole survey. Data analysis should relate the survey results to the questions and issues identified during the first step of the survey.

Data analysis may be restricted to the survey data alone or it may involve comparing the survey results with results obtained from other surveys or data sources. Often, it consists of examining tables and charts of various summary measures such as frequency distributions, means and ranges. More sophisticated types of data analysis may also be performed – statistical inference may be applied in order to verify hypotheses or study the relationships between characteristics.

In order to make inferences about the population, the sample design must be properly accounted for. For simple survey data, standard formulas can be obtained from statistical textbooks. For more complex data, a specialist should be consulted.

Bibliography

Agresti, A. 1996. *An Introduction to Categorical Data Analysis.* John Wiley and Sons. New York.

Aldrich, J.H. and F.D. Nelson. 1984. *Linear probability, Logit and Probit Models.* Quantitative Applications in the Social Sciences Series. 07-045. Sage Publications, California.

Ardilly, P. 1994. *Les Techniques de sondage*. Editions Technip, Paris.

Bausch, T. and U. Bankhofer. 1992. Statistical Software Packages for PCs - A Market Survey. *Statistical Papers [formerly: Statistischen Hefte],* 33: 283-306.

Binder, D.A. 1984. Analysis of Categorical Data from Surveys with Complex Designs: Some Canadian Experiences. *Survey Methodology,* 10(2): 141-156.

Box, G.E.P., W.G. Hunter and J.S. Hunter. 1978. *Statistics for Experimenters*. John Wiley and Sons, New York.

Bouroche, J.-M. and G. Saporta. 1980. *L'Analyse des données*. Collection Que sais-je? 1854, Presses Universitaires de France, Paris.

Brogan, D.J. 1998. Pitfalls of Using Standard Statistical Software Packages for Sample Survey Data. *Encyclopedia of Biostatistics*. John Wiley and Sons, New York.

Brackstone, G. 1999. Managing Data Quality in a Statistical Agency. *Survey Methodology,* 25(2):139-149.

Carlson, B.L. 1998. Software for Statistical Analysis of Sample Survey Data. *Encyclopedia of Biostatistics*. John Wiley and Sons, New York.

Chambers, R.L. and C.J. Skinner. 2003. *Analysis of Survey Data.* John Wiley and Sons.

Cohen, S.B. 1997. An Evaluation of Alternative PC-Based Packages for the Analysis of Complex Survey Data. *The American Statistician,* 51: 285-292.

Draper, N.R. and H. Smith. 1981. *Applied Regression Analysis*. Second Edition. John Wiley and Sons, New York.

Dubois, J.-L. and D. Blaizeau. 1989. *Connaître les conditions de vie des ménages dans les pays en voie de développement : Analyser les résultats*. Collection Méthodologies. Ministère de la coopération et du développement, Paris.

Dufour, J. 1996. *Labour Force Survey Data Quality*. Statistics Canada. HSMD-96-002E/F.

Ehrenberg, A.S.C. 1982, A *Primer in Data Reduction – An Introductory Statistics Textbook*. John Wiley and Sons, Great Britain.

Everitt, B.S. 1998. *The Cambridge Dictionary of Statistics*. Cambridge University Press, United Kingdom.

Fellegi, I.P. 1980. Approximate Tests of Independence and Goodness of Fit Based on Stratified Multistage Samples. *Journal of the American Statistical Association,* 75: 261-268.

Fink, A. and J. Kosecoff. 1998. *How to Conduct Surveys: a Step-by-Step Guide*. Sage Publications, California.

Freund, J.E. and R.E. Walpole. 1987. *Mathematical Statistics*. Fourth edition. Prentice Hall, New Jersey.

Friendly, M. 1995. *Categorical Data Analysis with Graphics*. Statistical Consulting Service Short Course, York University, Toronto.

Hidiroglou, M.A. and J.N.K. Rao. 1987. Chi-squared Tests with Categorical Data from Complex Surveys, I and II. *Journal of Official Statistics,* 3: 117-140.

Holt, D., T. M. F. Smith and P. D. Winter. 1980. Regression Analysis of Data from Complex Surveys. *Journal of the Royal Statistical Society, Series A (General),* 143(4): 474-487.

Johnson, S., N.L. Kotz and C.B. Read. 1982. *Encyclopedia of Statistical Sciences*. John Wiley and Sons, Toronto.

Lee, E.S., R.N. Forthofer and R.J. Lorimor. 1989. *Analyzing Complex Survey Data.* Quantitative Applications in the Social Sciences Series. 07-071. Sage Publications, California.

Lehtonen, R. and E.J. Pahkinen. 1995. *Practical Methods for the Design and Analysis of Complex Surveys, Statistics in Practice*. John Wiley and Sons, New York.

Lepkowski, J. and J. Bowles. 1996. Sampling Error Software for Personal Computers. *The Survey Statistician,* 35:10-17.

Levy, P.S. and S. Lemeshow. 1999. *Sampling of Population: Methods and Applications*. Third edition. John Wiley and Sons, New York.

Lohr, S. 1999. *Sampling: Design and Analysis*. Duxbury Press, U.S.A.

Mendenhall, W. 1991. *Introduction to Probability and Statistics*. Eighth edition. PWS-Kent Press, Boston.

Nathan, G. and D. Holt. 1980. The Effect of Survey Design on Regression Analysis. *Journal of the Royal Statistical Society, Series B (Methodological),* 42(3): 377-386.

Porkess, R. 1991. *The Harper Collins Dictionary of Statistics.* Harper Collins, New York.

Rao, J.N.K. and A.J. Scott. 1981.The Analysis of Categorical Data from Complex Sample Surveys: Chi-Squared Tests for Goodness of Fit and Independence in Two-Way Tables (in Applications). *Journal of the American Statistical Association,* 76(374): 221-230.

Rao, J.N.K. and A.J. Scott. 1987. On Simple Adjustments to Chi-square Tests with Sample Survey Data. *Annals of Statistics,* 15: 385-397.

Rao, J.N.K., S. Kumar and G. Roberts. 1989. Analysis of Sample Survey Data Involving Categorical Response Variables: Methods and Software. *Survey Methodology,* 15(1): 161-186.

Särndal, C.E., B. Swensson and J. Wretman. 1992. *Model Assisted Survey Sampling*. Springer-Verlag, New York.

Skinner, C.K., D. Holt and T.M.F. Smith. 1989. *Analysis of Complex Surveys*. John Wiley and Sons, Chichester.

Snedecor, G. and W.G. Cochran. 1989, *Statistical Methods*. Eighth edition, Iowa State University Press, Ames Iowa.

Steel, R.G.D. and J.H. Torrie. 1980. *Principles and Procedures of Statistics – A Biometrical Approach.* Second edition. McGraw-Hill, U.S.A.

Thompson, S. K. 1992. *Sampling*, John Wiley and Sons, New York.

Tillé, Y. 2001. *Théorie des sondages : Échantillonnage et estimation en populations finies*. Dunod, Paris.

Tukey, J.W. 1977. *Exploratory Data Analysis*. Addison-Wesley Publishing Company, Reading, MA.

Wonnacott, T.H. and R.J. Wonnacott. 1977. *Introductory Statistics*. John Wiley and Sons, New York.

Wonnacott, T.H. and R.J. Wonnacott. 1991. *Statistique: Économie - gestion - sciences – médecine*. Economica, Paris.

Chapter 12 - Data Dissemination

12.0 Introduction

Most people ultimately judge the entire survey through the reports or data that are disseminated. This chapter discusses ways to release survey results to users, with a focus on one of the main methods of dissemination: a survey report with tables and charts.

A data quality evaluation should be performed in order to inform users of the quality of the survey so that they can judge for themselves the usefulness of the data. It may also provide valuable input to improve the survey (if repeated) or other surveys. This evaluation and its accompanying report should include a description of the survey methodology along with measures and sources of sampling and nonsampling error.

Before the data are released, they must be examined to ensure that the confidentiality of respondents is not violated. This process, called disclosure control, may result in the suppression or modification of some data.

The purpose of this chapter is to present different methods of dissemination, provide tips on how to organise a written report, and explain methods of disclosure control for tabular data and public-use microdata files.

12.1   Data Dissemination

Data dissemination is the release of the survey data to users through various media. Communicating survey results to users consists of reducing a large set of information into concise and important details while indicating the strengths and weaknesses of the data. When delivering the results to users, it is important to ensure that the information is accurate, complete, accessible, understandable, usable, timely, meets confidentiality requirements and is appropriately priced. Those responsible for dissemination should exploit technological advances in order to enable users to process the statistical information cost-effectively and efficiently in their own working environments.

In order to generate interest and to maintain – and be seen to maintain – a position of neutrality, release dates for survey results should be pre-announced. If unexpected circumstances arise, there should be a plan to explain the reasons for the delay.

Data can be disseminated through various media: a press release, a television or radio interview, a telephone or facsimile response to a special request, a paper publication, a microfiche, electronic media including the Internet or a public-use microdata file on a CD. (A public-use microdata file is an anonymised file containing individual records with each respondent's answers to the questionnaire.)

Several types of reports may be published including:
-   a main survey report which includes the methods as well as the main findings and tabulations;
-   a data analysis report;
-   a data quality evaluation report;
-   a report of the survey's methodology;
-   specialised reports on data processing procedures, data collection, methodological studies, etc.

The following section focuses on how to organise a survey report.

12.2   Main Survey Report

The main survey report is one of the most important products of the survey. It is usually the first report produced and released to users and therefore contains information on the goals and methodology of the survey, documentation on concepts and definitions, as well as the main findings and tabulations. Uniformity in the structure of the survey report helps users seek out and find specific information about the survey.

The statistical agency likely has specific policies, standards and guidelines concerning the content, organisation and appearance of these reports. Subject to these the following is a suggested structure for the survey report and is applicable in most situations.

i.   Title page

This item is required. Statistical agencies usually develop a standard layout including logos and numerical identification for printing controls.

ii.   Table of contents

This item is required. It helps the user to find the information needed.

iii.   List of tables and charts

This item is required. Many users look for a visual representation of the results for their own presentation or to compare with other sources.

iv.   Highlights or executive summary

This item is optional but highly recommended. An executive summary reveals the most important findings or highlights of the survey in no more than two or three pages. It is a quick reference for those who may not have time to study all the details of the main report, but who need to know the essentials of the survey findings. Sometimes, it gives a very brief description of the objectives of the survey, when and where it was conducted and the key topics covered. It should then describe, in no more than a short paragraph each, the most noteworthy findings, beginning with the more global results and going on to highlight some of the more specific or unexpected findings. Sometimes, it can be just a summary of the most important findings in point form. Highlights should be self-explanatory. Examples are: *The total area of field crops decreased 3% since 1986; Respondents have a growing concern toward telephone interviews. Most stated they would not provide financial information over the phone.*

v.   Introduction

The introduction should give background information relevant to the development of the survey, such as the history of the project, sponsors, study objectives, a short overview of the methodology and the purpose of the report. It may also give a very brief synopsis of what was done and what was learned, but this should be in general terms, since the detailed results will be given in the subsequent sections. It gives the general overview of the sections to come and the links between them.

vi. Objectives

This section is optional. For surveys with multiple clients or users covering a very wide range of topics, it is a good idea to have a section entirely dedicated to explaining the objectives of the survey. However, these details are usually covered in the introduction.

vii. Body

The body of the report is divided into several sections. One of the first sections should provide definitions of concepts and key variables (an appendix may contain more details) and explain the methodology of the survey, collection procedures, processing, etc. This is usually followed by survey results (including measures of quality, such as precision) and tabulations.

The body of the report is where all the details about the main conclusions are to be found. Each section presenting results should start with main results and findings followed by more detailed information. Ideas should be arranged logically in order of importance. Tables, charts, along with explanations of what the results mean and their significance all belong in the body of the report. One of the biggest challenges when writing a report is keeping the attention of the audience. To ensure that the important messages are read and understood by users, they should be ordered by level of importance. Also, information should be presented in the simplest language possible for the intended readership.

viii. Conclusions

This section presents a synopsis of the implications of the findings. Any appropriate conclusions or recommendations about necessary action may be given here. The conclusions have to be supported by appropriate analysis and consideration of the potential effects of sampling and non-sampling errors. While major decisions will undoubtedly be made by policy analysts and funding ministries or donor agencies, this section presents a unique opportunity for the persons closest to the survey to present their understanding of the implications of what has been learned.

ix. Recommendations

This section is optional. In technical reports, recommendations can be made to solve problems met during any activity of the survey. This is usually done for the benefit of other surveys that may encounter the same situation.

x. Bibliography/List of references

All references should be clearly identified.

xi. Contacts

This section is mandatory. For any survey, a clear and direct contact to someone knowledgeable about the project must be given to the users. A phone number, fax number, email address and mailing address should all be provided. Increasingly, reference is made to a website where information may be found.

xii. Appendices

The purpose of appendices is to give a brief but clear idea of topics not described in the body of the report or to provide essential details that would make the text too cumbersome. Appendices can contain: details

about the survey objectives and the population under study, the questionnaire, more details on the survey methodology, additional measures of data quality including the formula used to estimate the sampling variance, a description of statistical tests, etc. Sometimes, the procedures used to collect the data in the field are included (e.g., the data collection method, the training and supervision of field staff). Mention may be made of the hardware or software employed and about the development of the computer systems.

12.2.1 Guidelines for Writing

The choice of an appropriate form and style for the report depends heavily on the intended audience and the purpose of the report. Reports may be written for survey staff, other survey-takers, for subject matter and policy analysts, for political leaders or for the general public.

One commonly used and often effective structure for each section of the body of the report consists of an interesting question, a logical organisation of evidence used to answer the question and the answer.

Some guidelines for writing include:

i.   Concise, clear language

A good report conveys a number of specific messages but is not cluttered with unnecessary detail. While concise language is desirable, shorter is not always better and clarity should always take precedence. For example, *life insurance companies' assets and segregated longer-term, retirement-oriented investment asset funds* may be shorter, but *the assets of life insurance companies and their segregated funds (longer-term, retirement-oriented investment assets)* is definitely clearer.

ii.   The active versus the passive voice

Usually (and preferably) the subject responsible for the action expressed by the verb is mentioned first in the sentence, for example: *Manitoba and Alberta registered the largest provincial increases in cash receipts during the period.* This is the active voice and it gives the sentence action, conviction and a confidence not expressed by verbs in the passive voice. Compare this with the same sentence written in the passive voice: *The largest increases in cash receipts for the period were registered provincially in Manitoba and Alberta.*

iii.   Abbreviations and acronyms

Use abbreviations and acronyms sparingly and, when in doubt, spell them out. Do not assume that the reader knows what they mean. Write terms out in full at first mention, followed by the abbreviated form in parentheses, for example: *The Consumer Price Index (CPI)*. The abbreviation or acronym alone may then be used in the remainder of the text.

iv.   Consistent terminology

Terminology used in various elements of the report must be consistent. For example, if the title and text refer to *assets and liabilities,* the table or graph should not be labelled *balance sheet*. And, as explained in **Chapter 2 - Formulation of the Statement of Objectives**, it is helpful if the terminology is consistent with other surveys.

v.   Residual categories

Although residual categories are often large and noteworthy, the term *other* is vague and ambiguous. Where possible, define the category or identify its components rather than referring to it simply as *other*.

vi.   Dates

Ambiguous references to dates such as last year or last month should not be used. The specific year and month should be used in the first mention, for example: *The slump of almost 26% in domestic shipments in July 1993 looked large, but it was comparable to the 23% decline recorded in July 1992*.

vii.   Reference period

The reference period should be given immediately under the main descriptive title of each release and data announcement, for example: *Monthly Survey of Manufacturing, December 2002*. If the data are preliminary, this should be indicated in the reference period line to avoid repeating 'preliminary' throughout the text.

viii.   Keep ratios simple

It is acceptable to use one-half, one-third, one quarter, and one-fifth to express results. Beyond these, ratios are difficult to understand. Be consistent – do not mix ratios in the same sentence. Use whole numbers when possible: use descriptions such as *two out of three women compared to one out of three men...* Use simple ratios, e.g., *Women were twice as likely*...

ix.   Percentages

Put percentages in parentheses, e.g., *About two-thirds (66%) of lawyers and one-third of dentists (32%)...* Report whole percentages*, e.g., say 45% instead of 45.3%*, unless more detail is warranted and precise. Avoid including too many percentages in the same sentence or over-reporting categories. For example, instead of reporting results as *...definite yes (17%), probably yes (25%), probably no (27%), and definite no (14%)...* it may be simpler and clearer to report that *respondents were divided about evenly between yes (42%) and no (41%),* if the details are provided in a table.

x.   Too many numbers in the text confuse the reader and obscure the message

An example of confusing text is: *The national rate for total offences per 100,000 people rose steadily from 1979 to 1981 then recorded consecutive yearly decreases between 1982 and 1985. In 1986, however a 4.1% increase was recorded over 1985 followed by a 2.5% rise between 1986 and 1987. In 1988, a 1.2% decrease was recorded over 1987. Over the 1979-1988 period this rate rose 9.1%.*

xi.   Titles, headings and subheadings

The main title may include references to base years and dates, for example: *Real gross domestic product at factor cost by industry, July 1993 (preliminary)*. Subsequent subheadings should be used as guides or signposts that take the reader through the text, for example: *Goods-producing industries*. Subheadings that are too numerous, too long and laden with jargon lose their impact. They should provide information about what follows, not act simply as uninformative labels. Make each word, and each subheading, count.

xii.   Communication services

Many agencies can use the services of communications professionals who point out difficulties for intended readers and make suggestions to improve the text. These people can review the report or even help in preparing it before it is written. Editing as well as translation reviews are part of the services.

12.2.2 Tables

As explained in **Chapter 2 - Formulation of the Statement of Objectives**, tables are one of the major outputs of a survey. The tables should directly address the stated objective and the specific output requirements of the survey. Tables are used to illustrate or examine quantitative aspects of the data. They can quickly reveal relationships among several variables and allow for the direct comparison of amounts.

During analysis and before documentation of the results, the analyst should verify the estimates and tables produced. Are the results internally consistent? This means that marginal totals about the same variables in different tables should be the same. Sub-population counts should add up to the total population, etc. Are the totals in line with other sources?

The following guidelines should be followed when producing tables:

i.   Tables should be simple and show only the key information, generally to make just one point at a time. It is better to have two simple tables than one that is too complex.

ii.   The overall format, spacing, and the wording, placement and appearance of titles, row and column headings and other labelling should contribute to the clarity of the data in the tables and prevent misinterpretation.

iii.   The design should be clear, logical and consistent between tables.

iv.   Titles should be clear and succinct and abbreviations should be avoided.

v.   Headings should be presented to support the message of the analysis in a rational order and all units of measurement should be clearly stated.

vi.   As much as possible, tables should be designed such that, if photocopied, the copy is legible. Also, there should be enough information in the table (title, footnotes, etc.) that it does not lose its value when copied.

vii.   Data should be rounded to help the reader understand the precision of the estimates.

viii.   When the data come from a sample survey, estimates and their measures of precision should be generated using the final sample weights (i.e., the design weights which may be adjusted for nonresponse and auxiliary data). See **Chapter 7 - Estimation** for how to generate estimates using the sample weights.

12.2.3 Charts

Charts and diagrams are used to visually display data. They focus on relative patterns, shapes or distributions, and orders of magnitude. Good charts should complement the text and tables, not merely repeat information. They should be used to explain or support major points in the text. The text should refer to the charts and the charts should be placed next to the reference.

The presentation of charts and diagrams is also discussed in **Chapter 11 - Analysis of Survey Data**. Much the same basic set of rules applies to charts and diagrams as to tables. They should be kept simple and show only the key information, generally to make just one point at a time. They should not require detailed explanations. Charts should be used to convey an intuitive, visual interpretation of highlights or trends, and therefore should be clean and uncluttered. An attempt to convey too much information in a single chart or table may simply confuse the reader. When charts are used to illustrate points about the population, the final sample weights must be used for data from a sample survey.

Care should be taken not to mislead the reader. While charts are very effective in conveying information, they can be easily misused. Carelessly labelled axes, legends and titles, improper shading, distorted or non-uniform scales, etc., are common abuses. Three-dimensional presentations should generally be avoided but might be appropriate in some circumstances (e.g., a plot of a surface).

Use consistent intervals for line charts. For example, do not use 1, 2, 5, 8 even if there are no data points for the other values. Instead use 1, 2, 3, 4, 5, 6, 7, 8. Also, when starting with a large number, or when there is a gap in the values of one of the axes, use a symbol to indicate the gap.

12.3   Data Analysis Report

The main survey report includes some basic results and findings, but if more in-depth analysis is planned, a data analysis report, or reports, should be produced. Ultimately, the analytical activities should result in a written report that provides clear answers to the questions that initiated the survey. The data analysis report may be structured much like the main survey report presented in section 12.2. In the data analysis report, there should be a summary of the analytic methods, as well as a description and discussion of the possible effects of sampling and nonsampling errors, caveats and assumptions made on the results and the statistical significance of the results.

For details on methods of data analysis, see **Chapter 11 - Analysis of Survey Data**.

12.4   Data Quality Report

A data quality evaluation is an important step in any survey and should be documented in the main survey report or in a separate data quality report. ***The data quality evaluation refers to the process of evaluating the final product in light of the original objectives of the statistical activity, in terms of the data's accuracy or reliability***. Such information allows users to make more informed interpretation and use of the survey results. Users must be able to assess the degree to which errors in the data restrict their uses of the data, but few users are in a position to independently assess the accuracy of the data produced by a survey. Therefore, a statistical agency has a responsibility to perform the required data quality evaluations and to disseminate the results of such evaluations to its users in a timely and easy-to-use fashion. Data quality evaluations are also of benefit to the statistical agency. To the extent that errors can be traced to

specific steps in the survey process, such evaluations can be used to improve the quality of subsequent occasions of the survey and of other similar surveys.

The analyst should also consider using *certification methods*. *Certification* involves a thorough review of data quality indicators, various univariate and multivariate analyses and numerous comparative studies, comparing the survey results with alternate sources and historical time series. For example, all Canadian Census data undergo a rigorous quality assessment and critical review to determine their suitability and reliability for public release at specific levels of reporting geography. Suitability refers to the data meeting specific quality and confidentiality standards.

Documentation on data quality should integrate information on the survey methodology with indicators of data quality. The level of detail to be provided in the data quality documentation depends on the following factors:
- type of survey (census, sample, administrative data, etc.) and its frequency (one time or repeated);
- type of data collected;
- type of analysis performed;
- intended uses of the data (i.e., impact on policies, social and economic planning, etc.);
- the potential for error and its significance to the use of the data;
- intended use of the quality report (e.g., for general information, for future improvements, etc.);
- intended audience of the quality report;
- the medium of dissemination (i.e., publication, public use microdata file, etc.);
- the total budget of the program and the cost of the quality evaluation relative to the overall cost.

The following elements are a non-exhaustive list of items that can be included in a data quality document. This information should normally accompany the statistical product. If for some reason it is not possible to include this documentation, an explicit reference to the availability of such documentation on data quality should be made available.

i.   Note(s) to users (if applicable)

This item should be included if applicable. It may consist of highlights of information provided in one or more of the following sections, or particular explanations or warnings of which users should be aware.

ii.   Data sources and methodology

This subsection should cover:
- general methodology (differences between the target population and survey population, data sources, collection methodology, processing, estimation and validation);
- reference period;
- revisions, if applicable;
- adjustments, if applicable.

iii.   Concepts and variables measured

This subsection should cover key concepts, variables and classifications used as well as key indicators.

iv.   Data accuracy

There should be a statement on accuracy issues, including sample size and the types and sources of nonsampling error (e.g., nonresponse rates, imputation rates, etc.) by geographic region and characteristic.

v.   Comparability of data and related sources

If applicable, this subsection advises that data are or are not comparable over time and why (e.g., in case of a change in question wording).

vi.   Other quality indicators and assessments (if applicable)

For any analytical results, this subsection provides a summary of the analytic approach or methods, as well as a brief description and discussion of the possible effects of accuracy issues, assumptions and caveats on the results and their statistical significance. It also includes a description of other important potential sources of error, or of any events (for example, a strike) which likely influenced the accuracy, timeliness and interpretation or use of the data.

vii.   Appendices (if necessary)

12.5   Confidentiality and Disclosure Control

Most statistical agencies are required by law to protect the confidentiality of respondents' information. Confidentiality can be assured through measures such as:
- protecting questionnaires during data collection and when in transit;
- requiring that all employees swear an oath not to disclose confidential information;
- restricting access to buildings and servers with confidential information;
- implementing disclosure control methods.

For a statistical agency, protecting respondents' confidentiality is essential to maintaining the public's confidence and hence of obtaining good quality data and high response rates.

Disclosure control refers to those measures taken to protect disseminated data so that the confidentiality of respondents is not violated. It involves, for instance, suppressing cells in a table that may reveal confidential information about a specific respondent. Sometimes, applying disclosure control has a negative impact on the quality of the data since some data may have to be suppressed or modified in the process. The goal of disclosure control is to ensure that the confidentiality of the respondent is respected while preserving the usefulness of the data to the greatest extent possible.

12.5.1 Disclosure

There are two main types of disclosure that are of concern: identity disclosure and attribute disclosure. ***Identity disclosure occurs when an individual respondents (person, household, business, etc.) can be identified from the released data and confidential information is revealed as a result.*** This is more of an issue with microdata, where identifying a respondent's record almost certainly leads to revealing chracteristics of the respondent. ***Attribute disclosure occurs when it is possible from released data to reveal confidential information about a respondent.*** This is more of a problem with census or

administrative data, since the presence of sampling error helps to protect the results from disclosure. For example, a census may provide a narrow (accurate) range for the income of doctors in a certain area.

There are different types of disclosure with differing degrees of seriousness. The following definitions are not mutually exclusive:

i.   Oneself to him/herself

If a respondent is able to deduce the information he or she provided, but is the only one able to do so, then there is not a disclosure problem. However, there might be the perception of one since the respondent may feel that others can also deduce the information, even if this is not the case. For this reason, statistical agencies should try to avoid releasing results in a format that allows this to occur.

ii.   One to another

If someone else is able to deduce the information provided by a respondent. This is the most serious problem and the focus of disclosure control.

iii.   One through him/herself

This is a problem specific to surveys with multiple respondents connected to each other. For example, a survey about children may have a section for the parents, one for the teachers and one for the children. If a father recognises himself in a microdata file, he may be able to determine the answers provided by his children and their teachers.

iv.   Direct

This occurs when confidential information can be deduced by simply looking at a cell. A very simple example is a table that gives average incomes by occupation for a certain area. If there is only one person with an occupation in an area, his or her salary is the average. Note that if there are two, each person can use the average to deduce information about the other (a case of residual disclosure).

v.   Residual

Residual disclosure occurs if other information released or otherwise available allows the accurate estimation of suppressed information. For example, if one component of a total were suppressed, residual disclosure would occur because the missing component could be estimated by subtracting the other components from the total.

vi.   Exact

This occurs when an individual can deduce the exact value of the confidential information. The example given in direct disclosure above is an example of exact disclosure.

vii.   Approximate

This occurs if an individual cannot deduce the exact value of the confidential information but can determine an interval with very high probability of containing the confidential value. To be considered disclosure, the interval must be small enough to potentially cause prejudicial actions against the respondent. For example, if a manufacturer dominates the total production of a certain product (say, over

95%), releasing an estimate of the total production for that product gives an approximate estimate of the production for that manufacturer.

12.5.2 Techniques to Avoid Disclosure

Two approaches used to protect the confidentiality of data are restricted access methods and restricted data methods. Restricted access methods prevent or restrict access to the data, for example, by limiting access to a site or server to authorised staff, using password-protected files and encryption, sharing data under the terms of a license agreement, etc. These methods will not be covered here. Restricted data methods are methods that protect the data themselves. Restricted data methods are classified into data reduction methods (i.e., reducing the information released) and data perturbation methods (i.e., modifying the data).

The techniques developed to avoid disclosure vary with the statistical product – the three most common products being tables of frequencies (counts or weighted counts), tables of magnitude (for quantitative data) and public-use microdata files. The techniques will be described below.

12.5.2.1 Protection of Tabular Data

The cells in a table of magnitude give numeric (usually non-negative) values such as means or totals of dollar values, or number of employees. Such tables present a disclosure risk especially when the data come from a business survey. This is because the skewed nature of business data may cause some cells to be dominated by one or two large businesses, and releasing these cells' values may yield a reasonably good estimate of the values of these large contributors. The first step is therefore the identification of sensitive cells (i.e., cells at risk of disclosure). Many rules have been developed to identify sensitive cells. Here are a few examples of rules that define a cell in a table of magnitude as sensitive:

i.   Cut-off rules

There must be a minimum number of respondents in a cell (e.g., at least three respondents). Under this limit, the cell is declared sensitive.

ii.   The (n,k) rule

A cell is declared to be sensitive if too much of the cell's total is concentrated in too few respondents. More precisely, if the largest *n* respondents account for at least *k*% of the total cell value. For example, the (2,90) rule states that if the largest two respondents make up more than 90% or more of the cell total, then the cell is sensitive.

iii.   The p-percentage rule

A cell is sensitive if publishing it would enable someone to estimate the contribution of another respondent to within *p*-percent of its value. The greatest threat is posed when the second largest respondent in the cell attempts to estimate the contribution of the largest respondent by subtracting its own value from the published total. Assuming that the cell comprises m respondents, disclosure is equivalent to the condition that: $x_3 + ... + x_m < (p/100)x_1$. Where x_1 is the value of the largest contributor, x_3 is the value of the third largest contributor, etc.

The (*n,k*) rule and the *p*-percent rules are two examples of rules that are used to identify cases of dominance by one or two large units. These are not the only choices of rules available – there are others. At Statistics Canada, the Duffett rules are sometimes used. Duffett rules are sets of (*n,k*) rules, where the parameters depend on the number of units in the cell. Whatever the rule or rules used, it is generally best to keep the values of their parameters confidential.

The cells in a frequency table give counts or estimated counts of units sharing the characteristics of the cell. Frequency tables can present a disclosure risk when they reveal characteristics of a respondent. As mentioned above, the risk of attribute disclosure is greatest with census and administrative data, although sample data may present disclosure risks when sample units' survey membership becomes known (e.g., to other household members). Three potential problems are full cells, zero cells and low frequency cells.

Full cells occur when all the respondents are in a single response category, such as when only one cell inside a row or column is non-zero. Full cells can present a disclosure risk when they allow confidential information to be obtained about a sub-population. For example, a table may reveal that all the support staff in an institution have the education level of 'high school diploma'. If a table of income distribution puts them all in the '$20,000-29,999' range, then information about their salary is disclosed.

Zero cells – i.e., cells with no units or where the total is zero – may also present a disclosure risk for reasons similar to those of full cells (which they are responsible for causing). For example, the table above may reveal that support staff are in only two education categories: 'did not complete school' and 'high school diploma'. A table of income distribution for a plant that has employees in three income categories: '$20,000-29,999', '$30,000-39,999' and '$90,000-99,999' may provide a good estimate of the plant engineers' salaries (the last range).

Low frequency cells are cells with few respondents, e.g., less than 3 or 5. Low frequency cells may present a disclosure risk when they allow the identification of their respondents and reveal some of their characteristics. For example, a frequency table for a census in a small area that shows two single-parent households headed by widowed men may identify those households. Any additional characteristics revealed about the cell's members may constitute attribute disclosure. Another problem with small cells is that they can give the impression that disclosure has occurred even when that is not the case. For example, revealing that there was only one new case of colon cancer detected in Prince Edward Island in 2001 does not reveal anything about the person concerned.

There are several ways to handle sensitive cells.

1.   Data Reduction methods include:

i.   Cell collapsing

Cell collapsing groups categories to increase the number of entries per cell (e.g., reduce the level of industrial detail provided). This simple method can reduce much information by suppressing details in the data.

ii.   Cell suppression

When sensitive cells are suppressed, usually non-sensitive cells must also be suppressed, so that the sensitive cell values cannot be derived from the marginal total. These other cells are called *complementary suppression cells*, and many rules exist to choose which cells to suppress. The choice of which rules to apply in a specific case depends on the nature of the variable and the degree of protection

sought. Complementary cell suppression could be optimised by minimising the number of suppressed cells, minimising the sum of the values of the suppressed cells, minimising the number of respondents suppressed, or by a method providing a compromise between those needs. Other rules may be used, for example, preference could be accorded to identifying complementary suppressions from within the same industry grouping.

2. Data Perturbation methods include:

i.   Deterministic rounding

Data in a cell are rounded according to a deterministic rule (e.g., round down to the next multiple of 10 if the unit's last digit is below 5, and round up otherwise). However, this can result in bias and the equality of rounded values with rounded marginal totals may not be maintained.

ii.   Random rounding

The direction of the rounding is determined randomly. This method offers more protection than deterministic rounding using the same rounding base because it is more difficult to estimate the original value. It is also unbiased. Again, marginal totals may not be maintained.

iii.   Controlled random rounding

In controlled random rounding, pre-defined aggregate margins are preserved. Applying this method to multi-dimensional tables is a non-trivial problem. Solutions can be found for tables of up to three dimensions but do not exist for higher dimension tables.

iv.   Adding noise

Random noise can be added to table results, to introduce more uncertainty and decrease the disclosure risk.

v.   Disclosure control methods for microdata (see following section).

Apply disclosure control methods to the microdata file, then all tabulations can be safely run from this file.

When multiple tables are produced from the same survey, confidentiality protection cannot be performed independently for each table since combining information from different tables may lead to disclosure. Consequently, the techniques described above ideally need to be applied by considering the tables already published and those yet to be released. For tables of magnitude, tabulations should be pre-defined as early as possible since protection of ad hoc tables is particularly difficult. When combining hundreds of tables, the number of cells may easily reach into the thousands or tens of thousands making automation necessary.

If the survey is repeated regularly, special attention must be paid to developing a pattern of suppression to be used for the entire series. Note though, that over time, a cell or record that once required suppression may no longer need it (for example, a cell may grow in size making it no longer sensitive). The opposite can also occur.

12.5.2.2 Protection of Public-Use Microdata Files

Public-use microdata files, which contain individual records, are released because they allow users to perform analyses on survey data, something that is difficult to do with tabular results. Public-use microdata files are very sensitive and need special confidentiality consideration before dissemination to ensure respondents' identities remain confidential. Public-use files are usually only released for sample-based data since the risk of identifying respondents increases with the sampling rate (note that for a census a public use file could be released for a sample of respondents). Usually, there are direct or personal identifiers on the survey's master file that can uniquely identify an individual (e.g., name, address, identification number). These must be removed. There are also indirect identifiers – variables that can be used to identify respondents (e.g., geographic area, age, occupation, race, even income in some cases).

Indirect identifiers on the public-use file are examined to see if they can be used to identify respondents. Some of the verifications done are:

i.   Check indirect identifiers for unique records.

For example, look for individuals with very high incomes or for exceptional household sizes.

ii.   Analyse 2 and 3-dimensional tables of indirect identifiers (e.g., age, sex, education, etc.).

For example, look at tabulations of age by sex by education and look for unique combinations (e.g., a very old person who is still employed).

Other verifications may be done, depending on the nature of the survey (e.g., population structure, sample design, data collected or used). For example, design information and survey weights are examined to ensure that they do not reveal sensitive information about the geographic location of sample units, if survey data are hierarchical (e.g., household-person) then the relation between units is examined (e.g., looking for rare combinations of spouses' ages), if data come from an administrative source, the probability of successfully linking public-use file records to the administrative database is studied, etc.

Several methods are available to reduce the risks of disclosure. The methods all come at a cost in terms of analytical usefulness of the resulting data. When implementing the methods, care must be taken to preserve as much of the analytical value of the data as possible (e.g., variable means and correlations).

1.   Data Reduction methods include:

i.   Suppress direct identifiers (this should always be done).

ii.   Suppress indirect identifier variables that augment the disclosure risk (e.g., country of origin, questions on visual impairment).

iii.   Suppress individual records (e.g., for a well-known public figure).

iv.   Suppress individual data for a particular record (e.g., an ethnicity that is very rare in a specific region).

v.   Recode the data:
-        reduce geographical detail – geographical information can substantially increase the risk of disclosure and should be provided only at very aggregate levels;
-        top and bottom code data (e.g., incomes greater than $100,000 could be top-coded to $100,000);
-        categorise quantitative variables such as age or income;
-        further aggregate categorical variables.

vi.   Sample the microdata file

Provide data for only a sample of survey units (and adjust sampling weights accordingly). This is useful for introducing uncertainty for units having unique characteristics in the sample. It must be done if the original file is a census.

vii.   Microaggregate records

Microaggregation consists of grouping records, say 3 at a time, and replacing the values of quantitative variables with the average values for the groups. Categorical variables can be used to define groups of similar units.

2.   Data Perturbation methods include:

i.   Round microdata or add noise

For example, apply random or deterministic rounding to the data, or add normally-distributed random noise to the data values.

ii.   Data swap

For a sample of microdata records, matching records are identified based on a predetermined set of variables, and values for other variables are swapped between matched records. Data swapping can be used to swap indirect identifier variables or variables that may be sensitive. For example, a small sample of microdata records could be selected and their income values could be swapped with records that match on geographic information, age and sex. However, this technique may affect correlation analysis.

iii.   Delete information and replace it with imputed data

For example, for small populations, replace reported values with average values.

When external databases such as administrative datafiles exist that have common variables with the survey users may attempt to link their data with the public-use datafile. In these cases the extent of perturbation applied must be even greater.

12.5.3 Other Confidentiality Considerations

The balance between the need for information for public use and the need to protect the privacy of sample units constitutes one of the challenges facing a statistical agency. Because a statistical agency relies on respondents' goodwill, their generosity and non-remunerated use of their time, an implicit contract is made with the providers of the data. In order to respect the implicit contract, the statistical agency must consider four factors during the planning of a survey:

i.   Intrusion into privacy should be limited. 'Does society really need the information? Can the information be found without asking the individuals? Is a smaller sample size possible?'

ii.   There must be no risk of indirect harm to the respondent. In answering the questions, will the respondents put themselves in a potentially dangerous situation? For example, in a survey about household violence, the persecutor may overhear the interview and then harm the respondent after the interviewer has left.

iii.   Respondents should be guaranteed of confidentiality. They should know that all information will be publicly released in a format that will prevent the disclosure of personal information concerning them.

iv.   So that respondents can provide informed consent (meaning they understand and agree to the uses of their data), they must be informed of:
        -   the purpose of the survey (including the expected uses and users of the survey data);
        -   the authority (law) under which the data are collected;
        -   the collection registration details (for follow-up);
        -   the mandatory or voluntary nature of the survey;
        -   confidentiality protection;
        -   the plans to link the data to other files;
        -   the identity of the parties to any agreements to share the information.

These conditions are essential to obtaining reliable information from respondents. In order to make sure that respondents provide informed consent, a statistical agency should rely on a uniform policy of informing respondents of the necessity of the survey and their rights and responsibilities. The information required by this policy must, for all surveys, be prepared in written form and made available to respondents prior to or at the time of collection. In the case of telephone surveys without introductory materials, the information must be provided verbally and provided in writing on request. (See **Chapter 5 - Questionnaire Design** for information that should be included in a questionnaire.)

Additional confidentiality considerations include:

a. Questionnaires need protection during collection, transmission, storage and retrieval of data.

b. Interviewers should not interview in public places (parks, restaurants, etc) since others could overhear the answers. Avoid interviewing on sensitive subjects where other members can overhear.

c. Some surveys select individuals from a list and a tracing procedure takes place if the person moved. Interviewers must be aware of the risk of disclosure during tracing (for example, a follow-up survey targeting respondents suffering from asthma should not inform persons other than the respondent the reason why the respondent is being followed).

d. Means of electronic transmission such as cordless phones, cellular phones and the Internet rely on public bandwidth, and all the information travelling from them is accessible by anyone who cares to look. As a result, confidential information should never be transmitted through either unless securely encrypted. Respondents using these cordless or cellular phones during an interview should be told of the risk and asked to use a phone with a physical landline if possible. Surveys conducted via the Internet should be encrypted. Encryption is available with most web browsers and e-mail programs.

e. After the data have been compiled into machine-readable format and processing is finished, questionnaires should be destroyed (shredded, burned, etc.), assuming that this is consistent with the statistical agency's policy on confidentiality.

12.6 Summary

Data dissemination and evaluation are very important steps in a survey. The goal is to communicate information to users so that they are able to understand the survey results and make decisions. Data evaluation should evaluate the final results in light of the survey's original objectives. It should indicate the survey's strengths and weaknesses so that users can assess the degree to which errors in the data restrict their use of it.

Methods of dissemination include written reports with tables and charts and/or a public-use microdata file. However, before the survey results (or data) are disseminated, they must be thoroughly tested to ensure that the confidentiality of respondents is respected.

Bibliography

Ardilly, P. 1994. *Les Techniques de sondage*. Editions Technip, Paris.

Boudreau, J.R. 1996. Assessment and Reduction of Disclosure Risk in Microdata Files Containing Discrete Data. *Proceedings of STC Symposium 95: from Data to Information – Methods and Systems*. Statistics Canada.

Brogan, D.J. 1998. Pitfalls of Using Standard Statistical Software Packages for Sample Survey Data. *Encyclopedia of Biostatistics*. John Wiley and Sons, New York.

Brackstone, G. 1999. Managing Data Quality in a Statistical Agency. *Survey Methodology,* 25(2):139-149.

Carlson, B.L., A. E. Johnson and S.B. Cohen. 1993. An Evaluation of the Use of Personal Computers for Variance Estimation with Complex Survey Data. *Journal of Official Statistics,* 9(4): 795-814.

Cox, B.G., D.A. Binder, B.N. Chinnappa, A. Christianson, M.J. Colledge and P.S. Kott, eds. 1995. *Business Survey Methods*. John Wiley and Sons, New York.

Doyle, P., J.I. Lane, J.M. Theeuwes and L.V. Zayatz, eds. 2001. *Confidentiality, Disclosure, and Data Access – Theory and Practical Applications for Statistical Agencies*. North-Holland.

Dufour, J. 1996. *Labour Force Survey Data Quality*. Statistics Canada. HSMD-96-002E/F.

Ehrenberg, A.S.C. 1982. *A Primer in Data Reduction – An Introductory Statistics Textbook*. John Wiley and Sons, Great Britain.

Everitt, B.S. 1998. *The Cambridge Dictionary of Statistics*. Cambridge University Press. United Kingdom.

Fink, A. and J. Kosecoff. 1998. *How to Conduct Surveys: a Step-by-Step Guide*. Sage Publications, California.

Freund, J.E. and R.E. Walpole. 1987. *Mathematical Statistics*. Fourth edition. Prentice Hall, New Jersey.

Groves, R.M. 1989. *Survey Errors and Survey Costs*. John Wiley and Sons, New York.

Johnson, S., N.L. Kotz, and C.B. Read. 1982. *Encyclopedia of Statistical Sciences.* John Wiley and Sons, Toronto.

Levy, P. S. and S. Lemeshow. 1999. *Sampling of Population: Methods and Applications*. Third edition. John Wiley and Sons, New York.

Lohr, S. 1999. *Sampling: Design and Analysis*. Duxbury Press, U.S.A.

MacNeill, I.B. and G.J. Humphrey, eds. 1987. *Applied Probability, Statistics and Sampling Theory*. Reidel, Boston.

Mendenhall, W. 1991. *Introduction to Probability and Statistics*. Eighth edition. PWS-Kent Press, Boston.

Mood, A.M., F.A. Graybill and D.C. Boes. 1974. *Introduction to the Theory of Statistics*. Third edition, McGraw-Hill Series in Probability and Statistics, McGraw-Hill, U.S.A.

Public Works and Government Services Canada Translation Bureau. 1997. *The Canadian Style: A Guide to Writing and Editing*. Dundurn Press, Toronto.

Schackis, D. 1993. *Manual for Disclosure Control*. Eurostat, Luxembourg.

Steel, R.G.D. and J.H. Torrie. 1980. *Principles and Procedures of Statistics – A Biometrical Approach*, Second edition. McGraw-Hill, U.S.A.

Statistics Canada. 1993. *Standards and Guidelines for Reporting of Nonresponse Rates*.

Statistics Canada. 2000. *Policy on Informing Users of Data Quality and Methodology*.

Willenborg, L. and T. de Wall. 1996. *Statistical Disclosure Control in Practice*. Lecture Notes in Statistics 111. Springer-Verlag, New York.

Willenborg, L. and T. de Wall. 2001. *Elements of Statistical Disclosure Control*. Lecture Notes in Statistics 155. Springer-Verlag, New York.

Wilson, J.R. and M. Reiser. 1993. Transforming Hypotheses for Test of Homogeneity in Survey Data. *Journal of Official Statistics,* 9(4): 815-824.

Chapter 13 - Survey Planning and Management

13.0 Introduction

The planning and management of a survey is crucial to its success. Without a clear and effective management structure, there will not be a clear understanding of what is to be achieved and how it is to be achieved. There are a multitude of structures that could be used to manage a survey. One commonly used structure is the project or survey team approach. The interdisciplinary survey team is given responsibility for the planning, design, implementation, and evaluation of the survey and of its planned products. The team is composed of members having different technical skills required to plan and implement the survey. All members of the survey team plan, manage and co-ordinate activities within their scope of expertise and responsibility, and co-ordinate these activities with all other activities within the survey.

Planning and management are the keys to achieving the survey's objectives. Planning sets out the strategy that permits the statistical agency to meet the survey objectives. It is at the planning stage of a potential statistical activity that the requirements of the client and the means by which and the degree to which these requirements are expected to be met are examined and established (see **Chapter 2 - Formulation of the Statement of Objectives**). It is also during planning that the resource and funding requirements, and the schedule of activities are developed. The quality of the planning phase is crucial to the quality and cost of the entire project. Some amount of planning continues throughout most of the survey life cycle, ending only when the final data request has been delivered to the satisfaction of the final user.

Good planning requires good management, and knowledgeable and experienced people. Regardless of the management structure used, a manager should be appointed who is responsible for the proper functioning of all aspects of the survey activity. The manager should be answerable to senior management, usually to a steering committee, which provides direction and guidance. Key management functions include organising, directing, monitoring and controlling the survey.

The purpose of this chapter is to discuss how to plan a survey, with an emphasis on the survey team approach. At the end of the chapter is a checklist of activities or methodologies that should be considered during planning (see the Planning Checklist).

13.1 Approaches to Survey Planning and Management

The basic issues to be addressed when planning and managing a survey within a statistical agency are much like those for any project in any organisation, i.e., how are requirements to be clearly identified, effectively communicated and implemented in the shortest reasonable time, within budget and with the highest quality that is affordable and consistent with requirements? Although the specifics are very different, the critical common elements to meet the objectives of any project remain the same: communication, knowledge, skills, commitment, efficiency and effectiveness.

The style and nature of planning and management of a survey depend, in part, on the resources available within the statistical agency, its functional organisation and on how responsibilities are allocated within the agency and within the national statistical system. The organisation must take into account the responsibilities and the operating culture and practices of the statistical agency, provincial statistical offices, the overall statistical organisation in the country at all levels and the relevant professional groups.

A commonly used and effective framework for survey planning and management is a project team structure. With the right people and with the commitment of senior management, a survey team can bring together knowledge and skills, engender commitment, and simplify and improve communication-giving opportunity for greater efficiency and effectiveness. Other frameworks or approaches are possible, and may be necessary in some situations. However, if the project team structure is not explicitly used, greater emphasis and reliance must be placed on precisely written specifications as a form of communication, with limited occasion for modification. Greater reliance must also be placed on the specific abilities of participants, with less opportunity for effective monitoring and control.

13.1.1 The Survey Team

Often, an interdisciplinary survey team is given responsibility for the planning, design, implementation, and evaluation of the survey and of its planned products. It is composed of members having different technical skills required to plan and implement the survey. All members of the survey team plan, manage and co-ordinate activities within their scope of expertise and responsibility. They also co-ordinate these activities with all other activities within the survey. Although the survey team members have individual responsibilities, they share responsibility for meeting the objectives of the survey. All proposals, plans, budgets, options, strategies and major instruments or specifications are reviewed by each team member and then discussed by the team to identify the best way to proceed. For most surveys, individual team members are supported by other staff who are assigned activities to be carried out on the team's behalf. Conversely, every organisational unit involved in a survey does not need to be directly represented on the survey team. For example, services in logistics, printing, data capture or administration need not be represented on the project team.

The survey team is not a committee or a set of individuals each with a separate purpose and agenda. It is a group of people working jointly and collaboratively on a single project. Other than the project manager, there should be no hierarchy within the team, only roles. Communication, effective resolution of problems and issues, and nurturing of innovation, efficiency, commitment and quality are the characteristics sought in the team approach. There must be ongoing and open discussion, constructive comments, positive feedback, flexibility and a willingness to consider all requirements, issues and points of view. The team also must be thorough, thoughtful, self-directed and decisive. Proposals, issues, problems and disagreements must be resolved unequivocally, appropriately, in a timely manner and with a clear understanding of the consequences of decisions.

Survey teams are typically composed of a survey manager, an expert in the field of study covered by the survey (a subject matter expert), a survey statistician, a computer systems analyst, and a data collection and operations expert.

i.   Survey manager

The survey manager is responsible for the management of the survey. He or she ensures that the objectives, budget and schedule are respected. The survey manager is usually responsible for determining the required resources for the survey, developing a preliminary plan and co-ordinating the preparation and updating of the plan, preparing the budget and monitoring resource utilisation and progress. The survey manager also liaises with, and reports progress to, senior management and the client. He or she ensures adherence to departmental legal, legislated and regulatory commitments and to departmental policies, standards, guidelines and regulations. The survey manager presides over team meetings and is the representative of the client on the team, regardless of the survey manager's functional or organisational relationship to the client.

ii.   Subject matter co-ordinator

The subject matter co-ordinator is responsible for the content of the survey. When more than one field of study is involved (e.g., for a survey studying demographic, education, labour force and income data), the co-ordinator manages the activities and inputs of the subject matter participants who are not members of the survey team. Through discussions with the client and the team, he or she is responsible for ensuring a clear and appropriate representation of the subject matter and intended uses of the data in the statement of objectives, design and implementation. In particular, the subject matter co-ordinator conducts or co-ordinates the preparation of definitions and concepts, the collection and analysis of relevant historical data (for planning and development), content development and testing of the questionnaire, preparation of all subject matter reliant data collection and processing specifications, design of statistical outputs, development and implementation of data analysis and preparation of the analytical text. He or she also co-ordinates the validation or certification of survey results and provides subject matter expertise for the evaluation of data quality and preparation of related subject matter documentation.

iii.   Statistical methodology co-ordinator

An experienced survey statistician (or survey methodologist) is responsible for conducting and co-ordinating the design and development of the statistical methodology to be used for the survey. He or she is responsible, in particular, for the sample design, weighting and estimation, design of quality control methodologies, data quality evaluation designs and measures, the design of edit and imputation mechanisms or strategies, and statistical aspects of data dissemination and analysis. The survey methodologist also acts as a consultant and adviser to all other members of the survey team on matters of statistical methodology, and ensures adherence to the use of sound and efficient statistical methods.

iv.   Computer systems co-ordinator

The systems analyst is responsible for the design and development of the computer systems and programs, as well as the identification, integration and modification of existing or commercial software that are required to conduct the survey. He or she ensures that these systems function according to specifications provided by other team members and participants. The systems analyst also acts as a consultant and adviser to all other members of the survey team on matters of computing, and ensures adherence to the use of sound, compatible, verifiable and efficient methods throughout. He or she also co-ordinates or ensures effective implementation of some aspects of statistical processing (e.g., edit and imputation, weighting and estimation, and tabulation), depending on the role of an operations manager.

v.   Data collection and operations manager

The data collection and operations manager is responsible for development of data collection, capture and coding specifications and procedures. This manager is also responsible for planning and co-ordinating the recruitment, training, monitoring and control of data collection staff such as interviewers and supervisors, as well as data capture and coding staff, if applicable. His or her responsibilities includes the development, implementation and management of collection operations and public relations programs, preparation of material (e.g., manuals and maps) and logistical support requirements. He or she also acts as a consultant and adviser to all other members of the survey team on operational matters related to his or her expertise and ensures the specifications and requirements developed by other team members – e.g., interviewer edit and follow-up specifications – are properly built into the procedures. This manager's role may encompass field collection through Regional Offices, separate data capture and coding operations, as well as implementation of manual and some automated operational activities performed at Head Office. For larger projects these roles may be assigned to two different persons – a data collection manager and a processing manager.

vi.   Other members

A larger number of managers or co-ordinators might be required for large undertakings, such as a population census. For these projects, separate managers may be assigned for communications or publicity, geographic inputs and outputs (associated with the frame, and geographic variables and products), and survey products. Large surveys or censuses may also be sub-divided into particular tasks (e.g., questionnaire design and development, data collection, edit and imputation) and sub-tasks (e.g., collection quality control, coding, etc.). Each task and sub-task has its own team. Such teams may differ in the nature of their membership, but each has a manager reporting to a manager in the next level up in the survey team structure.

There are two dimensions to management. The survey team provides one dimension, that of managing resources. This is usually termed *matrix management.* The functional organisation provides the other – through the delivery of contracted services or intermediate products, and through provision of team members and technical review and supervision of their contribution to the survey.

13.1.2 Additional Planning and Management Committees

To be effective, the planning and management structure requires more than a project or survey team. For major surveys, or for groups of surveys forming a coherent statistical program, a number of committees may be used to provide direction and advice.

i.   The statistical agency's management committee (under various names – e.g., Policy Committee) ensures that the survey is relevant in the overall context of the agency's statistical program and is effectively managed. This committee (or an equivalent level functional manager) ultimately approves the initiation of the survey, and the budget and resource allocation for the survey.

ii.   A steering committee, composed of managers with responsibility for a group of similar surveys, provides expert or technical resources or services to surveys. The role of the steering committee is to approve the statement of objectives, the schedule, the allocation of resources within the approved budget, the detailed content and output and methodology. It also provides overall direction and guidance to the survey team, monitors progress and resolves issues that cannot be resolved by the team. Regardless of the ultimate sponsor of the survey, the steering committee is often considered to be the client for the project team. The survey manager should be a member of this committee or report directly to it, and attend its meetings. If the survey is funded by an external department or agency, then it may be useful for a representative of that agency to sit on the committee.

iii.   A subject matter committee provides advice and guidance on subject matter content, concepts, definitions and classifications. Such a committee co-ordinates functions across statistical programs to promote subject matter standards and consistency. In lieu of such a committee, the subject matter co-ordinator should liaise with his or her technical colleagues to obtain guidance and background.

iv.   In some cases, a consultative committee with regional or provincial membership, or with members from other government departments can provide advice on broad issues, priorities, content and user requirements, and specific outputs. This committee reflects the vested interest of the members in the survey or its outcome. In lieu of such a committee, the project manager and the subject matter co-ordinator must ensure effective liaison with users and groups that might have a vested interest in the survey.

v.   Finally, a professional advisory committee consisting of independent (outside) experts can provide advice of a technical nature and ongoing review of the statistical methods and outputs. In lieu of such a committee, the survey methodologist should seek advice, and take care to carry out appropriate research and testing of methods.

Any or all of these committees may serve as part of the planning and management process. Their involvement reflects and coalesces support for the program, and situates the priority of the survey within the agency's overall statistical program. This ensures the commitment of all levels of management to the survey and access to the expert resources required. The nature of the committee structure depends on the importance of the survey, on the structure of the national statistical system and on the management practices of the statistical agency.

The *infrastructure and functional organisation* of the statistical agency affords the team a wide variety of support. For development and design, technical supervision should be performed by the functional organisation, i.e., the supervisors within functional areas review the contributions of their subordinates working on teams. The team members, for their part should solicit technical advice or guidance from their functional supervisor and from colleagues within their infrastructure. The team manager should be able to assume that the input to his project has the approval and support of the member's supervisor (assuming that the functional organisation accommodates supervision based on technical or professional expertise), or reflects some form of peer assessment and support.

In addition, the team should seek assistance or services that may be available within the organisation – data capture and collection facilities and services, computing services, printing services, media or public communication services, training services and facilities, interdepartmental or federal-provincial liaison services, etc. It would be unusual for a survey team to carry out all such aspects of a survey on its own. Although the functional manager or supervisor liaises with and reports to the appropriate survey team member on matters related to the survey, the management of these operations is usually carried out within the functional organisation or unit.

13.1.3 Alternative Management Approaches

The survey team approach is highly effective for development of new surveys and for major survey redesigns. However, not all organisations are set up to operate in this manner, especially for very large statistical projects. Several variants are described below:

i.   Large survey or census

For a project such as a census of population, or in a statistical organisation with few centralised sources or centres of technical expertise, the survey team structure may reflect only a management role rather than a management, design and implementation role. In such situations, the survey team has to depend on several major component project teams, task teams and sub-task teams to carry out the detailed planning, design and implementation. A likely consequence of this structure is that the team would be composed of component project managers, largely managing a set of operations or modules of the overall survey (e.g., data collection). The roles of the statistical methodology, subject matter and computer systems co-ordinators might be fulfilled only at the level of the component project or task team. There would be a loss in communication, efficiency and quality as a result, but this loss must be assessed in terms of requirements of control and effective management. The potential loss is much greater for a new survey. The potential loss should be less for an ongoing survey such as a census of population if there is adequate evaluation and long inter-censal development time.

ii.   Outside supplier of skills and services

If the agency does not have the technical infrastructure or facilities to conduct all aspects of the survey, it will have to add these skills from external sources – for example, under short-term contract or by contracting out the functions to an external organisation. For example, if the agency does not have staff or adequate facilities for printing of questionnaires and interviewer manuals, or for data capture, it will have to seek external services for these activities. Specifications for the functions or services to be provided, under what conditions and expectations, will have to be prepared by the project and agreed upon by the contractor. It then becomes the external organisation's responsibility to implement those specifications, under the terms of the contract. Most surveys contract out some parts of the survey to internal (outside the project team) or external service providers.

Some new surveys are sufficiently straightforward operationally that 'off the shelf' methods or commercial facilities can do the work with little need for direct involvement with the survey team (for example, in printing). For complex functions, larger surveys and censuses, contracting out adds risk and requires specific controls. For a national statistical agency external contractors may be other government departments, institutions, or private enterprise organisations or individuals. The rules and regulations of the statistical agency as well as those of the government, including those for procurement and contracting out, must be followed. The project team must be careful to have access to the necessary internal management, legal and administrative knowledge and experience. Diligence, properly commensurate with the significance and risk, must be applied in selecting the contractor, preparing and agreeing on specifications and requirements, and in monitoring and managing their implementation and fulfilment.

iii.   Providing specific services to project committee

Some surveys might be planned and managed through a project or steering committee, with survey development, design and implementation participants working separately through designated committee members with no team role. The survey typically is only one aspect of the committee's mandate and is not directly part of the committee's objective. Surveys being conducted by a government department other than a statistical agency (but with some design support from the statistical agency) are often organised in this manner. In such cases, the committee is within the host department. Surveys requiring specialised measurement or direct observation skills (e.g., blood tests or other medical or dental measurements) might also operate in this manner.

iv.   Limited redesign

In many situations, the design work encompasses only one component of an ongoing survey – for example, the redesign of the questionnaire or a sample redesign. Such cases are frequently handled without a survey team even though many aspects of the survey may require updating or upgrading. Time and cost are usually the reasons for doing without a survey team.

In all these cases, the various skills and the knowledge necessary to plan and conduct the survey or the particular component is provided in a contractual manner. Most statistical agencies operate in this manner for a variety of projects, for example, in providing consultative services to other government departments, for conducting their own one-time surveys (for example, on client/user/employee satisfaction or on public opinion) and for partial redesign projects.

For those components that can be specified precisely and for which an organisational unit or external contractor has the technically specialised knowledge and resources needed to design, develop or produce the required component on schedule, contracting out might be the most cost effective approach. However,

communication needs to be effective and there has to be evidence of capacity, ability, progress and compliance to specifications.

v.   Functional manager is the survey manager

There are some cases for which most of the skills needed are available within the functional unit that initiated the survey. Where this is a meaningful distinction, the survey manager is also a functional manager of most or all of the participants. Notwithstanding, the participant team should function in the manner of a survey team as described above. However, many of the positive attributes of the survey team – a sense of collaboration, openness, shared responsibility, independence and objectivity – may be unsustainable. The levels of experience and knowledge may differ and differences in functional levels may more frequently result in conflict. Participants from outside the functional area may have less influence, and may be given a narrow focus of responsibility and few team roles.

13.2   Survey Planning

It is hopefully clear that various decisions have to be made throughout survey design and implementation to ensure the survey meets its objectives. The survey is also part of a larger statistical system. So too the survey must meet the broader objectives and requirements of the statistical organisation – considering among other things the merits of the objectives of the survey, the overall agency program and mandate, and the opportunity cost to produce the data or information. These objectives and requirements form five basic sets of criteria that have to be met in the planning, design and implementation of any survey or statistical project.

i.   The survey data must be 'fit for use'.

Among statistical agencies there is no commonly accepted definition of what constitutes 'fitness for use'. However, whether the survey data and statistical information are fit for use can be assessed in terms of the following six characteristics: relevance, accuracy, timeliness, accessibility, interpretability and coherence (for a definition of these terms, see **Appendix B - Quality Control and Quality Assurance**).

ii.   The imposed response burden or likely public reaction must be justified.

How long does the questionnaire take to complete? How much time is required for the respondent to check records or to obtain information from other members of the household or business? How intrusive are the questions? Will the survey collection period interfere with the work of the respondent (e.g., conducting a survey in rural areas during planting or harvest periods)? Are basic definitions different from those of other surveys using similar concepts? Has the population been surveyed too many times before? Will the survey harm the reputation of the organisation or have some negative impact on other surveys (e.g., reduced response because controversial, or because conducted at the same time)? Will the response burden and survey cost be justified by the inherent social value of the data that will be yielded by the survey, and will this be demonstrable to the respondents and the public?

iii.   Results disseminated from of the survey should reflect all of the valid results.

Dissemination and analysis by the statistical agency must not be limited so as to, in effect, unduly reflect, imply or support a particular perspective, agenda, conclusion or point of view. (This is a not uncommon and unintentional result of releasing incomplete, or limited analytical results.) The survey results should not be used to support a particular perspective, point of view or conclusion unless other plausible or contrary outcomes or conclusions have been tested and rejected by way of clear statistical evidence and tests. Further,

the statistical confidence or reliability of those tests, and results or conclusions must be clearly presented with the results.

iv.   Requirements of the policies, regulations, administrative procedures, standards and guidelines of the agency and government must be satisfied, and sound practices and methods used.

There will be a variety of 'rules' for conducting a survey – from formal authorisation for the particular data collection through to the use of statistically valid and efficient methods. Sound practices and methods are required so as not to waste resources, to more effectively meet and to be shown to meet the criteria of 'fit for use', and as a consequence, to support the professional reputation of the agency.

v.   A survey meeting all of these criteria must be achievable within an agreed upon and approved budget, and with available means and resources.

13.2.1 Stages of Survey Planning

Survey planning should be conducted in phases of increasing detail and exactitude. At the preliminary, or survey proposal stage, only the most general notion of the feasibility and data requirements of the survey may be known. In consultation with users and the client, the team proceeds to make the data requirements and analytical concepts more precise and to develop some appreciation of frame options, the general sample size and precision required, data collection options, schedule and cost. They will, at the same time have a sense of the limitations that will be imposed by the client on cost and time, while having some knowledge of what resources might be available for the survey. In the later stages, plans are revised, elaborated and refined, and more detailed aspects are examined. Each and every activity and operation needs some form of plan for design, development and implementation. Still, planning continues. Modifications and adjustment have to be made and contingency plans and corrective procedures may be required.

A survey or statistical project goes through the following five stages of planning:

i.   setting the survey proposal;

ii.   establishing feasibility and the survey plan;

iii.   preparing plans for the components of the survey;

iv.   finalising plans during design and development;

v.   adjusting and supplementing plans during implementation and evaluation.

13.2.1.1 Stage 1: The Survey Proposal

The first step in planning a survey is the identification of an information gap and the preparation of a survey proposal. Transforming an identified need into a survey first requires approval or agreement to proceed with preliminary planning. Most likely, members of the agency management committee or some members of the steering committee would appoint an interim survey manager who would provide initial information on alternatives to a survey (e.g., data available from another survey or administrative source), and on cost and feasibility of a survey. The preliminary stage of a survey redesign or to a survey request from an external organisation would be similar.

Such initial studies may have to be done quickly and, as a result, may be more superficial than desirable. Nonetheless, the preliminary examination should be based on consultation with experts from the various disciplines that could be expected to be involved in the eventual survey team (although these members may not be, in the end, members of the actual survey team). Some documented process of agreement and support from these experts should be undertaken prior to, and as part of, the decision making process on how or whether to proceed with more substantive development towards a statement of objectives, and a full feasibility study and survey plan.

Once a survey proposal has been prepared, reviewed and discussed, senior management is in a position to decide whether to proceed with further planning and development. Once established, the survey team must develop the statement of objectives and quickly confirm feasibility and some broad options or alternatives.

13.2.1.2 Stage 2: Establishing Feasibility and the Plan for the Survey

This is a critical stage of planning since the cost of the survey is established at this stage (within a narrow range). This is particularly important if the cost limit set by the funding organisation is close to or below the estimated cost. The main goals of this stage of planning are to:

i.   establish the (draft) statement of objectives, cost limits, quality targets and rough time frame;

ii.   identify and assess adequacy and accessibility of existing sources of data and identify information gaps (administrative data and existing surveys);

iii.   identify frame and potential statistical units for sampling (if applicable) and data collection;

iv.   determine what methodology approaches have been used for other surveys of the same target population and for surveys of other statistical agencies on the same general topic;

v.   provide preliminary assessment of cost, time frame, feasibility and response burden, including an assessment of the appropriateness and impact of sampling in regard to cost and quality requirements;

vi.   prepare feasibility and planning report – with options, special issues, requirements and limitations (e.g., in relation to policies and regulations, legal practices/limitations/requirements) – covering every step of conducting the survey, including the statement of objectives, as well as options for the frame, sample design, data collection, processing, disclosure control, testing, dissemination, budget, etc.

At any step within this stage, it is possible to report back to the Steering Committee and to terminate the process, if the team has sufficient indication that a survey would not be viable under the terms and conditions of the draft statement of objectives. If planning proceeds to the point where a feasibility and planning report is prepared, the survey proposal should be reviewed and assessed by the Steering Committee. A decision on whether or not to conduct the survey, as well as, its parameters and general design is made on the basis of the survey proposal. Any decision to undertake further planning or design work usually leads to Stage 3.

13.2.1.3 Stage 3: Prepare Component Plans

Each team member prepares the components of the plan associated with his or her responsibility within the team. Each also provides input to the plans of others to which they contribute expertise. Task and sub-task teams prepare plans similarly and co-ordinate these with the survey team member responsible. All plans are

reviewed and refined by the survey team. The steps in preparing these plans are:

i.   prepare development, design, implementation and evaluation activity plans, schedules, estimates of resource requirements and refined cost estimates for implementation for each component and phase of the survey or statistical project;

ii.   review all component plans, identifying inputs and outputs for each component and dependencies;

iii.   conduct development required as major input to plans of other components;

iv.   establish links and consistency within and between components;

v.   revise schedules as required;

vi.   prepare major milestones and overall schedule;

vii.   prepare final testing proposal and plan;

viii.   revise budgets and make adjustments to plans as required.

During this stage, planning becomes a more complex matter. In order to plan operational components (data collection, data capture and processing), substantive development work must be included as part of the planning for the sample design (size and allocation should be established), questionnaire content, the collection methodology in detail, and editing and quality assurance requirements. Collection plans, for example, are meaningless without an accurate estimate of the length of the interview.

At the end of this stage, assuming approval by the steering committee, the team arranges or finalises arrangements for the resources required. The reference date, the data collection date, the budget and resource requirements should now be fixed.

13.2.1.4 Stage 4: Finalise Plans for Design, Development and Implementation

At this stage the focus shifts from deciding what to do to doing it. Outstanding planning issues should only be at very detailed levels and should be well within the bounds of existing plans (for cost, time and resources). It is only at this stage that testing and implementation plans can be finalised. As indicated above, various aspects of design and development start at different times, with different degrees of certainty as to what methods, procedures and systems will be used. In some cases those receiving and having to implement specifications may have only a general understanding of what they must transform into more detailed specifications, procedures or computer systems. A few last minute changes in specifications during development or as a result of testing can always be counted on. Trade-offs may have to be made to meet the agreed upon cost, time and resource constraints.

13.2.1.5 Stage 5: Adjustments and Supplementary Plans

As design, implementation, and quality evaluation proceed, it may be discovered that not all aspects of the survey have proceeded according to plan. Response rates may be higher or lower. Tracing may be more costly. A greater proportion of the work of interviewers may be rejected during quality control, causing delays. The edit failure rate for a particular variable may be excessively high. At the data quality certification

stage, it might be found that many respondents have misinterpreted a question, etc. These situations should be reviewed by the survey team and plans prepared quickly.

If there is added cost, a need for additional resources, an expected delay or an impact on the survey objectives or quality requirements, the supplementary plan should include options and consequences. The approval of the Steering Committee must also be sought.

Even without any of these serious issues, day to day adjustments to plans may be required. As the reference date and then the completion date of the survey get closer, small issues rapidly grow into big issues.

13.2.2 Estimating Costs, and Resource and Time Requirements

During survey planning, estimation of costs (budget), and of resource and time requirements (schedule) are conducted in phases of increasing detail and exactitude. To start with, estimates are based on broad assumptions of the methodology to be used, of how many and what staff and other resources are needed to plan, design, implement and evaluate the survey, and of the requirements for logistics, materials, supplies, transportation needs, etc. These estimates have to be more exact and more detailed at each stage of planning.

The estimates must be prepared or reviewed and supported by experts representing the specific functional areas that are providing resources or services. Estimates should be based on historic information on resource utilisation, duration and cost (from past surveys and other current surveys, as well as on utilisation to date for the survey under development) and administrative information on current unit costs. This information must then be applied to the specific application of the survey under development.

The relevant activities or methodologies among those itemised in the Planning Checklist (at the end of this chapter) represent at least a partial list of inputs to costs and that require resources and time to complete, prepare or deliver. Resource, time and cost estimates, however, should consider the following:
- the primary uses of the data and the quality requirements;
- the nature of the target population and the survey content;
- the length and complexity of the questionnaire and of the interview (if applicable);
- complexity of the sample design and the type of frame (e.g., area frame, list frame, random digit dialling or telephone lists);
- sample size and sample distribution;
- data collection methodology (personal interview, telephone interview, mail out questionnaire, etc.);
- field procedures (proxy/non-proxy interview, tracing and follow-up requirements and strategy);
- the number and complexity of the built-in edits;
- expected response rate;
- experienced/inexperienced staff, as well as need for recruitment and training;
- computer hardware and software, as well as computing costs;
- what specifications, procedures and systems need to be designed, developed and tested, and which ones can be reused or modified;
- resource requirements (equipment and personnel requirements and costs by type and level of staff);
- management and administrative reporting requirements;
- frequency and length of meetings (team and steering committee, etc.).

Costs, schedules and resource requirements must incorporate the activities of the survey manager and other members of the team, as well as all other participants. Estimates should include all activities from inception to delivery of the last product and report.

13.3   Management of the Survey

Regardless of the management structure used, the management of a survey, beyond planning, involves organising, directing, monitoring and controlling the survey.

i.   Organise

Organising is the management function by which people, functions, and physical factors are brought together to accomplish the goals of the organisation. The survey manager is responsible and accountable for the management of the survey but must rely on the survey team (and on managers within functional groups providing services) to share this responsibility. For this purpose, team members participate in and agree on the assignment of responsibilities. Responsibilities should be allocated according to expertise and experience and to specific sets of compatible activities or components of the survey. All activities must be covered with respective individuals responsible for inputs or outputs from each activity of the survey. One of the roles of the survey manager is to ensure there are no gaps and no conflicts.

ii.   Direct

Directing the survey, or more specifically the work of participants, entails making decisions, giving guidance and acquiring or providing assistance where needed. Managers must provide leadership and training and development opportunities, motivate and maintain good communications. Conflicts must be resolved quickly and clearly. If starting with a good plan, confidence, trust, and clear and well-understood objectives, then motivated, well-trained staff are a manager's guarantee of meeting the objectives of the survey.

iii.   Monitor and control

Monitoring and controlling is the management function of being and staying informed and reacting to any problems to keep the survey progressing according to plan. The survey team must ensure that the resources assigned to the survey are available and are used efficiently and effectively. It must ensure that survey plans are properly implemented, and that any necessary corrections and adjustments are made. The manager must ensure that plans, policies and procedures are followed, ensure that objectives are adhered to, prepare and issue instructions and ensure that they are followed, set performance standards, follow-up to ensure completion of tasks and ensure adherence to schedules.

Monitoring is done through regular team meetings, discussion, day-to-day contact with participants, and through the use of plans and a variety of management information reports. The planning report, and the budget and schedule are key benchmarks. Resource utilisation, expenditures and progress must be tracked and reported. Each team member should regularly submit a report (either written or verbal depending on the situation) on progress, utilisation and expenditure. Operational data such as response rates, interviewer completion rates, follow-up rates, and information from production reports, and quality control or quality assurance operations should be reported and reviewed. The frequency of meetings and reporting should be based on the potential urgency of reacting to any problems.

The schedule and cost forecasts for critical activities on a strict schedule, such as interviewing, should be broken down to the lowest level of component steps. If possible and meaningful, these steps should be scheduled to the level of the day, and monitored. Without this, it cannot be easily determined how long these activities will take, whether they are in reality on schedule, and whether corrective actions, adjustments or changes of plans are necessary.

iv.   Communicate, co-ordinate and review

The survey team and in particular the survey manager is responsible for ensuring co-ordination and communication. The survey team and functional managers are responsible for all review and communication within their sphere of activity, and for providing feedback to the team and the survey manager. Plans, budgets and schedules, statements of responsibility and mandates are primary communication and co-ordination tools. A complete set should be available to all participants. Participants need to know their roles, but also their purpose and where and how they fit into the overall survey. The survey team must also ensure it receives adequate communication in order to monitor and report.

To aid in communication and co-ordination, the team schedule should include major milestones for the survey. There should be a decision record (a list of relevant decisions made by the team). There should be a problem notice procedure for major operations and systems (a brief report on errors, inconsistencies and solutions that require modification to procedures, operations or systems, or to other changes not reflected in the approved specifications or plans). The decision record and the problem notices require broad distribution. Flow charts, or similar devices, showing the schedule and interdependencies of activities should be prepared and provided to managers and team members.

As noted earlier, the functional manager or supervisor should review the input to the survey of his or her staff. The survey team also has this responsibility. The team must ensure assure itself that inputs (specifications, procedures, manuals, the questionnaire, etc.) meet survey requirements; to ensure that all the components meet their individual objectives, fit together and are consistent with the survey objectives and plans.

13.3.1   Role of the Survey Manager

The survey manager has co-ordinating and hierarchical responsibilities not shared by the survey team as a whole. In addition to the duties listed in the previous section, someone has to be in charge, with overall responsibility and accountability to make timely decisions consistent with the mandate provided by the Steering Committee. Someone must interact directly with the Steering Committee. Someone must represent the survey team with users in general and with users providing funds, in particular. These are part of the management role of the survey manager.

Along with other members of the team, the survey manager works with the client and users to determine their data and analytical needs. However, it is the survey manager who must ensure that decisions made during the course of the survey do not compromise the fundamental fitness of use of the final data. The manager responds to the client's questions about ongoing progress, explain the reasoning behind decisions, communicate the client's preferences to the survey team, and ensure that the client's money is being spent appropriately and within budget. The manager also acts as a buffer between the client and the survey team, allowing the project team to carry out their work without interruption or interference. The survey manager has the same role with the Steering Committee. If the client is not a member of the Steering Committee, then the survey manager must ensure there is effective three-way communication of requirements, decisions and outcomes.

It is critical that the survey manager be personally and directly assured at all times that the client and key users know what they want, and understand what they will receive, what the limitations are, and how the data will or will not meet their needs. The costs, consequences and appropriate alternatives must also be made clear. A similar condition applies to the Steering Committee.

The manager co-ordinates the activities of the survey team and ensures all plans, specifications, decisions, etc. are properly communicated to members of the team. The manager reacts to any unexpected problems and ensures that the appropriate people and information are brought together to take the necessary actions. The manager must ensure that it is possible to monitor progress, quality and issues that arise. He or she must have sufficient information at all times to be able to personally support the credibility of the survey and its results, as well as to understand its limitations.

The survey manager must ensure that activities of the survey team are properly co-ordinated with infrastructure and functional groups or service providers within and outside the statistical agency. He or she must also be aware of any similar surveys and of new techniques and methods. The manager must ensure that these participants are aware of the extent and timing of their involvement in the survey and that they are informed, in a timely manner, of any changes to the plan. The survey manager must monitor their involvement and seek clear evidence of required performance. Much of this type of activity may be delegated to survey team members, but the survey manager should have the ability to keep an independent check on progress, usually through monthly contact with the corresponding managers.

The manager may represent the survey and the agency to the public. The survey manager is the final point of contact for survey respondents, and others who want to obtain more information about the survey or if there are complaints or issues. When the survey data are released, the survey manager is a contact point (along with the subject matter co-ordinator) for questions from the media, data analysts, and researchers.

Finally, the survey manager has primary, but not exclusive, responsibility to anticipate, prevent and resolve problems. Survey managers must use their experience and knowledge judiciously. They must be careful to be sceptical, realistic and supportive simultaneously. They have to decide on the basis of what is pragmatic, which is not always the ideal in terms of staff relations and users demands. They have to avoid adjusting or changing the wrong things, and as a result only perpetuating, cloaking or exacerbating problems. They have to avoid tinkering, disrupting and interfering.

The survey manager must monitor the participation of team members. To prevent problems, the manager must attempt to keep the team together throughout the survey as long as it remains of benefit to the success of the survey. Nonetheless, the manager must not expect all participants to stay to the end of the survey. The manager should consider an informal strategy for succession and give some thought to alternatives or options. Adjustments have to be made for team members or participants absent due to extended illness, participants who are promoted, change positions or who leave the organisation. Adjustments have to be made to replace members or other participants who are making an inadequate or disruptive contribution to the survey.

13.3.2 Why Do Things Go Wrong?

Finally, the survey manager should have sufficient knowledge and experience to know why things go wrong. A few of these that should be kept in mind are (in no particular order):

- team members do not have the same relative skill levels and experience or some lack adequate skills;

- inappropriate or disproportionate allocation of responsibilities within the team;

- poor communication or occasional serious communication gaps;

- survey run by Steering Committee chairperson and survey manager (the team is not clear on the direction, do not consult with some team members before making decisions, react to problems or issues without

getting background information from the survey team);

- changing or vague objectives (client and/or users do not know what they want or do not understand issues, adding requirements late, attempting to do too much in one survey);

- excessive complexity in methods, concepts or questions;

- inadequate testing;

- errors in planning (forcing or accepting an inflexible plan, unrealistic schedule or inadequate resources, lack of sufficient scrutiny of plans and specifications – review only if something goes wrong, being too optimistic about, or not knowing, how long activities take and what might go wrong, fewer resources than planned for);

- outside interference;

- lack of understanding of cause and effect in assessing problems and in designing solutions;

- focusing on the methodology (as an end in itself) and not the objectives;

- lack of commitment or participation when required by the Steering Committee or senior management;

- lack of commitment by team members (participants have too many other assignments/commitments or are diverted to other activities outside the survey or to additional imposed activities within the survey – trouble shooting or dealing with information requests beyond the planned scope of the survey, team members looking to or undertaking future assignments before completing current survey, unable to get people to do what they do not want to do or do not believe in).

13.4   Summary

This chapter covered the main topics in planning and managing a survey, specifically:

i.   Methods of organising the planning and management of surveys

Particular attention was paid to the survey team approach because of its ability to bring together knowledge and skills, engender commitment, and simplify and improve communication – giving opportunity for greater efficiency and effectiveness.

ii.   The stages and process of planning

Survey planning must be conducted in phases of increasing detail and exactitude, progressing from setting the survey proposal to establishing feasibility and the survey plan to preparing plans for the components of the survey to finalising plans during design and development to adjusting and supplementing plans during implementation and evaluation.

iii.   How to manage the survey to meet its objectives

Good planning requires good management, and knowledgeable and experienced people. A manager should be appointed who is responsible for the proper functioning of all aspects of the survey activity. Key management

functions include organising, directing, monitoring and controlling the survey.

Bibliography

Amabile, T.M. 1998. How to Kill Creativity. *Harvard Business Review*. September-October 1998: 65-74.

Biemer, P.P, R.M. Groves, L.E. Lyberg, N.A. Mathiowetz and S. Sudman, eds. 1991. *Measurement Errors in Surveys*. John Wiley and Sons, New York.

Brackstone, G.J. 1993. Data Relevance: Keeping Pace with User Needs. *Journal of Official Statistics,* 9: 49-56.

Brackstone, G. 1999. Managing Data Quality in a Statistical Agency. *Survey Methodology,* 25(2): 139-149.

Cialdini, R., M. Couper, and R.M. Groves. 1992. Understanding the Decision to Participate in a Survey. *Public Opinion Quarterly*. 56: 475-495.

Collins, J. 1999. Turning Goals into Results: The Power of Catalytic Mechanisms. *Harvard Business Review*. July-August 1999: 71-82.

Cox, B.G., D.A. Binder, B.N. Chinnappa, A. Christianson, M.J. Colledge and P.S. Kott, eds. 1995. *Business Survey Methods*. John Wiley and Sons, New York.

Dinsmore, P.C., ed. 1993. The American Management Association Handbook of Project Management. AMACON, American Management Association, New York.

Drucker, P.F. 1999. Managing Oneself. *Harvard Business Review*. March-April 1999: 65-74.

Early, J.F. 1990. Managing Quality in National Statistics Programs. *Proceedings of Statistics Canada Symposium 1990: Measurement and Improvement of Data Quality*. Statistics Canada.

Eisenhardt, K.M., J.L. Kahwajy and L.J. Bourgeois III. 1997. How Management Teams Can Have a Good Fight. *Harvard Business Review*. July-August 1997: 77-85.

Fellegi, I.P. 1992. Planning and Priority Setting – the Canadian Experience. *Statistics in the Democratic Process at the End of the 20th Century*; *Anniversary publication for the 40th Plenary Session of the Conference of European Statisticians*. Federal Statistical Office, Federal Republic of Germany, Wiesbaden.

Fellegi, I.P. 1996. Characteristics of an Effective Statistical System. *International Statistical Review,* 64(2).

Freedman, D.H. 1992. Is Management Still a Science? *Harvard Business Review*. November-October 1992: 26-38.

Goleman, D. 1998. What Makes a Leader? *Harvard Business Review*. November – December 1998: 93-102.

Groves, R.M. 1989. *Survey Errors and Survey Costs*. John Wiley and Sons, New York.

Kish, L. 1965. *Survey Sampling*. John Wiley and Sons, New York.

Linacre, S.J. and D.J. Trewin. 1989. Evaluation of Errors and Appropriate Resource Allocation in Economic Collections. *Proceedings of the Annual Research Conference*. U.S. Bureau of the Census. 197-209.

Lyberg, L., P. Biemer, M. Collins, E. de Leeuw, C. Dippo, N. Schwarz and D. Trewin, eds. 1997. *Survey Measurement and Process Quality*. John Wiley and Sons, New York.

Pinto, J.K., ed. 1998. *The Project Management Institute Project Management Handbook*. Jossey-Bass Inc, San Francisco.

Project Management Institute. 2000. *A Guide to the Project Management Body of Knowledge*. 2000 Edition. Project Management Institute, Newton Square, PA.

Smith, T.M.F. 1995. Problems of Resource Allocation. *Proceedings: Symposium 95, From Data to Information – Methods and Systems*. Statistics Canada. 107-114.

Statistics Canada. 2000. Policy on Informing Users of Data Quality and Methodology. *Policy Manual*. 2.3.

Statistics Canada. 1987. *Quality Guidelines*. Second Edition.

Statistics Canada. 1998. *Statistics Canada Quality Guidelines*. Third Edition. 12-539-X1E.

Statistics Canada. 2002. *Quality Assurance Framework*.

Sull, D.N. 1999. Why Good Companies Go Bad? *Harvard Business Review*. July-August 1999: 42-52.

Wang, R.Y. and D.M. Strong. 1996. Beyond Accuracy: What Data Quality Means to Data Consumers. *Journal of Management Information Systems,* 12(4): 5-34.

Planning Checklist

The following are some considerations when planning the steps of the survey:

1. Formulation of the Statement of Objectives

- the information needs of the survey;
- the primary uses and users of the data;
- concepts and operational definitions;
- the survey content;
- the analysis plan (i.e., the framework and level of detail of the survey results).

See **Chapter 2 - Formulation of the Statement of Objectives**.

2. Selection of a Survey Frame

- define target population;
- define survey population based on available frames;
- area versus list frame versus multiple frame;
- use of existing frames;
- cost to build a new frame;
- available data to create frame;
- frame units;
- quality of the frame:
  - undercoverage;
  - overcoverage;
  - duplicates;
- how up-to-date is the frame?

See **Chapter 3 - Introduction to Survey Design**.

3. Determination of the Sample Design

- census versus sample;
- for sample surveys, probability versus non-probability sampling;
- if probability sampling:
  - simple random sampling;
  - stratified simple random sampling;
  - cluster sampling;
  - multi-stage sampling;
  - multi-phase sampling.
- if stratified sampling:
  - stratification variables;
  - method of allocating sample to strata;
- sample size;
- method of estimation;
- desired level of precision (variance) of estimates;
- repeated or once-only survey?

See **Chapter 6 - Sample Designs, Chapter 7 - Estimation** and **Chapter 8 - Sample Size Determination and Allocation**.

4. Questionnaire Design

-   method of collection:
    -   interviewer-assisted, self-enumeration or direct observation;
-   if interviewer assisted:
    -   personal or telephone;
-   if self-enumeration:
    -   method of delivery and pick-up of questionnaire;
-   use of some administrative data for some data collection?
-   use of proxy respondents?
-   questionnaire content;
-   question wording;
-   question types:
    -   closed versus open answers;
-   order of questions.

See **Chapter 4 - Data Collection Methods** and **Chapter 5 - Questionnaire Design**.

5. Data Collection

-   how to locate and contact selected units;
-   selection of interviewers;
-   training of interviewers;
-   supervision of interviewers;
-   controlling documents (tracking number of questionnaires completed, etc.);
-   field work procedures;
-   control of quality of field work:
    -   observation of interviewers;
    -   re-interviews;
-   field edits;
-   follow-up of nonresponse.

See **Chapter 9 - Data Collection Operations.**

6. Data Capture and Coding

-   data capture;
-   coding data:
    -   classification schemes to be used;
-   methods of measuring, controlling and correcting errors:
    -   quality assurance;
    -   quality control.

See **Chapter 10 - Processing** and **Appendix B - Quality Control and Quality Assurance**.

7.   Editing and Imputation

-   field edits to be performed;
-   edits to be performed after field collection (both manual and automated edits);
-   type of edits to be performed:
    -   validity edits;
    -   consistency edits;
-   consistency of edits;
-   methods of imputation to be used;
-   consistency of imputation;
-   preparing and testing edit and imputation systems.

See **Chapter 10 - Processing**.

8.   Estimation

-   calculation of design weights;
-   possible adjustments for:
    -   total nonresponse;
    -   auxiliary data;
-   parameters to be estimated (point estimates):
    -   totals;
    -   ratios;
    -   proportions, etc.
-   estimators for point estimates;
-   estimators for sampling variance of point estimates.

See **Chapter 7 - Estimation**.

9.   Data Analysis and Presentation of Survey Results

-   measures of sampling error;
-   measures of non-sampling error:
    -   coverage error;
    -   nonresponse (e.g., nonresponse rates);
    -   measurement error;
    -   processing error (e.g., edit failure rates);
-   methods of measuring, controlling and correcting errors:
    -   quality assurance;
    -   quality control;
-   evaluation of all survey operations;
-   type of analyses to be performed;
-   tabulation of data;
-   reports to be generated;
-   methods of disclosure control;
-   suppression of data versus modification of data.

See **Chapter 11 - Analysis of Survey Data**, **Chapter 12 - Data Dissemination** and **Appendix B - Quality Control and Quality Assurance.**

10. Data Dissemination

- users and uses;
- vehicle for dissemination:
  - paper publication;
  - public speech or presentation;
  - television or radio interview;
  - microfiche;
  - electronic media:
    - internet;
    - microdata file;
- methods of disclosure control.

See **Chapter 12 - Data Dissemination**.

11. Documentation

- intended audience:
  - management;
  - technical staff;
  - planners of other surveys;
  - etc.;
- survey report;
- methodology reports;
- data quality evaluation reports;
- training manuals (e.g., for interviewing);
- performance reports on interviewers;
- instruction manuals (e.g., for respondents);
- schedule of activities;
- specifications for systems programs;
- feasibility report;
- progress reports;
- survey report (documenting the implementation of all steps of the survey);
- data analysis report;
- general report versus technical reports.

See **Chapter 9 - Data Collection Operations** for documentation of field operations and **Chapter 12 - Data Dissemination**, for documentation in general.

Cost Checklist

Some factors to take into account when assessing survey costs include:

- planning;
- design and development:
  - survey design;
  - survey procedures (e.g., data collection);
  - post survey processing;
- evaluation of survey;
- documentation;
- training personnel.

Costs for *survey processing* would include personnel time, hardware and software purchases or rental and other services – offices, furniture, supplies.

The design and development of a *Computer Assisted Interview (CAI) application* depends on the following criteria:

- the length and complexity of the questionnaires;
- the number and complexity of the built-in edits;
- the software package used;
- the requirements to prefill information from a previous cycle;
- the functionalities required such as tracing, management reports, etc.;
- the sampling system i.e., random digit dialling or telephone lists, etc.;
- the training package to be built into the application;
- the number of revisions to the specifications;
- the time frame for the development;
- the testing requirements;
- the size of the sample (i.e., if special actions required because of large volume of data).

The following factors determine the cost of *training personnel*:

- type of training (classroom, home study, etc.);
- levels of training (who trains whom);
- duration (hours, days);
- location;
- number of interviewers trained;
- equipment rental (e.g., telephone, computers, PC viewer).

The cost of *data collection* is based on the following factors:

- sample size;
- sample distribution;
- sample frame;
- length of interview;
- data collection methodology (personal, telephone, mail, etc.):
  - e.g., number of interviewers if interviewer-assisted;
- response rate expected;
- follow-up strategy;

- target population (proxy vs. non-proxy interview);
- tracing requirements;
- data collection time frame;
- manual edits and coding;
- data capture and verification requirements;
- equipment rental (telephone, computers);
- space rental;
- cost of travelling for interviewers.

Appendix A - Administrative Data

1.0 Introduction

Demands for statistics on many aspects of society continue to grow. Of course, one method of obtaining statistical data is through the use of surveys. However, budget constraints and concerns about respondent burden have led statistical agencies to examine alternative methods of obtaining statistical data. One alternative is the use of administrative data. ***Administrative data are those that have been collected for administrative purposes (e.g., to administer, regulate or tax activities of businesses or individuals) as opposed to statistical purposes (to study groups of individuals, businesses, farms, etc.)***.

2.0 Using Administrative Data

The main statistical uses of administrative data are:

i.   Direct tabulation or analysis

This means that the administrative data are the main source of data for some or all of the sample units. The data are aggregated, analysed and disseminated in the same fashion as survey data. When administrative data are used to replace a sample survey, the statistical agency must implement some, but not all, of the survey steps discussed in this manual. For example, data collection, capture and coding would normally be done by the administrative organisation, but the statistical agency would still need to perform editing, imputation and data analysis. In some cases, administrative data may be the only practical source of data (e.g., detailed information on health costs).

ii.   Indirect estimation

This includes the use of administrative data as an input to the estimation system, through regression estimation, calibration, etc. For example, using administrative data for auxiliary variables in model. For more detail, see **Chapter 7- Estimation**. It also includes the combination of data from several administrative sources to produce estimates.

iii.   Survey frames

Administrative data are often used to create, supplement or update survey frames. For more information on survey frames, see **Chapter 3- Introduction to Survey Design**.

iv.   Survey evaluation

Administrative data can be used to evaluate survey data at a micro or aggregate level. For more details, see **Chapter 12- Data Dissemination**.

There are six major sources of administrative data:

i.   Records maintained to regulate the flow of goods and people across borders. These include records of imports, exports, immigration and emigration.

ii.   Records resulting from legal requirements to register events such as births, deaths, marriages, divorces, business incorporations, licensing, etc.

iii.   Records needed to administer benefits or obligations such as taxation, employment insurance, pensions, health insurance, family allowances, voter lists, etc.

iv.   Records needed to administer public institutions such as schools, universities, health institutions, courts, prisons, etc.

v.   Records arising from the government regulation of industry such as transportation, banking, broadcasting, telecommunications, etc.

vi.   Records arising from the provision of utilities such as electricity, telephones, water, etc.

The usefulness of administrative data depends on their concepts, definitions and coverage (and the extent to which these factors stay constant), the quality with which the data are reported and processed, and the timeliness of their availability. These factors can vary widely depending on the administrative source and the type of information. Before deciding to use administrative data, they should be thoroughly evaluated, keeping in mind the following considerations:

i.   Timeliness

Depending on the source of the information, a survey that uses only administrative data may be able to produce results in a more timely fashion than a sample survey. Conversely, the administrative program may be slower at producing data than a sample survey (particularly if the administrative data constitute a census or if they have to be collected from several government jurisdictions). Processing the administrative data after receipt may be particularly slow if many files must be combined.

ii.   Cost

Many of the survey steps may be eliminated (particularly, data collection), thereby lowering costs.

iii.   Response burden

If administrative data are used in lieu of administering a questionnaire then there is no response burden.

iv.   Coverage

The target population is defined by administrative requirements, which may not coincide with statistical requirements.

v.   Content

Since the content is defined by administrative requirements, not all topics of interest may be covered by the administrative data.

vi.   Concepts and definitions

The administrative program, designed for other objectives, may use different concepts or definitions than the survey taker would have chosen. In fact, the concepts used by the administrative source may not be suitable for the research problem.

vii.   Sampling error

If the administrative data cover the entire target population (i.e., constitute a census), then there is no sampling error. If the administrative data replace data for a sample of the population, sampling error is still present.

viii.   Nonsampling errors

Control of nonsampling errors is often more difficult than for a sample survey. The administrative data may contain more errors or omissions than would survey data (making editing and imputation crucial). Also, whenever individuals or businesses benefit or lose based on the information they provide to the administrative source, bias may be present in the information supplied. In some cases, administrative data may contain fewer errors than survey data, for example, when recall error may impair the ability of the respondent to accurately answer the questions or when the respondent is likely to round their answer to a survey question (income).

ix.   Quality control

The quality of data collection, data capture and coding are under the control of the administrative program and may be less stringent than that used by a statistical agency. Therefore, it is necessary to implement continuous or periodic assessment of incoming data quality

x.   Reliability of the administrative source

The administrative source may not be reliable in terms of consistently providing the data when needed. Also, it is possible that the coverage, content and concepts may change over time. Therefore, one should collaborate with the designers of the administrative system and maintain contact to remain up-to-date on proposed changes to concepts, definitions, coverage, frequency and timeliness that may affect their statistical use and to lobby for changes that will enhance rather than detract from their statistical use.

xi.   Format of the data

The administrative data may not be in a convenient format. For example, the data may only be in aggregate form while the statistical agency would prefer individual records for each unit. The data may come from more than one source introducing the problem of matching and standardising data across different formats. Also, the files may not be well documented.

xii.   Privacy issues

The use of administrative data may raise concerns about the privacy of the information in the public domain, particularly if the administrative records are linked to other sources of data. Therefore, one should consider privacy implications and disclosure control issues, especially when linking to other files.

Bibliography

Brackstone, G.J. 1987. Issues in the Use of Administrative Records for Statistical Purposes. *Survey Methodology,* 13(1): 29-43.

Brackstone, G.J. 1988. Statistical Uses of Administrative Data: Issues and Challenges. Proceedings of Symposium on Statistical Uses of Administrative Data. Statistics Canada.

Cox, L.H. and R.F. Boruch. 1988. Record Linkage, Privacy and Statistical Policy. *Journal of Official Statistics*. 4: 3-16.

Hidiroglou, M.A., M. Latouche, B. Armstrong and M. Gossen. 1995. Improving Survey Information Using Administrative Records: The Case of the Canadian Employment Surveys. *Proceedings of the Annual Research Conference*. U.S. Bureau of the Census. 171-197.

Internal Revenue Service. 1999. *Statistics of Income: Turning Administrative Systems into Information Systems*. Washington, D.C.

Internal Revenue Service. 2000. *Statistics of Income Bulletin*. 19(4). Washington, D.C.

Kilss, B. and W. Alvey, eds. 1984. *Statistical Uses of Administrative Records: Recent Research and Present Prospects*. 1. Department of the Treasury. Internal Revenue Service. Statistics of Income Division.

Kilss, B. and W. Alvey, eds. 1984. *Statistical Uses of Administrative Records: Recent Research and Present Prospects*. 2. Department of the Treasury. Internal Revenue Service. Statistics of Income Division.

Konschnik, C.A., J.S. Johnson and J.N. Burton. 1998. The Use of Administrative Records in Current Business Surveys and Censuses. *Proceedings of the Section on Survey Research Methods*. American Statistical Association. 202-207.

Michaud, S., D. Dolson, D. Adams and M. Renaud. 1995. Combining Administrative and Survey Data to Reduce Respondent Burden in Longitudinal Surveys. *Proceedings of the Section on Survey Research Methods*. American Statistical Association. 11-20.

Monty, A. and H. Finlay. 1994. Strengths and Weaknesses of Administrative Data Sources: Experiences of the Canadian Business Register. *Statistical Journal of the United Nations,* ECE 11: 205-210.

Singh, M.P., J. Gambino and H.J. Mantel. 1994. Issues and Strategies for Small Area Data. *Survey Methodology*, 20(1): 3-22.

Statistics Canada 1996. Policy on Informing Survey Respondents. *Policy Manual*. 1.1

Statistics Canada 1996. Policy on Record Linkage. *Policy Manual*. 4.1

Statistics Canada. 1998. *Quality Guidelines*. Third Edition. 12-539-XIE/F.

Sweet, E.M. 1997. Using Administrative Record Persons in the 1996 Community Census. *Proceedings of the Section on Survey Research Methods*. American Statistical Association. 416-421.

Wolfson, M., S. Gribble, M. Bordt, B. Murphy and G. Rowe. 1987. The Social Policy Simulation Database: An example of Survey and Administrative Data Integration. *Proceedings of the International Symposium on the Statistical Uses of Administrative Data*. Statistics Canada. 201-229.

Appendix B - Quality Control and Quality Assurance

1.0   Introduction

There are a host of problems that, if not anticipated and controlled during implementation of the survey, can introduce non-sampling errors to the point of rendering survey results useless. In order to minimise and control errors that can be introduced at various stages of a survey, it is good practice to devote a part of the overall survey budget to quality control and quality assurance programs.

Quality control is a technique used to ensure that quality is above an established level by measuring the quality characteristic of interest, comparing it to a standard and taking corrective action if the standard is not achieved.

Quality assurance includes all activities that are aimed at ensuring quality. The goal of quality assurance is to prevent, reduce or limit the occurrence of errors in a survey – to get it right the first time. Quality assurance follows a comprehensive approach to ensuring quality whereby all processes and systems are well-planned, tested and monitored to ensure that they are performing as expected. Thus, quality assurance anticipates problems while quality control responds to observed problems.

Before explaining quality control and quality assurance procedures in more detail, a definition of quality is required. At Statistics Canada, quality is defined as 'fitness for use' of the data. Fitness for use encompasses not only the statistical quality concepts of variance and bias, but also other characteristics such as relevance and timeliness that determine how effectively statistical information can be used.

Statistics Canada defines quality or 'fitness for use' of statistical information in terms of six constituent elements or dimensions: relevance, accuracy, timeliness, accessibility, interpretability and coherence (Statistics Canada, 2002).

The ***relevance*** of statistical information reflects the degree to which it meets the real needs of clients. It is concerned with whether the available information sheds light on the issues of most importance to users. Assessing relevance is a subjective matter dependent upon the varying needs of users. The statistical agency's challenge is to weigh and balance the conflicting needs of current and potential users to produce a program that goes as far as possible in satisfying the most important needs within given resource constraints.

The ***accuracy*** of statistical information is the degree to which the information correctly describes the phenomena it was designed to measure. It is usually characterized in terms of error in statistical estimates and is traditionally decomposed into bias (systematic error) and variance (random error) components. It may also be described in terms of the major sources of error that potentially cause inaccuracy (e.g., sampling, coverage, measurement, nonresponse, processing).

The ***timeliness*** of statistical information refers to the delay between the reference point (or the end of the reference period) to which the information pertains, and the date on which the information becomes available. It is typically involved in a trade-off against *accuracy*. The *timeliness* of information will influence its *relevance*.

The ***accessibility*** of statistical information refers to the ease with which it can be obtained from the statistical agency. This includes the ease with which the existence of information can be ascertained, as well as the suitability of the form or medium through which the information can be accessed. The cost of the information may also be an aspect of *accessibility* for some users.

The ***interpretability*** of statistical information reflects the availability of the supplementary information and metadata necessary to interpret and utilize it appropriately. This information normally covers the underlying concepts, variables and classifications used, the methodology of data collection and processing, and indications of the accuracy of the statistical information.

The ***coherence*** of statistical information reflects the degree to which it can be successfully brought together with other statistical information within a broad analytic framework and over time. The use of standard concepts, classifications and target populations promotes coherence, as does the use of common methodology across surveys. *Coherence* does not necessarily imply full numerical consistency.

These elements of quality are overlapping and interrelated. It is very difficult to build an effective statistical model bringing them all together in a single indicator. There have been but few attempts (see Linacre and Trewin, 1993), except in simple or one-dimensional cases, at developing a general statistical model for determining whether any particular set of the quality characteristics achieved would provide higher overall quality than another set.

Achieving an acceptable level of quality is ultimately the result of addressing, managing and balancing over time the various elements that constitute quality, with due attention to the program objectives, the major uses of the data, costs, and the conditions and circumstances that affect quality and user expectations. As the elements of quality form a complex relationship, an action taken to address or modify one aspect of quality will tend to affect other elements of quality. Thus the balance of these factors may be altered in ways that cannot be readily modelled or adequately quantified in advance. The decisions and actions which achieve this balance are based on knowledge, experience, reviews, feedback and consultation, and inevitably on judgement.

2.0   Quality Control

Quality control is used to measure actual performance, compare it to standards and act on the difference. Thus it focuses on one element of quality: accuracy. Quality control is most commonly applied at the processing stage of a survey to work that is typically performed by persons with various levels of training and ability, and where the task is repetitive and manual. It therefore applies to activities such as coding, data capture and editing.

Quality control is directed only at what can be measured and judged acceptable or not; if measurement is not possible, then quality control cannot be performed. Sometimes, where measurement is possible, quality control may be too expensive and time-consuming to implement (e.g., assessing whether the answer to an open question was properly coded).

Usually, the amount and significance of error varies between activities and between individuals working on the same activity. Quality control can be used to identify significant contributors to error and to ensure acceptable outgoing quality levels.

Statistical quality control is the application of statistical techniques for measuring against standards and achieving a given level of quality. Statistical quality control programs ensure that error levels, introduced as a result of survey operations, are controlled to within specified levels, with minimum inspection.

The outputs of work activity can be viewed from two different quality perspectives. On the one hand, the outputs represent individual products (or services) that either conform to standards or not. On the other hand, the work may be viewed as a sequence of tasks that are performed under relatively stable conditions to produce the required outputs (i.e., a process perspective). Both views are valid and are required

depending on the process assumptions and the purpose of the quality control procedure. These two views give rise to two fundamental methods of quality control: statistical product control and statistical process control.

2.1   Statistical Product Control

Statistical product control uses sampling and decision rules to determine which batches of work are acceptable and which are not. With product control, the focus is on the individual batch, not the process. The purpose of quality control here is to determine which individual units or batches of units conform to established quality requirements. Product control is corrective since batches that are identified as not meeting the quality standard are improved (re-worked). Also, any errors found in the sample used to measure the quality of the work are usually corrected. (Errors in 'accepted' samples may not always be corrected, for example errors occurring during data collection that would require follow-up with the respondent.) Although it is good practice to determine and correct if possible the causes of poor quality, this is not necessary. *Acceptance sampling* is the main tool.

2.1.1   Acceptance Sampling

Acceptance Sampling is a quality control technique that establishes the sample design and the decision rules to determine which batches are acceptable or unacceptable. In its simplest form, acceptance sampling involves dividing the work into batches, selecting and checking a probability sample from each batch and accepting or rejecting the batch depending on the extent of errors encountered in the sample. The remainder of rejected batches is usually completely inspected and rectified as required.

Specifically:
-    production is grouped into batches of units of size *N*;
-    a sample of size *n* is selected from each of the batches;
-    the units of work in the sample are inspected;
-    the total error count, *d*, in the sample is compared with a predetermined limit, the acceptance number, *c*;
-    if $d > c$ then the batch is rejected and the remainder of the batch is inspected; if $d <= c$ then the batch is accepted and no further inspection is done.

Batching of work is generally done to create batches which are as homogeneous (in terms of quality) as possible. Batches usually contain the work of only one person, over a relatively short time period. If the person is working on different types of cases (for example, coding two different variables at the same time), batches should only contain one type of case. However, larger batches tend to result in less inspection, so a compromise must be found.

The sampling plan is specified by the two numbers *n* and *c*. The method of determining these two parameters depends on the goals of quality control. There are many different forms of acceptance sampling. In survey processing applications, the values of *n* and *c* are selected to provide an outgoing error rate below a certain value, called the *average outgoing quality limit* (AOQL), while minimising the total amount of inspection required. This method aims to ensure that the overall quality of the work (over all batches combined) is above a certain quality level. Thus, it ensures that once quality control is finished the overall proportion of units still in error is below the AOQL.

The values of *n* and *c* depend on:
-    the expected incoming quality (before inspection);
-    the desired overall outgoing quality;

- the batch size, *N;*
- the probability of a good batch being rejected (Type I error);
- the probability of a bad batch being accepted (Type II error).

Other considerations affecting the quality control methodology include:
- the definition of the sampling unit (e.g., part of the questionnaire, all of the questionnaire);
- batch formation (e.g., one day's work);
- the quality measure (e.g., percent defective or defects per hundred units);
- definition and classification of errors;
- the sample selection method (e.g., simple random sample (SRS), systematic, cluster sampling);
- feedback procedures.

For more information on Acceptance Sampling and how to calculate sampling plans see, Smith and Mudryk (1989), Duncan (1986), Dodge and Romig (1959) or Hald (1981).

Wherever a formal quality control program has been put into place, feedback is usually an integral part of the program. Verbal or written feedback is normally provided through reports, tables or graphs of the quality results and assessments compiled during the inspection process. These results are then fed back regularly to various levels of staff associated with the survey operation. Feedback can help to reduce error, which may enable a relaxation of sampling rates (reduction of *n*) thus reducing costs.

Some examples of feedback include:

i.   Providing operators (e.g., processing clerks) with information on group performance and their personal performance (current and historical) and the most frequent causes of their errors. They are then able to track their own progress, compare their performance with that of their peers and identify explicitly where they are making errors. Such feedback improves their ability, morale and productivity.

ii.   Providing supervisors with feedback on operator performance. This information includes error rates, inspection and rejection rates and estimates of outgoing quality. This provides the supervisors with information to effectively manage staff, allocate resources and distribute work, identify problem operators and areas and determine training needs.

iii.   Providing management with summaries of key quality indicators. This helps management track the progress of the application in terms of quality and costs, recommend changes to operational objectives and obtain an assurance of quality for the survey process. Over a sustained period, it may lead to changes in methodology, changes in procedures or modified sampling plans resulting in reduced inspection.

2.2   Statistical Process Control

A process is a planned sequence of activities directed toward a desired outcome or goal, for example, manufacturing an automobile component. Each step in conducting a survey can be thought of as a process, for example, selecting a sampling frame, selecting the sample, collecting the data, processing the data, etc. There are inputs and outputs to any process. The inputs can include: people, material, methods, equipment, environment, management. The outputs of the process are the product or service.

With statistical process control, the work outputs must be the result of a well-defined and consistent process which is fairly predictable in terms of its outputs and which consistently produces output that

meets or exceeds the quality standard. Such a process is said to be 'in control'. Under this approach, the purpose of quality control is to sample the well-behaved process at specific intervals of time to determine if anything in the process has changed (i.e., deteriorated).

Statistical process control is the application of statistical techniques for measuring and analysing variation in processes. Variation always exists since outputs produced by the same process vary somewhat. Sampling (via SRS, systematic, cluster sampling, etc.) and decision rules are used to monitor process quality and trigger action when there is evidence that the process is no longer in control (i.e., out of control). This procedure does not react to minor fluctuations in the measurements that may be due to sampling variability. However, when measurements deviate significantly, the reasons for the deviations are determined and corrections to the process are made to bring it back in control.

Process control is a preventative measure since the causes of error are identified and removed thus preventing large amounts of defective output. No effort is made to directly improve quality by correcting errors. The focus is on identifying the causes of errors and removing them. If operationally feasible, the process is halted when it goes out of control until the causes of the increase in errors are found and removed.

While it is usually possible to identify the root cause of most problems, sometimes this may be difficult. Several tools are available to help accomplish this including control charts, Pareto analysis, cause and effect diagrams, brainstorming, etc. For more on Pareto analysis and cause and effect diagrams, see Juran and Godfrey (1998).

As with product control, feedback on process control should be provided to operators, their supervisors and management.

2.2.1   Control Charts

The control chart is the main tool for statistical process control. A control chart plots consecutive sample measurements collected periodically from a process and examines whether they are within the limits set by the process variation. The limits set are called control limits. The upper and lower limits may be assigned based on an expert's knowledge of the process or, more commonly, they are set to three standard deviations from the centre line, where the centre line represents the average value and is referred to as the process average. This is equivalent to calculating the boundaries of a confidence interval (**see Chapter 8 - Sample Size Determination and Allocation**). The control lines are values outside of which the process is considered to be out of control. The vertical axis represents the quality measure (such as the percent defective) and the horizontal axis shows the value of each sample observation in time sequence.

In general, if all sample observations fall within the control limits, the process is considered to be in control. If one or more observations fall outside the control limits, an investigation should be conducted. Even if no observation falls outside the control limits, but certain trends are observed, such as several samples in a row falling above the centre line, or a steadily increasing error rate, an investigation should be performed.

Different control charts are available depending on the quality measure used and whether the sample size is fixed or variable. The most common attribute control chart is the *p* chart, illustrated below.

Process Control Chart
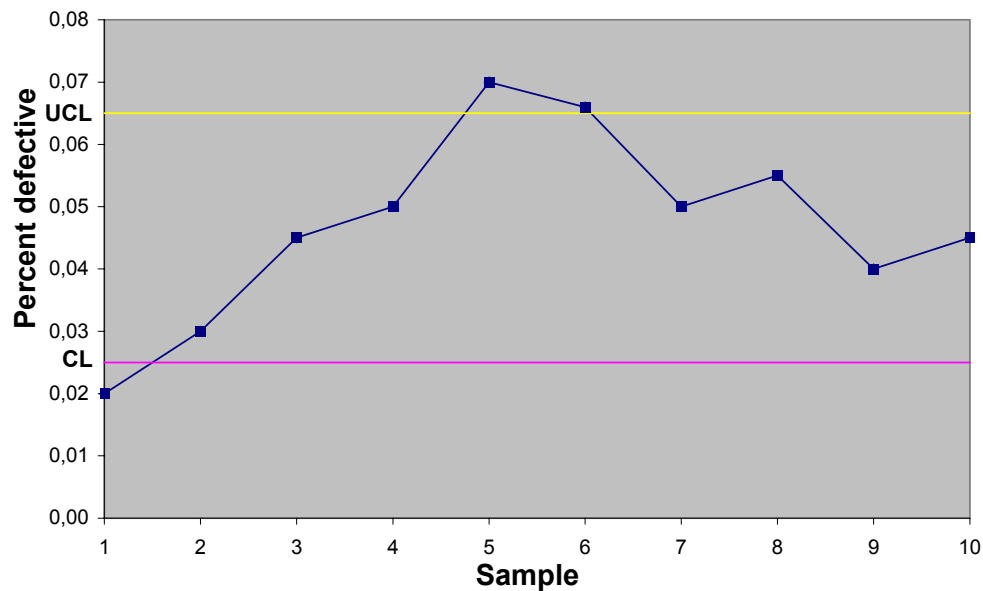
Note that the graph above does not include the lower control limit; typically, in survey operations where the measure of interest is the error rate, the lower control limit is not of interest since there is no cause for concern if the error rate drops.

For details on other control charts as well as, on how to calculate their centreline and control limits see, Duncan (1986), Schilling (1982) or Wheeler (1986).

2.3   Statistical Product Control versus Statistical Process Control

In Statistical product control (usually acceptance sampling), the focus is on the output of the process – the product. The goal in survey applications is to find and correct enough errors in the product to ensure that the quality meets the standard. Quality control plans may be set up to minimise the probability of a batch of poor quality getting through (i.e., minimise the probability of a type II error), or they may be set up to ensure that the overall quality, over all batches, is acceptable. With Statistical process control, the focus is not on finding and correcting errors, but to assume that the quality is already acceptable – no correction of errors is needed – and to simply take samples of the work and measure the quality periodically to make sure that this assumption is still correct. If the data indicate that the assumption is false, then rather than correct errors to ensure quality, the cause of the problem in the process is determined and corrected.

Statistical process control is used less frequently in survey operations since it requires an operation that has been demonstrated to be consistently and reliably producing the required quality. In survey operations involving manual processing, this is rarely the case. As operators become more reliable, they tend to get promoted or switch to another project. Furthermore, if a clerk suddenly starts producing work with a significantly higher error rate, it may be difficult to bring the error rate back down quickly, as the cause may be due to fatigue, boredom, attitude, etc.

However, statistical process control is always preferable to acceptance sampling because it costs less; statistical process control samples tend to be much smaller than the amount of sampling required to do

acceptance sampling.

One area where statistical process control has proven useful is in automated data capture operations (Intelligent Character Recognition). Statistical process control was used for the capture of the 2001 Canadian Census of Agriculture. Since the work was done by a machine, once it could produce the required quality, it could be trusted to continue to do so. If the error rate suddenly went up, simple adjustments or replacement of a work part usually corrected the problem. Another place where statistical process control is used is in monitoring of CATI operations. In this case, calls are sampled and errors tabulated (e.g., questions not asked properly, a rude operator, etc.). Because such errors cannot be corrected, a statistical process control is taken.

2.4   Acceptance Control

An important question that needs to be addressed in survey operations is when to apply which method of statistical quality control, specifically *acceptance sampling* or *statistical process control*. As explained above, many survey processes start out being highly unpredictable since they involve a large staff with high turnover. However, with training, experience and ongoing feedback, these processes often become more stable over time. Therefore it is often good practice to take advantage of this stabilisation and modify the inspection procedures so that the rates of inspection and associated costs can be reduced.

Various inspection strategies are available to address the changing stability of an operation, including: reduced inspection (i.e., taking smaller samples with a greater risk of accepting poor quality), tightened inspection (i.e., taking larger samples with a lower risk of accepting poor quality), normal inspection, 100% inspection, statistical process control and spot checks. It may also require relaxing the quality target if it is too costly or time-consuming to achieve.

The method that should be used depends on the amount of process stability that is evident in the process and the quality of the process. Generally speaking, the more stable and predictable that a process is and the higher its quality, the less inspection that is required (i.e., more sampling risk can be justified).

Schilling (1982) postulated the *acceptance control approach which involves a continuing strategy of selection, application and modification of acceptance sampling procedures to a changing inspection environment*. The inspection procedures are periodically modified as a function of the *quality level* that is achieved and the *quality history* that is available. The overriding principle in acceptance control is to continually adapt the acceptance procedures to existing conditions (which generally change over time). The framework of when to switch inspection procedures is shown in the following table. This table is discussed in greater detail in Chapter 19 of Schilling (1982).

It can be seen in Table 1 that the inspection process under acceptance control becomes dynamic and changes as the process improves or degrades. In general, as the quality improves and the quality history to support this becomes extensive, sampling plans are modified from normal plans to reduced plans to skip-lot plans (acceptance sampling where some batches are skipped – not inspected – if the quality in previously inspected batches is high enough), to statistical process control plans to periodic spot checks. The ultimate aim of the acceptance control strategy is to reduce inspection and its associated costs continually, while at the same time maintaining the specified quality levels.

Table 1: Acceptance Control - Inspection Procedure by Quality History and Past Results
Relative Quality History

Past Results	Little	Moderate	Extensive
	< 10 Lots	10 to 50 Lots	> 50 Lots
Excellent	Normal Plan	Reduced / Skip-Lot	Statistical Process Control / Spot Checks
Average	Normal Plan	Normal Plan	Reduced / Skip-Lot
Poor	100%	100% / Tightened	100% / Tightened

3.0   Quality Assurance

Since errors can be expensive and difficult to resolve, emphasis should be placed on error prevention in the early stages of the survey. Quality assurance encompasses all elements of quality; its goal is to prevent problems from occurring in the first place.

For example, a general quality assurance strategy for the control of non-sampling errors is to anticipate problems before they happen and take steps to prevent or minimise them, ideally at the planning and design phases of the survey. The survey must also be designed and implemented to ensure, for example, that the data are relevant to users and produced in a timely manner and that users are made aware the data are available in a medium they can access.

Examples of quality assurance include:
- intensive planning;
- conducting a feasibility study;
- conducting a pilot survey (i.e., testing entire survey system from start to finish on a small scale);
- training for interviewers, supervisors, data capture operators, coders, etc.;
- debriefing exercises;
- improving the sampling frame;
- improving the sample design;
- improving the questionnaire design;
- modifying the data collection methodology (e.g., moving from paper-based to computer-assisted collection);
- better follow-up routines;
- clearer processing procedures;
- thoroughly testing all processing systems before they are used;
- spot-checking data collection and outputs of other major survey activities.

Statistics Canada's Quality Guidelines (1998) recommends the following quality assurance activities during the design and implementation phase of a survey:

i.   Use of a project management and steering committee regime to ensure that statistical programs are carried out according to their mandate. This provides a mechanism to review, monitor and report on progress, problems and issues; and to ensure the proper interpretation of the mandate and objective and that appropriate judgements are being made.

ii.   Use of an interdisciplinary project team/project management approach for the design and implementation to ensure that quality considerations receive appropriate attention.

iii.   Whenever specific methods are applied, they should be within the realm of commonly accepted and defensible statistical practices under the given circumstances. The use of new technologies and innovations to improve quality and efficiency should be encouraged, but well tested to minimise risk. Questionnaires should be tested to ensure that respondents understand the questions and can provide the desired responses with an acceptable level of quality. It is important to monitor quality, react effectively to unanticipated problems and verify or support the credibility of the results, as well as understand their limitations.

iv.   At the design or redesign phase and as part of ongoing reviews, there should be technical assessments of methods proposed or in place, as well as evaluations of operational effectiveness and cost performance. These will serve as a test of the suitability of the technical proposals or practices. They will also serve to improve and guide implementation of specific components of methodology and operations, within and across programs.

v.   Besides being used to inform and to describe statistical phenomena and to recognize data gaps, data analysis should also be a means to assess or to measure the accuracy and coherence of the data. In this context, the results of analysis may lead to, for example, additional or modified editing procedures, questionnaire design changes, supplementary data collection procedures, additional staff training, the adoption of new methods, procedures or systems, or to a redesign.

With respect to the working environment, it is important to foster an environment that encourages a concern for quality and the production of the best quality possible within operational and budgetary constraints. This includes:
- the recruitment of talented staff and their development to appreciate quality issues;
- an open and effective network of internal communications;
- explicit measures to develop partnerships and understanding with the agency's suppliers (especially respondents);
- the development and maintenance of standard definitions, classifications, frameworks and methodological tools to support interpretability and coherence.

Finally, all quality control and quality assurance procedures should be documented. This documentation should include:

i.   Options, eventual choice and justification: The particular choice of quality control and quality assurance procedures for any operation is not obvious and the factors that were taken into consideration should be discussed.

ii.   Procedures: A set of instructions and/or a manual for supervisors and those performing the verification should be produced.

iii.   Reports: Periodic reports on the results of the quality control procedures and the performance of individual operators should be produced so that the quality can be reported or individual operators identified for retraining.

Bibliography

Brackstone, G. 1999. Managing Data Quality in a Statistical Agency. *Survey Methodology*. 25(2): 139-149.

Dodge, H.F. and H.G. Romig. 1959. *Sampling Inspection Tables: Single and Double Sampling*. Second edition. John Wiley and Sons, New York.

Dufour, J. 1996. *Labour Force Survey Data Quality*. Statistics Canada. HSMD-96-002E/F.

Duncan, A.J. 1986. *Quality Control and Industrial Statistics*. Fifth edition. R.D. Irwin Inc., Illinois

Fellegi, I.P. 1996. Characteristics of an Effective Statistical System. *International Statistical Review*. 64(2).

Groves, R.M. 1989. *Survey Errors and Survey Costs*. John Wiley and Sons, New York.

Hald, A. 1981. *Statistical Theory of Sampling Inspection by Attributes.* Academic Press, New York.

Juran, J.M. and A.B. Godfrey. 1998. *Juran's Quality Handbook.* Fifth Edition. McGraw-Hill, New York.

Linacre, S.J. and D.J. Trewin. 1989. Evaluation of Errors and Appropriate Resource Allocation in Economic Collections. *Proceedings of the Annual Research Conference*. U.S. Bureau of the Census. 197-209.

Linacre, S.J. and D.J. Trewin. 1993. Total Survey Design – An Application to a Collection of the Construction Industry. *Journal of Official Statistics*. 9(3): 611-621.

Lyberg, L. 1997. *Survey Measurement and Process Quality*. John Wiley and Sons, New York.

Mudryk, W. 2000. Course Reference Manual for *Statistical Methods for Quality Control – Course 0446*. Statistics Canada.

Mudryk, W., M.J. Burgess and P. Xiao. 1996. Quality Control of CATI Operations in Statistics Canada. *Proceedings of the Section on Survey Research Methods*. American Statistical Association. 150-159.

Schilling, E.G., 1982. *Acceptance Sampling in Quality Control*. Marcel Dekker, New York.

Smith, J., W. Mudryk and R. Stankewich. 1989. *Standardization of QC Sampling Plans for Survey Operations, Part 1: Guidelines and Rationale*, Quality Control Section, Business Survey Methods Division, Statistics Canada.

Statistics Canada. 1998. *Statistics Canada Quality Guidelines*. Third Edition. 12-539-X1E.

Statistics Canada. 2002. *Statistics Canada's Quality Assurance Framework – 2002*. 12-586.

Wheeler, D.J. and D.S. Chambers. 1986. *Understanding Statistical Process Control.* SPC Press, Knoxville, TN.

Williams, K, C. Denyes, M. March and W. Mudryk. 1996. Quality Measurement in Survey Processing. *Proceedings of Symposium 96: Nonsampling Errors*. Statistics Canada. 119-128.

Survey Methods and Practices - Case Study

Preface

The Case Study is a fictitious survey designed to illustrate the steps in the development of a general household survey, according to the methods and principles presented in the corresponding chapter of the Survey Methods and Practices. In this way, a common example is used for the entire manual. The Case Study survey development process is described from the point of view of the project team.

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Chapter 1 - Introduction to Surveys

1.0   Introduction

In recent years, the country of Belleterre has been undergoing rapid economic change as the country goes through the process of economic reform. The Belleterre Bureau of Statistics (BBS) is fully aware of the increasingly urgent need for up-to-date information on the state of the economy and the socio-economic situation of its population, and has begun efforts aimed at modernising several aspects of its statistical program.

In particular, the BBS recognises the need to obtain relevant, objective and accurate information on the situation of households in both the urban and the rural areas. To this end, it has been seeking resources to conduct an ongoing household survey, to be tentatively known as the General Household Survey (GHS). The national government has indicated its support for the survey, and is currently determining the resources to be dedicated to this effort.

Preliminary studies of information demands from various user departments indicate that the GHS should be conducted at least once a year, and should be representative of the population both nationally and at the level of important urban centres and sub-national economic regions. Broad topics to be covered by the survey would include:
-   socio-demographic characteristics;
-   labour market activity;
-   income and expenditure patterns;
-   indicators of living conditions.

A number of important national ministries would also like to obtain information from the GHS. The Ministry of Health would like detailed information on the population's health status, while the Ministry of Agriculture has requested data on household agricultural activities in both rural and urban areas. Several economic ministries would like information on small businesses. All these additional activities are being considered, but no firm decision has yet been made on which, if any, will be included in the GHS.

In the context of these broad objectives, a project team is to be formed to design and implement the new survey. You have been selected as a member of the project team and will soon begin to participate in the survey's development. The team's first meeting will be held soon, so you start by spending some time reviewing the available information on Belleterre from the last census and from other household surveys. You soon realise that most of that information is not only out-of-date but also insufficient since the existing data do not reflect the new economic realities. See Annex 1.1 for an overview of Belleterre.

Review questions:

Why has a survey been proposed?

What are the basic issues to be addressed by the survey?

Annex 1.1: Statistical Profile of Belleterre

The following notes summarise the available information on the demographic and economic situation of Belleterre. Data are taken from censuses held in 1980 and 2000. The notes include some preliminary estimates and projections based on the 2000 census.

The population of Belleterre is estimated to be about 44 million persons in 2005, up from about 30 million in 1980 and just under 41 million at the time of the 2000 census. The rate of population growth continues to be moderate, and the population is expected to reach 55 million by 2025. This population growth, combined with a high level of rural-to-urban migration, has accelerated the recent changes in the nation's economic structure.

Over the past two decades, Belleterre has seen increasing urbanisation, with substantial migration from the countryside to urban centres, especially to the three largest cities. As a result, only about 40% of the population now live in urban areas.

The capital city, City A, is found in the central-valley region. Its rapidly growing population is expected to approach four million by 2005. The other two major urban centres are City B, in the south of the country, and City C, in the north, each growing at a similar pace and smaller than City A. These three cities, which accounted for just under one twelfth of Belleterre's population in 1980, now contain almost one fifth of a larger total, and continue to attract a steady flow of migrants from the surrounding countryside.

The nation's economy is still largely agrarian and natural resource based, the principal agricultural products being rice and coffee. Mining, particularly of coal and copper, contributes foreign exchange to the economy. There is a rapidly growing manufacturing base, especially in textiles and electronic components, much of which is also exported overseas. Overall, per capita income is estimated to have grown by an average of 6.4% annually since 1990.

The following tables give a brief summary of important demographic and economic indicators.

Table 1.1: Population of Belleterre

Year	Population (at mid-year)	Source
1980	30,110,000	Census
2000	40,850,000	Census
2005	43,840,000	BBS estimate
2010	47,200,000	BBS demographic projection
2015	50,000,000	BBS demographic projection
2020	52,800,000	BBS demographic projection
2025	55,300,000	BBS demographic projection

Table 1.2: Belleterre: Population (in thousands of persons), by Region

Region	Source		
	1980 Census	**2000 Census**	**2005 BBS estimate**
City A	1,760	3,250	4,080
City B	925	1,675	2,060
City C	2,145	3,189	3,625
District D	1,885	2,467	2,600
District E	3,400	4,450	4,690
District F	3,670	4,800	5,045
District G	3,085	3,975	4,160
District H	2,300	2,965	3,080
District I	3,200	4,120	4,320
District J	4,260	5,480	5,640
District K	3,480	4,470	4,540
Total	**30,110**	**40,850**	**43,840**

Table 1.3: Belleterre: Gross Domestic Product per capita

Year	GDP per capita (1990 prices)	Source
1990	5150	Intercensal estimate (BBS)
2000	6175	Adjusted Census data
2005	9600	Preliminary estimate

Chapter 2 - Formulation of the Statement of Objectives

2.0 Formulating the Statement of Objectives

The project team responsible for developing the new General Household Survey (GHS) has been officially named, and holds its first meeting to begin its work. The team will report to a Steering Committee composed of senior professionals and management representatives, and must quickly prepare a detailed work plan for presentation to that Steering Committee.

Knowing that the GHS is to cover a wide range of topics, and must provide timely information several times per year, and recognising that the country has many millions of people, the team immediately sees that it will not be feasible, or necessary, to attempt a census. A sample survey will be sufficient and likely preferable to a census (see Case Study Chapter 3), although what type of sample, and how large, is not yet clear.

The team decides that the first few meetings will have to be devoted to preparing a Statement of Objectives for approval by the Steering Committee before detailed development of the survey can be begun.

2.1 Determining the Information Needs

At its second meeting, the project team begins working on the Statement of Objectives. Considering the long list of information requests known to exist, the overall purpose of the GHS might be loosely stated as 'to study the social and economic conditions of the population.' This statement is much too vague to be put directly into practice, and certainly you cannot expect to obtain useful information by simply asking people about their 'social and economic conditions.'

The team therefore faces two challenges. The first is to convert the vague general statement of needs into specific topics for study, while the second is to identify which of those topics can and should be covered by the survey.

The four broad themes of socio-demographic information, labour market activity, income and expenditure patterns, and living conditions have already been identified as being of high priority. Various ministries have also requested data on health, agricultural production and small business activity.

The team must consider whether it is possible, or necessary, to incorporate such a variety of topics into a single survey and is expected to make recommendations to the Steering Committee on the feasibility, benefits and risks of including each major subject area.

To determine the specific information needs, the team must attempt to identify and consult the principal data users, and to inform themselves about the relevant subject matter concepts and definitions.

2.2   Users and Uses of the Data

With some guidance from the Steering Committee, a list of key data users is drawn up. Some of them are within the BBS, working in specialised subject-matter areas such as the national accounts, demographic analysis and manufacturing statistics divisions. Many others are policy analysts in the central program ministries, concerned with such areas as employment and industrial policy, housing construction policy, transportation development and the education sector.

For each of the proposed survey themes, a team member is assigned to consult with as many as possible of the key data users in that area and prepare a summary of those discussions for the next meeting. After the preliminary discussions with the data users, the project team meets to study the reports on each consultation. In fact, so much has been learned that three more meetings are needed.

The team member assigned to look into socio-demographic characteristics reports first, saying that the main users are subject-matter specialists primarily interested in basic demographic events in the family such as births, deaths, marriages, family composition and migration (e.g., region-to-region or urban-to-rural migration, emigration, immigration). After some discussion, it is agreed that the team member will seek out more detailed information on each of these subjects, particularly regarding the availability of suitable information from existing sources such as vital registers.

The second team member informs the team that the main topics relevant to labour market activity include labour force status (employed, unemployed, not in labour force), working as an employee or on one's own account, whether work is full-time or part-time, industry, occupation, hours worked, etc. Several users, particularly planners in the ministries of employment, education and construction, insist that none of the existing surveys adequately meets the need for labour market information in the context of the rapid and ongoing changes in the nation's economic structure. Thus, for example, they require accurate and objective estimates of how many people are working in particular activities, such as building construction, in each region or city of the country. Similarly, the analysts need to know how many workers are working at more than one job, and their actual hours of work and earnings. Again, the responsible team member is assigned to take the next step of finding out more detailed information on data needs, as well as investigating possible existing data, such as those provided by any existing surveys.

Your own report concerns household income and expenditures. You have learned that household income can be defined to include all income (gross or net) in cash or in kind received by all household members during a reference period, such as the previous month or year. Expenditures may include monies paid for food, clothing, shelter, transportation, education, health care and so forth, as well as goods or services exchanged directly (bartered) for other goods and services received. The household's assets and debts may also be considered relevant for the survey's analytic purposes.

You have also found that there are many potential users of data on these subjects. The BBS would like more detailed data on income and expenditures to strengthen certain components of the national accounts. In particular, the existing accounts are less complete in the area of private-sector income, both labour income and business income. Those concerned with measuring retail trade, purchasing power and expected residential construction are interested in the evolution of family incomes and changes in spending patterns, to strengthen their reports to the economic policy-makers. It was also found that estimates of disposable income are of great interest to the manufacturing industry as well as to the tourism authorities. Much work still must be done to arrive at the appropriate level of detail, and you agree to undertake the second round of investigation in this area. Once again, you will have a closer look at the availability of relevant existing data.

Finally, the fourth team member reports that the most important indicators of living conditions appear to refer to housing conditions, transportation access and use, and access to educational services, all of which are very important for national and city infrastructure planners. Once again, a second round of research is initiated into this subject.

Meanwhile, the project manager has held some preliminary discussions on the possible additional themes, and also makes a brief report:

i.   The household's use of health care services during the past year could range from the purchase of pharmaceutical products, to visits to local doctors or clinics, or to in-patient care such as surgery in hospitals. These topics are of particular interest to the Ministry of Health, which wants to measure the rate of change in demand for the different types of health care services.

ii.   Interest in household agricultural activity may be defined in terms of production of crops or livestock on land owned or rented by the household or on communal land, whether that production is for market sale or for own consumption. The analysts from the Ministry of Agriculture want updated information on the types and quantities of agricultural production being sent into the urban markets, to help in their planning and policy making.

iii.   Home business activity (other than the sale of agricultural products) could include small-scale manufacturing, informal restaurants, hairdressing and a large number of other activities ranging from baking to shoe making. Economic planning analysts are interested in obtaining this information to understand the structure of the economy and track the rate of movement toward small, private-sector business.

The ministries interested in additional themes have been given a rough estimate of the cost of including their subjects in a large multi-purpose survey, and the latest news available suggests that they are reluctant to provide the necessary resources, at least for this year. In addition, the team is worried about tackling such a large number of topics in the first round of the GHS because of the large response burden and the possible negative effects on the quality of the data. After sharing what they have learned with the Steering Committee, the team is advised to concentrate its efforts on defining the Statement of Objectives in terms of the four core themes, leaving the possible additions until subsequent survey occasions.

Therefore, for each of the four core topic areas (socio-demographic characteristics, labour market activity, income and expenditure and living conditions), the team will continue to refine the Statement of Objectives while also considering the usefulness of existing data sources.

In light of the lengthy discussions at the recent team meetings, you continue your research into your assigned topic area – household income and expenditures. Several users and a variety of uses of the data have already been identified. In addition, central ministries need more up-to-date information on family income and particularly on food expenditures, to enable them to determine whether state subsidies are required to protect low-income families. Other users would like to have data to build econometric models to estimate increases in demand for consumer goods, as well as non-basic foodstuffs and improved housing. These estimates would provide information to the manufacturing and construction industries, allowing them to plan new projects and make decisions on hiring additional workers.

However, before you have advanced very far in this second level of definition, the team is called to an unexpected meeting with the Steering Committee. The team is informed that the expected budget for the first round (first year) of the GHS has been sharply cut (by over 50%). The team is instructed to concentrate on the most important of the core themes, while still preparing a survey infrastructure that can be readily expanded in the second year when, it is hoped, the required resources will be made available.

The Steering Committee and the project team consider what has been learned to date, and come to the following conclusions:

i.   While not perfect, almost all the demographic measures required can be produced satisfactorily from existing data such as vital statistics and housing registers, either directly or using indirect methods, for one more year at least.

ii.   Several ministries insist that none of the existing sources provide adequate labour market information in the context of the changing economic circumstances.

iii.   Several members of the Steering Committee argue that the income and expenditure information from present surveys can continue to be used for the medium term, especially if it can be strengthened by better information on the evolution of the labour market from the GHS.

iv.   With respect to the desired information on living conditions, the main immediate need is for better labour market data to improve projections of housing, transportation and education requirements.

Given all this, it becomes clear that the initial design of the GHS will have to concentrate on the labour market component, and leave aside the remainder of the initial broader list of subjects for this year.

2.3   Concepts and Operational Definitions

Now that the scope of the GHS has been much more narrowly defined, the team's next task is to specify clear subject-matter concepts and working definitions for the survey topics, and then to proceed to the determination of detailed survey content. The workload is again distributed among the team members.

The team begins tackling some of the concepts crucial to describing the labour market activity of Belleterre – labour force, employed, unemployed. The team members think about the concepts, but come up with more questions than answers. For example:

i.   Labour Force

Who should be included? Does the concept of labour force apply equally in the urban and in the rural areas? What is to be done about those workers who work or reside in one region but whose permanent home is in another region? For practical purposes, should such a person be considered part of the labour force for his/her place of permanent residence, or in the region where he/she is currently working? How should persons be classified if they are able to work, are not yet retired, but are not working or seeking work?

ii.   Employed

Does the definition of employment include only working for monetary pay, or should provision of labour in exchange for goods and services be included? How are full-time and part-time work to be defined? Can a person have one full-time job and another part-time job, and if so, does the definition depend on the number of hours worked, or some other criterion? Are there suitable definitions of employer, employee and self-employment? Again, should the definitions of employment differ according to whether the person lives in a rural or urban area? If a person is working in a place other than his/her place of

permanent residence, should he/she be counted as employed there, and should he/she be counted as employed, not employed or simply not present in the place of permanent residence?

iii.   Unemployed

Is a person considered to be unemployed if he/she is simply not working? What if he/she does not want to work? What if he/she has looked for work for so long that he/she has become discouraged and given up on ever finding a job?

The team is having considerable difficulty in answering the questions that have arisen. Some members research definitions used in other countries and discover the following standard definitions used by the International Labour Organisation (ILO):

i.   Labour Force*:* A person will be considered to be part of the Labour Force if he/she is employed or unemployed (see below).

ii.   Employed: Employed persons are those who, during the reference period:

a. did any work at all at a job or business, that is, paid work in the context of an employer-employee relationship, or self-employment. It also includes unpaid family work, which is defined as unpaid work contributing directly to the operation of a farm, business or professional practice owned and operated by a related member of the same household;

or

b. had a job but were not at work due to factors such as own illness or disability, personal or family responsibilities, vacation, labour dispute or other reasons (excluding persons on layoff, between casual jobs, and those with a job to start at a future date).

iii.   Unemployed: Unemployed persons are those who, during the reference period:

a. were on temporary layoff with an expectation of recall and were available for work;

or

b. were without work, had actively looked for work in the past four weeks, and were available for work;

or

c. had a new job to start within four weeks from the reference period, and were available for work.

iv.   Not in the Labour Force: Persons not in the labour force are those who, during the reference period, were unwilling or unable to offer or supply labour services under conditions existing in their labour markets, that is, were neither employed not unemployed.

The team decides to design the questionnaire so that the resulting data can be used to estimate measures conforming to the ILO concepts. This will allow comparability to international measures on labour market activity. The team notes that the ILO definitions restrict analysis to persons 15 years of age and over. The team decides to use this standard throughout.

The team also notes the difficulty in defining certain key concepts such as dwelling, household and family. After some research, the team decides to adopt the following standard definitions:

v. Dwelling: any set of living quarters that is structurally separate and has a private entrance outside the building or from a common hall or stairway inside the building.

vi. Household: any person or group of persons living in a dwelling. A household may consist of any combination of: one person living alone, one or more families, a group of people who are not related but who share the same dwelling.

vii. Family: a group of two or more persons who live in the same dwelling and who are related by blood, marriage (including common-law) or adoption. A person living alone or who is related to no one else in the dwelling where he or she lives is classified as an unattached individual.

The team notes that a survey strictly on labour force activity will not allow analysts to paint a very detailed picture of the labour force in Belleterre. The team realises that, in addition to information on labour market activity, additional data on demographics, education, income, etc. will have to be collected for classification purposes.

2.4 Survey Content and Analysis Plan

To help clarify the survey content, the team begins to draft some preliminary output tables, at each step asking what analytic questions they may help to answer. For example, it seems clear that the GHS will have to be able to produce tables such as 'Labour Force Status by Education level' and 'Employment by Age and Sex'. So, information must obviously be collected on employment as well as the demographic characteristics of the household.

You set up a dummy table for the first heading:

Table 2.1: Labour Force Status by Education

Education Level	Labour Force Status			
	Employed	**Unemployed**	**Labour Force**	**Not in Labour Force**
Below average				
Above average				
Total				

This is clearly inadequate. As far as 'below average' and 'above average' education go, does this refer to the average education level to be calculated from the survey data, or to some exogenous concept of 'average level of education'. And what values go into the cells of the table? Will they be counts (estimated numbers of persons), proportions, percentages?

Keeping in mind that greater detail in the questions (therefore on the datafile) can always be grouped for tabulation, you consider the other extreme:

Table 2.2: Labour Force Status, by Years of Education (Number of Persons)

Years of Education	Employed	Unemployed	Labour Force	Not in Labour Force	Total
1					
2					
3					
…					
99					
Total					

This level of detail would be difficult to collect and interpret sensibly. You decide that education levels should be grouped in a meaningful way for tabulation, even if the exact number of years of schooling is asked to permit detailed analysis of the education variable. For the above table, perhaps education could be grouped as primary school, junior high school, senior high school, technical college, and university (the question could refer to highest level completed or attended).

It has been suggested that reliable estimates are required for each of the eleven regions of Belleterre (3 cities and 8 districts). For the moment you leave aside the possible need for finer detail, and contemplate tabulations that will show the eleven specified regions separately.

Table 2.3: Labour Force Status by Region for Belleterre's Adult Population (Weighted)

Region	Employed	Unemployed	Labour Force	Not in Labour Force	Total
City A					
City B					
City C					
District D					
District E					
District F					
District G					
District H					
District I					
District J					
District K					
Total					

You are unsure of the most effective way to present this table, but that decision can be postponed, as it will not affect the questions to be asked.

You work out several similar tables, in each case trying to decide on an appropriate level of detail. Finally you are ready for the next team meeting, at which the suggestions of each member are discussed and compared. The team has nearly 20 tables, for example:
- labour force status by age and sex;
- labour force status by education;
- employment by industry;
- labour force status by region;
- average usual hours of work of employees by selected characteristics;
- average wages of employees by selected characteristics.

By this time, the detailed list of topics is taking shape, and the team begins writing up the Statement of Objectives, covering the project team's interpretation of the survey's information needs, identifying the main known users, giving provisional definitions of key concepts, and proposing a number of tables for preliminary descriptive analysis. At this point, the team does not feel in a position to comment on precision, as neither the sample design, indeed not even the survey's frequency, have been decided.

The team sends Annex 2.1 to the Steering Committee members for discussion at the next meeting. (It is agreed to present it with the explanation that it is still a draft.) This will allow the Steering Committee members time to prepare detailed comments, while at the same time the project team will continue to work on the details of the proposed survey content.

Review questions:

Provide definitions for the target population and the survey population.

Explain in your own words why the GHS will cover a much more restricted content than initially thought.

Attempt to make a more explicit statement of the data needs and uses for the Demography Division and the Ministry of Economic Planning.

Propose five tables to be included.

What definitions of labour force, employed and unemployed would you propose to the Steering Committee? Would these alter the proposed topics?

Annex 2.1: Draft Statement of Objectives for the Belleterre General Household Survey

Introduction

At the request and under the direction of the GHS Steering Committee, the GHS Project Team has prepared the following Draft Statement of Objectives for the initial round of the General Household Survey (GHS), to be conducted next year.

The survey will cover labour market activities (employment and other income-producing activities, job search, hours of work, wages, etc.), as well as some socio-demographic characteristics. By way of background, it should be mentioned that the original goal was to develop a survey with a much broader thematic coverage, including numerous indicators related to demography, household income and expenditure, business activities, and possibly supplements on health and agriculture. Such a survey remains the BBS' medium-term goal. However, the initial project will be less ambitious and more narrowly focussed.

Preliminary research has shown that the demographic and income-expenditure subject areas can be covered adequately from existing sources (vital registers, and the urban and rural household surveys, respectively) for at least one more year. Information on high-priority areas within the other topics of importance can at least be strengthened through the data to be collected in this version of the GHS. This is the reason that the stated objectives refer principally to labour market activities.

Principal Data Users

The main users of the GHS data have been identified as the Labour Analysis Division of the BBS and economic planners in the ministries of employment, education and household-sector construction. Other users will include the Demography Division of the BBS, the Ministry of Economic Planning, and the National Labour Commission. Selected communications with those users concerning their data needs are attached as Annex A *(not shown here)*.

Key Concepts and Definitions

To ensure consistency with other statistical products of the BBS, standardised definitions of concepts such as dwelling, household and family will be used.

In order to facilitate international comparison, the project team recommends adopting the widely used International Labour Organisation (ILO) definitions of labour force, employed, unemployed and not in labour force.

Proposed Survey Content

The following topics will be included in the survey:

> **Dwelling/Household**
> Tenure (owned or rented)
> Household composition
> > Age
> > Sex
> > Education completed (level and years of schooling)

Labour Force Activity
Labour force status (employed, unemployed, not in labour force)
Industry (primary, manufacturing, sales, services, etc.),
Occupation (director, supervisor, professional, labourer, etc.)
Hours worked
Employment income
Other economic activity
    Self-employment
        Formal sector
        Informal sector (i.e., 'underground economy').

Preliminary Analysis Plan

The initial analysis will consist of tables of estimated numbers and percentages for each of the major items listed above, along with a number of cross-tabulations. Approximately twenty proposed key tabulations are included in Annex B *(not shown here)*.

Further details of analysis have yet to be worked out, but will likely include production of tables for more detailed regional and industry breakdowns.

Chapter 3 - Introduction to Survey Design

3.0   Introduction

Having received approval from the Steering Committee of its draft Statement of Objectives, the project team now meets to begin the substantive work of designing the GHS.

The first question, whether to do a census or a sample survey, has already been resolved. A census would be unthinkably costly, even if it were conducted only once a year. Also, even if the money were available, the operation would be so huge and unwieldy that it would inevitably suffer from so many logistical and management problems that the nonsampling errors (such as processing errors) would overwhelm the gains from avoiding sampling error (that would be incurred from a properly designed sample survey).

Only a sample survey can collect annual or sub-annual information from a population of nearly 44 million people. In fact, you have been informed that the survey should be designed to be conducted four times a year, that is, in such a way that useful estimates are obtained once for each calendar quarter. Therefore, the team will prepare a sample design that is manageable under such time constraints, and with a large enough sample to give reliable results for each quarter.

3.1   Target and Survey Population

At first glance, the target population seems easily defined and they tentatively define it to be the adult population of Belleterre. However, the project team identifies several problems:

i.   Temporary residents

Should persons who have moved into the country temporarily be included in the labour force? They are not part of the economy in the official sense, but they do occupy jobs and produce products. Conversely, persons who have moved to another country are occupying jobs and producing products in that country. They may be impossible to reach and it is not clear that they should be counted as part of Belleterre's economic activity although many may send part of their income home.

Where should persons who have moved from the rural to the urban part of the country be counted? (Such people usually live in temporary dwellings.) They have a large and increasing impact on the social and economic dynamics of the urban areas of the country with respect to unplanned increases or decreases in availability of labour in one urban area versus another (and, it might be added, an impact on rural areas in terms of the decrease in the available agricultural workforce).

The team decides to include as household members all people who usually live in the dwelling, in other words, anyone who regards the dwelling as his/her usual place of residence. The team realises that this concept will have to be defined much more clearly to be implemented, but at least this is a starting point.

ii.   Collective dwellings

Should the survey cover only residents of individual dwellings or should it also cover collective dwellings (that is, dwellings that contain multiple households)? Collective dwellings can encompass everything from small rooming or boarding houses to hospitals and prisons. Obviously, these are very different situations. In large institutional collectives, such as hospitals, prisons, military bases, etc., even if it were

decided that the residents should be covered by the survey, would it be feasible to conduct interviews with the residents? On the other hand, small collectives closely resemble private dwellings and the team wonders if they could be treated like private dwellings for the sake of data collection.

iii.   Remote areas

Finally, the team considers those persons living in certain remote and inaccessible areas that would be unreasonably costly to survey. (However, this group is very small in Belleterre, less than 1% of the population.)

The team will tentatively define the target population to be the adult population whose usual place of residence is in Belleterre. People living in remote areas will be excluded, as will residents of collective institutions such as hospitals, prisons, military bases, etc. The team realises that the final definition of the target population will depend on the sampling frame that is used, which will influence the reference period, what portions of the population should be excluded for practical reasons (e.g., too remote, too costly, too difficult to survey), etc.

3.2   Sampling Frame

Household surveys in Belleterre have traditionally been done using population and household registry lists as frames. Given the degree of administrative documentation of the population's movements, these lists have generally been considered quite complete and up-to-date. However, the recent increases in emigration and migration within and between regions mean that this may no longer be true.

Since available registry lists are largely maintained by local town and city public offices, it is not clear that they do not overlap to some degree, or that all the lists are updated with the same frequency or accuracy. To remove overlap between these frames, it would be necessary to join all these lists into a single big frame. Then, of course, there would be the problem of keeping that frame up-to-date, which would require continuous updating information from several hundred different offices on at least a quarterly basis. On the other hand, the team notes that it would be very costly to construct new lists for the entire country.

Considering these factors, the team recognises that it must study other possible sources of information for building the GHS frame.

Some countries without good population registers use area-based sampling frames for their household surveys. The team undertakes some research into the documentation available from other countries to judge whether this approach would be likely to allow them to cover a more fully representative population.

The team members know that, in theory, an area frame can offer almost complete coverage, but that it can also be costly to prepare. Also, given that they would need to start from the beginning, they are not sure that they can develop a good area frame and related sample design in time for the first round of the survey. However, during their discussions with representatives of the several other BBS survey teams, the GHS team learns of their recent decision to attempt to move to the use of area frames. In fact, they have already done substantial research into the issue. Since the results from this preliminary research look very promising, the GHS team proposes to the other survey teams and to the Steering Committee that they combine efforts in order to produce and implement an area frame. Given that the costs of creating and updating the frame would be shared with the other surveys, the Steering Committee approves the idea.

Given the decision to follow this approach, the team starts to evaluate the current state of the necessary maps and other cartographic information to begin preparing the area frame and to arrive at a reasonable estimate of the resources needed to complete that task in time for the survey.

The higher levels of the area frame (i.e., defining the primary sampling units) will depend on up-to-date large-scale topographic maps, which are generally in very good condition. The lower levels (i.e., defining secondary and tertiary stage sampling units) will have to be based on the identification of streets and eventually of dwellings in the urban areas, and villages and dwellings in the rural areas. The team notes that maintaining the frame will require a permanent effort on some sort of rotating basis, with extra attention to the high-growth areas.

This requires the team to begin developing a series of steps for delineation of sampling units at the various levels of the geographic hierarchy, ranging from identification of large-scale natural boundaries such as major rivers, to plans for doing the inevitable listing of dwellings in selected areas. Of course, the team cannot yet carry out the details of these steps, as that will depend on the decisions regarding the actual sample design.

Review questions:

Why is a sample survey the only practical solution to the data requirements?

Explain whether individuals living in collective dwellings should or should not be included in the target population. Include consideration of their accessibility as well as the likely pertinence and quality of their responses.

Explain any other differences that may exist between the target population and the final survey population.

If the list frame approach had been kept, what would have been the possible sources and impacts of nonsampling error?

What do you think are the three most important likely sources of nonsampling error associated with the use of an area frame? Suggest one or two ways to reduce or control each of them.

How many distinct scales of maps and sketches do you think will be needed to carry out the area frame sample design?

Chapter 4 - Data Collection Methods

4.0   Data Collection Method

The project team meets to decide on a method of data collection. Team members discuss the advantages and disadvantages of the three basic methods: personal interviewing, telephone interviewing and self-enumeration (e.g., mail-out / mail-back of a questionnaire).

Telephone interviewing does not seem very practical, since the percentage of households without a telephone is very high, particularly in the rural areas. There is also the fact that the population is not used to dealing with government authorities over the telephone, and many people would be very reluctant to respond to a survey in that form. Furthermore, some of the concepts to be addressed in the survey are complex, and people may not easily understand the explanations over the telephone. Finally, there is no up-to-date and complete telephone directory covering the household subscribers, since telephone coverage is increasing quite quickly in some areas. For these reasons, the team decides not to pursue the telephone option any further.

Since the area frame approach will of necessity be based on dwelling address information, the team does briefly consider the possibility of using a mail-out survey. However, the team has learned that the few market surveys that have been conducted by mail encountered very low response rates, and those returned had many incomplete or inconsistent responses. These problems become worse if the survey forms are simply sent to the dwelling addressed to 'Householder' rather than to a specific person. Since the GHS will have a much greater number of questions and some of the topics are quite complex, the mail-out option does not appear capable of providing data of suitable quality.

There seems to be no alternative but to use personal interviewing, despite the high cost of employing a large number of interviewers. The team begins to discuss the logistics of hiring and training a sufficient number of interviewers, to plan the preparation of the necessary supporting manuals, and to study the requirements for vehicles and other equipment.

Although the sample design is not yet very advanced, the survey methodologist recommends that selected households be interviewed over several quarters in order to get good estimates of change in labour force status. The team considers the possibility of doing the first interview face-to-face, but using telephone or mail-out for the subsequent interviews. However, the problem of undercoverage remains for telephone interviewing, and it is feared that mail-back response rates will be rather low, even after the personal contact of the first interview. Nevertheless, the team continues to consider the mail-out, mail-back option as a possible strategy for subsequent interviews.

Another factor that makes the team reconsider the self-enumeration option is the fear that certain questions may be seen by respondents as quite personal or sensitive, and thus they may be reluctant to provide an answer to an interviewer. A mail questionnaire might encourage them to respond to these questions. On the other hand, much of the questionnaire is expected to be better answered in a personal interview. One team member suggests using a mixed-mode approach – conducting a personal interview for most of the questionnaire, but asking the respondent to fill in a separate page to answer the sensitive questions, in private, and either place it in a sealed box held by the interviewer, or return it by mail. The team decides that testing of the questionnaire and the collection method will be needed to resolve the issue.

One important decision still needs to be made, and that is whether to use a paper questionnaire (pencil-and-paper, or PAPI interviewing), or to go to a computer-based approach (i.e., computer-assisted personal interview, CAPI). The main advantages of the PAPI method is that it does not require investment in as much expensive equipment, and that it is a well-understood approach since all the BBS' surveys have so far used this method. On the other hand, the GHS team members realise that, for the price of hand-held computers for the interviewers, plus some programming investment, they could eliminate a separate data capture stage and ensure that a large part of the data editing is done at the time of interview (when corrections are easiest).

The team members decide to calculate the probable cost of each of these approaches, and at the same time, they try to evaluate the likely improvements in data quality if CAPI is chosen, and weigh them against the additional complexity of developing the CAPI computer application. Of course, solid information on the data quality will only be available once the survey has been conducted. Still, some approximations can be made now, to help in making the required decision.

After reviewing the available information (the cost and time of set-up, the likelihood of changing the questionnaire after the first cycle, etc.), the team decides to conduct the first round of the GHS using PAPI and to revisit the issue in the future.

Review questions:

Should the team have considered the possibility of using a mixed-mode approach, with telephone interviewing in those areas of the major cities where telephone ownership is quite high? Discuss the advantages and disadvantages of such an approach.

Discuss the advantages and disadvantages of the different possibilities that have been suggested for dealing with the problem of sensitive questions.

Consider the security measures that will be needed to protect the equipment if CAPI is used.

Consider the measures needed in either case to protect the security and confidentiality of the data (questionnaires, or electronic files).

Chapter 5 - Questionnaire Design

5.0   Questionnaire Design

Knowing that designing the questionnaire will require a lot of work, the GHS project team meets to divide up responsibilities for writing the first draft of the various sections.

They begin by reviewing the Statement of Objectives since it already contains the nucleus of each question or block of questions. It now remains to convert each point into a clearly worded question that will have the best possible chance of eliciting the desired information from the respondents.

The first block of questions will deal with characteristics of the household and required demographic information. One team member (A) is assigned to prepare a first draft of this section, relying quite heavily on the sorts of questions used in existing household surveys

The core of the questionnaire will deal with labour force activities of eligible household members, defined as all persons aged 15 years or older. The content for this part is extensive so responsibility is divided among several team members:

i.   One team member (B) will deal with the questions to determine labour force status (as employed, unemployed or not in the labour force). It is clear that more than a single question will be needed.

ii.   Another team member (C) is given the task of drafting a series of questions on the type of activities engaged in by employed persons.

iii.   Team member D will prepare questions on other economic activities such as self-employment (including agriculture) and working in the informal sector of the economy.

iv.   Team member E will look at the secondary labour force activity questions dealing with hours worked and earnings.

5.1   Questionnaire Structure

Before much work is done on the questionnaire, team member A calls a meeting of the project team to discuss some issues encountered while developing the demographic questions. Team member A points out that, before the actual questions can be drafted, the team must decide how the questionnaire is to be structured. Should there be one questionnaire for everyone in the dwelling? Who should answer the questions? Should there be a different questionnaire for collective dwellings?

One member of the team suggests that there should be two different questionnaires: one for the dwelling and one for the individual respondents within the dwelling. Another person says that there should be three: one for the dwelling, another for each family, and the third one each individual.

There is some debate about these approaches. On the one hand, it is felt important to understand the family structure within the dwelling, as this information is relevant for determining how many people depend on the income of each worker. On the other hand, it is vital to identify all individuals living in the dwelling, and some team members fear that identifying families may lead to omission of individuals living in the dwelling who are not a member of a family.

It is eventually decided to try using two forms: one for the dwelling (to be called Form F1) and one for each individual aged 15+ (F2).

Form F1 will collect dwelling level information, a complete list of all people living in the dwelling, which family unit they belong to and their demographic information. This information will be used to decide which people should receive the individual level questionnaire. Form F2 will collect the individual level labour force activity information desired for the survey. The team decides that one person who is knowledgeable about the household will be asked all of the form F1 questions, while Form F2 will be asked of the individual concerned. The team notes that there must be a dwelling identifier on the individual forms so that the dwelling information can be linked to the individual information after collection.

One of the team members points out that, in a large household (or in a collective dwelling), the person responding to Form F1 may not know the demographic information of everyone in the household. The team discusses this issue and decides that if the person responding to Form F1 does not know the demographic information for the entire household, one person from each family unit will be consulted to complete this information.

The team members discuss whether proxy responses should be allowed for the individual questionnaires – they decide that the interviewers should first attempt to contact each individual for whom an F2 form must be completed, but if unable to, they can use proxy interviewing (asking the questions of a family member).

Next, the team considers creating separate questionnaires for collective dwellings and private dwellings. It has already been decided that large collective dwellings (military establishments, hospitals, prisons, etc.) will not be covered by the survey. Therefore, the team feels that the smaller collectives that they will encounter can be adequately covered by the same questionnaire as will be used for private dwellings. In addition, if the information is necessary, a private/collective derived variable can be created after collection based on the number of families or unrelated persons living in the dwelling.

5.2   Drafting the Questionnaire

Each team member continues with the consultation and research employed in the preparation of the Statement of Objectives, talking to key data users and consulting existing questionnaires. The team plans to prepare a reasonably complete draft of the entire questionnaire before undertaking extensive testing or cognitive research on any of the sections. This is because, until the majority of the questions are present in at least preliminary form, the order of the questions is not clear. Nevertheless, they feel that they may need to test individual questions earlier if it turns out to be difficult to decide how they should be worded.

The team soon meets to begin reviewing the draft questions of Form F2.

Team members B and D, believing that their questions would be very easy, had volunteered to do several time-consuming tasks related to the sampling frame and the sample design. Consequently, their drafts are quite incomplete. Discussion of their sections will be postponed until the next meeting.

The team turns to member C's questions on the type of labour market activity that people engage in:

For persons identified as being employed

> C1 Is your employer (please indicate only one option)?
> ❍ *a state corporation*
> ❍ *a public institution (e.g., hospital, school, ect.)*
> ❍ *a non-family private enterprise*
> ❍ *a family member*
> ❍ *other (please specify)_____*
>
> C2 What is your job title (e.g., sweeper, engineer, sales manager, driver)?
> _____
>
> C3 In which sector does your employer conduct its principal economic activity?
> ❍ *Agriculture, fisheries and forestry*
> ❍ *Extractive industires*
> ❍ *Transportation*
> ❍ *Construction*
> ❍ *Retail trade*
> ❍ *Wholesale trade*
> ❍ *Tourism*
> ❍ *Arts and cultural industries*
> ❍ *Other services*
> ❍ *Public administration (including security)*

It is clear that team member C is an expert in industry and occupation classification. Fortunately for the draft questionnaire, the other team members are not, and they quickly begin to ask questions. Almost all team members raise questions or objections about question C3, saying that respondents will not understand 'sector' or 'principal economic activity', though they agree that 'what does your employer do' is too vague. In addition, it is pointed out that the listed activities are the cornerstone of a classification system that only a few specialists are familiar with, after years of work. What is an extractive industry? Some people might think of dentists, while it really means mining and petroleum exploration and development. Similarly, a newspaper reporter might identify his employer as belonging to the arts and cultural industries, while a printing press operator working for the same company would likely indicate manufacturing. Several team members argue for asking this as an open question, and having it coded in the office. Team member C is not opposed to this, but is unsure how to word the question to provide enough detail for the coders to be able to do their job accurately. The debate on how to ask the question or questions lasts for several hours.

Next, the questions drafted by team member E for hours of work and wages are reviewed.

> E1 Do you work
> ❍ *full time (35 hours per week or more)*
> ❍ *part time (fewer than 35 hours per week)*
> ❍ *seasonal work*
>
> E2 How much are you paid?
> _____

E3 Does your employer provide the following benefits?
                a. Health insurance or health care   ❍ *Yes*   ❍ *No*
                b. Rent subsidy   ❍ *Yes*   ❍ *No*
                c. Retirement pension   ❍ *Yes*   ❍ *No*

Several objections are raised to question E2. 'How much are you paid' is not only imprecise, but sounds intrusive – and this is a topic which many people will be reluctant to answer even if it is well phrased. Team members recall the examples they have seen before, and insist that more precision is required. The question should refer to the person's total income from employment, in money terms, before deductions for participation in any shared-cost programs (for example, contributory pension plans). But how can that be asked in a single question? Clearly testing is required for this question.

One team member also feels that the very topic of income is too sensitive and thus requires a lead-in, such as 'the next question is one that we ask of all respondents to this survey, to better understand the country's employment situation.' He also suggests moving it to the end of the questionnaire.

Another member feels that question E1 as stated is too vague, but is not able to suggest an improvement. Yet another member says that the category 'seasonal work' does not belong with the distinction between full-time and part-time employment, and should be asked as a separate question.

5.3   Internal Review

It is now time for the next meeting with the Steering Committee, and the discussions to date are presented. The Steering Committee agrees with the general approach of using Forms F1 and F2. The Steering Committee also provides some detailed comments at the question level that are consistent with the feedback already provided by the project team.

Based on the comments of the project team and the Steering Committee, the team revises the questionnaire as follows. (Note that, only the sections for team members C and E will be followed through the review process.)

For persons identified as being employed

C1 What is your job title (e.g., sweeper, engineer, sales manager, driver)?
           _____

C2 What kind of business, industry or service was this?
           _____

E1 How many hours do you usually work in a week?
           _____

Now I'd like to ask a few short questions about your earnings.

E2 What is your hourly rate of pay (before taxes and other deductions)?
           _____

E3 Does your employer provide the following benefits?
        a. Health insurance or health care   ❍ *Yes*   ❍ *No*
        b. Rent subsidy   ❍ *Yes*   ❍ *No*
        c. Retirement pension   ❍ *Yes*   ❍ *No*

5.4 Questionnaire Testing

The team decides to conduct focus group testing of the current questionnaire to see whether it is easily understood by respondents and whether they are likely to provide the correct responses.

Since the BBS does not employ qualified focus group facilitators, the project team decides to bring in an expert in focus group testing – Mr. F. He has taken specialised training in conducting focus groups and should be able to fit the testing into his schedule.

For the focus group, several senior interviewers are brought in from the regional statistical offices in order to administer the questionnaire to respondents. Several dozen 'typical' respondents are selected by the project team, and several focus group sessions will be conducted over the course of a week. The team selects respondents who will represent the full range of respondents – some urban, some rural, some working, some students, some retired.

Before the focus group discussions take place, the interviewers administer the questionnaire to the respondents. Then, Mr. F leads separate discussions with the interviewers and the respondents to ask them about the questionnaire and any problems encountered.

Through the focus group discussions the team discovers the following problems with the questions on hours of work:

i.   Several respondents report that they find it difficult to answer the question about the number of hours they usually work in a week because their hours of work vary from week to week.

ii.   Many respondents ask whether their overtime hours should be included in their usual hours of work.

iii.   The questions are confusing for respondents with multiple jobs.

The following problems with the earnings questions come to light:

i.   Many respondents are not paid hourly, so they often say they do not know their hourly wages but instead provide their wages for a different time frame. Usually, the interviewers record this in the margins of the questionnaire.

ii.   Many respondents are unsure of whether their employer provides benefits. In addition, this question does not make much sense for self-employed individuals.

However, the team is very happy that there do not seem to be any problems for respondents or interviewers with the industry and occupation questions. Just to be cautious, team member C decides to send the responses to coders, trained in coding industry and occupation. After several hours, he finds out that, because the responses are too general and do not provide enough information, the coders are unable

to code them to a detailed level. It will be necessary to include several questions about industry and occupation so the coders have enough information to make a decision about the correct code to assign. The team obviously still has much work to do on the questionnaire.

5.5   Final Draft

After the comments resulting from the focus group testing have been incorporated into the questionnaire, the final draft of the sections written by team members C and E is as follows (Note that, these questions will only be asked of employed respondents):

JOB DESCRIPTION

The following questions refer to your main job (that is the job at which you work the most hours).

JD1   *Are you an employee or self-employed?*
                 ❍ *Employed (go to JD5)*
                 ❍ *Self-employed*

JD2   *Do you have an incorporated business?*
                 ❍ *Yes*
                 ❍ *No*

JD3   *Do you have any employees?*
                 ❍ *Yes*
                 ❍ *No*

JD4   *What is the name of your business? (go to JD6)*
                 _____

JD5   *For whom do you work?*
                 _____

JD6   *What kind of business, industry or service is this? (e.g., road maintenance, primary school, rice farm, retail shoe store, garage)*
                 _____

JD7   *What is your work or occupation? (e.g., legal secretary, plumber, fishing guide, school teacher)*
                 _____

JD8   *In this work, what are your main activities or duties? (e.g., prepare legal documents, install residential plumbing, guide fishing parties, teach mathematics)*
                 _____

WORK HOURS (MAIN JOB)

The following questions refer to your work hours at your main job (that is the job at which you work the most hours).

WH1   *Does the number of hours you work vary from week to week?*
            ❍ *Yes*
            ❍ *No (go to WH3)*

WH2   *On average, how many hours do you usually work per week? (go to next section)*
            _____

WH3   *How many hours did you work last week?*
            _____

WH4   *Last week, how many hours of paid overtime did you work at this job?*
            _____

WH5   *Last week, how many extra hours without pay did you work at this job?*
            _____

EARNINGS

Now I'd like to ask a few short questions about your earnings.

E1   *Are you paid by the hour?*
            ❍ *Yes (go to E2)*
            ❍ *No (go to E3)*

E2   *What is your hourly rate of pay? (go to next section)*
            _____

E3   *What is the easiest way for you to tell us your wage or salary, before taxes and other deductions? Would it be yearly, monthly, weekly, or on some other basis? What are your wages or salary?*
                        _____*/Yearly*
        OR   _____*/Monthly*
        OR   _____*/Weekly*
        OR   _____*/Other (specify time frame _____)*

Review questions:

Since this is the first version of the GHS questionnaire intended for use in a full-scale survey, what sorts of testing would you propose?

Propose other versions of the questions presented in section 5.5.

Chapter 6 - Sample Designs

Note to the reader: Chapters 6, 7, and 8 deal with Sample Design, Estimation, and Sample Size Determination and Allocation, respectively. Because each of these components of a survey design depends heavily on the others, in reality their development is carried out as a single, quite complex operation. To respect the order in which the material is presented in the corresponding chapters in the Manual, the three topics are considered separately here.

6.0   Sample Design

Since there are no current lists of the population of Belleterre and it would be prohibitively expensive to develop such a list, an area frame is chosen. In order to select members of households, the area frame must ultimately sample dwellings (i.e., the ultimate sampling unit is the household and the interview will be conducted with one member of the household who will report for everyone in the household.)

The exact form of the selection of dwellings is not immediately evident, but in order to avoid listing all dwellings, it seems logical to use a two- or three-stage cluster design (and thus only list those dwellings in areas sampled at the last stage). The team realises that three-stage sampling, while possibly more cost efficient, may be complicated to carry out in practice, and so they make all efforts to identify suitable units to permit a two-stage design.

The team agrees that the sample design will use geographic stratification at several levels of detail. Belleterre is naturally divided into eleven regions, namely the three major cities and eight additional districts. Within the districts, several more cities and large towns are considered as urban, and numerous villages and outlying areas are considered as rural (see outline in Chapter 1 of the Case Study).

Because of the recent changes in the population and labour force dynamics of the country, and differences between the major cities and the rest of the country, the Steering Committee has indicated that it wants the GHS to provide the same level of precision (sampling variance) for each major city and for each district. Given this requirement, it is more efficient to treat the three cities and eight districts as planned domains – that is to design them as strata – to guarantee the required sample in each of them. This gives, in effect, eleven first-level strata, where equal reliability must be obtained in each.

The team also wishes to make the sample as representative as possible for reasonably large areas within each city and district, and so to further stratify. These secondary strata are constructed to have roughly similar sized populations and to follow county or municipal boundaries.

This geographical stratification is also motivated by administrative convenience, as the proposed strata correspond for the most part to the different levels of administrative units such as cities, districts and counties.

While there are other desirable stratification variables, both demographic and economic, it does not seem feasible to use them in this design, as they will not be available on the area frame before the sample is selected. However, the possibility of post-stratification at the estimation stage will be considered later, and due attention will be paid to ensuring that the desired variables are collected in the survey questionnaire.

Consequently, a two-stage stratified cluster design is proposed in which each of the three major cities and the eight districts is a stratum and within each of these strata, sub-strata are created. The identification of relatively small sub-strata will make it much easier to adhere to a two-stage design.

To avoid confusion between the different levels, it is agreed to refer to the top-level strata (Cities A, B and C and the remaining eight districts) by the term 'region', and to reserve the word 'stratum' for the lower-level sub-strata. For ease of reference, the eleven regions are identified as follows:

Table 6.1: Regional Strata

Region	
1	City A
2	City B
3	City C
4	District D
5	District E
6	District F
7	District G
8	District H
9	District J
10	District K
11	District L

Within each stratum, a number of primary sampling units (PSUs), or clusters, will be defined, and at the first stage of sampling one or more PSUs will be selected in a stratum. For the sake of efficiency, the PSUs should not be too big. In fact, it would be desirable for them to be of a suitable size to be covered effectively by a team of interviewers in the amount of time planned for data collection. This would imply that the PSUs should be of roughly equal size, containing several hundred dwellings.

At the second stage of sampling, all dwellings within the PSU will be listed and then sampled (and one member of the household interviewed.) The number of dwellings sampled per PSU should be reasonable for an interviewing team. In discussions with the regional offices, this has been determined to be 40 dwellings.

The team knows that it is desirable to select at least two clusters per stratum to allow correct estimation of sampling variance, and that according to the classic texts, this estimation becomes more complex if more than two clusters are selected using probability proportional to size (PPS) sampling, as they consider necessary. Therefore they seek to arrange matters so that two clusters are selected in each stratum.

Subsequently, dwellings must be listed within selected clusters, and a sample of dwellings drawn at the second stage. Once the lists have been compiled, dwellings could then be selected using simple random sampling (SRS) or systematic random sampling (SYS). For practical reasons, such as attempting to distribute the sample as well as possible throughout the selected clusters, the team decides to recommend using SYS.

Although the details of the sampling fractions have not yet been worked out, it already seems clear that they will be fairly low within selected clusters (perhaps 40 in 400 dwellings, or one in ten), so SYS is quite practical. At the same time, although this spreads the sample out over a certain area, the territory covered by a single cluster should not generally be very large, so that the costs of moving around within the selected cluster will not be large compared to the costs of getting there in the first place.

After some preliminary work, it becomes evident that the cluster sizes will vary quite noticeably, if natural boundaries are to be respected. Yet those natural boundaries are quite important to the good control of field operations and selection of the right clusters and dwellings as indicated by the maps and lists.

It is eventually decided to select clusters using probability proportional to size sampling (PPS), using the most recent population estimates for each cluster as a size measure. Within each selected cluster, a fixed number of dwellings will be selected using SYS. (Chapter 7 shows that this means that all units in the same stratum have the same probability of selection.)

Having established the general structure of the sample design, the team begins to work out the details of the design for region 1 (City A) and region 4 (district D), planning to use the same approach in the remaining regions.

Review questions:

Is there a realistic alternative to the two-level stratification (region and stratum) developed by the GHS team?

Would a three-stage sample design, using larger PSUs and an intermediate stage of Second Stage Units (SSUs) as clusters, have been more efficient? Would it have been feasible in practice?

The sampling plan will use the PPS method for cluster selection. Would PPS Random or PPS Systematic be more appropriate? If you choose PPS Systematic, how would you suggest sorting the lists of clusters?

Considering the plan to use SYS for selection of dwellings in selected clusters, comment on the possible disadvantages of this approach in the truly rural areas. Suggest an alternative strategy for these areas.

The design has been made self-weighting within each stratum. Is there a reasonable way to make the sample self-weighting at the region level, i.e. to ensure that all selected dwellings in an entire region have the same design weight? Is this a desirable goal?

Chapter 7 - Estimation

7.0 Estimation

The GHS team now begins to work out the procedures needed to obtain survey estimates of the characteristics collected via the questionnaire.

Although the sample will include many thousands of households (see Chapter 8 of the Case Study for details), the information obtained by interviewing those households is intended to represent the country's entire population of nearly 11 million households.

Given the probability sample design developed in Chapter 6 of the Case Study, and with the sample size and allocation described in Chapter 8, the sample results will indeed provide representative estimates for the country's population, and will have the desired small sampling variance, as long as there are no serious problems with nonresponse.

7.1 Weighting

The GHS must produce estimates for a large number of variables, but all those estimates will be based on a set of weights attached to each responding household's data record, and determined by the product of three straightforward calculations:
- the design weight, calculated from the dwelling's probability of selection;
- an adjustment factor for nonresponse;
- a post-stratification adjustment to demographic benchmarks.

7.1.1 Design Weight

The first step is to calculate the design weight, which as its name suggests is derived directly from the sample design, namely the design weight is the inverse of the probability of selection. The sample design in this case is a stratified two-stage design with PSUs selected using PPS at the first stage and SSUs (dwellings) selected using systematic sampling at the second stage.

The design weight is calculated for the selected dwelling. The household living in that dwelling, and each person in that household, will have the same design weight. In a multi-stage probability design, the selection probability of a final-stage unit is simply the product of the selection probabilities at each stage. Equivalently, the design weight can be seen as the product of the weights at each stage, since each of them is the inverse of the corresponding probability.

Hence, for the GHS design, the complete design weight is just the product of the first- and second-stage weights. Thus every selected dwelling i in cluster j of stratum h has design weight equal to:

$$w_{d,hji} = \frac{1}{\pi_{1,hj}} \times \frac{1}{\pi_{2,hji}}$$

where $\pi_{1,hj}$ is the probability of selecting cluster j in stratum h at the first stage, and $\pi_{2,hji}$ is the probability of selecting dwelling i in cluster j of stratum h at the second stage (given that cluster j was selected at the first stage).

It should be noted that the numbering of the strata actually has two levels. The first is the identification of the city or district (first-level stratum) and the second is the stratum identification number within that city or district. This is indicated for convenience by the single subscript h.

Since clusters are selected with probability proportional to size (PPS), those probabilities must be calculated in terms of the size measures used at the time of the survey design. The size measure used is the number of dwellings in the cluster; this measure will be denoted by z, and cluster j in stratum h has size z_{hj}. The total size measure for any stratum h is:

$$z_h = \sum_{j}^{m_h} z_{hj}$$

where m_h is the number of clusters in stratum h.

If k_h clusters are selected in stratum h, the selection probability of cluster j is $k_h z_{hj}/z_h$ and so the first-stage design weight for that cluster is:

$$w_{d1,hj} = \frac{1}{\pi_{1,hj}}$$

$$= \frac{z_h}{k_h \times z_{hj}}$$

At the second stage, 40 dwellings are to be selected. This means that all dwellings in cluster j have second-stage selection probability $\dfrac{40}{z_{hj}}$. Consequently, the second-stage design weight for selected dwellings is:

$$w_{d2,hji} = \frac{1}{\pi_{1,hji}}$$

$$= \frac{z_{hj}}{40}$$

Note that the size measure z_{hj} refers to the size – number of dwellings in the cluster – at the time the sample is being designed. This could be different from the size measures obtained by the interviewer after listing has been performed within the selected clusters. The amount $\dfrac{z_{hj}}{40}$ is the interval used for systematic sampling at the last stage. Applying this fixed interval to the actual count of dwellings listed in the PSU will yield a variable sample size per cluster that is expected to be close to 40.

The GHS team recognises that the clusters will have to be selected using estimated sizes since it impossible to enumerate the entire country. They must then stick to those size measures for the second-stage weight calculation. In effect this means that the stratum post-censal population estimates serve as an anchor, which makes sense if the same figures are to be used for explicit post-stratification (see below).

Therefore,

$$w_{d,hji} = \frac{1}{\pi_{1,hj}} \times \frac{1}{\pi_{2,hji}}$$

$$= \frac{z_h}{k_h \times z_{hj}} \times \frac{z_{hj}}{40}$$

$$= \frac{z_h}{k_h \times 40}$$

and this may be denoted simply as w_{dh}.

Note that all selected dwellings in the selected clusters in stratum h have the same design weight, and the design is self-weighting at the stratum level.

7.1.2 Nonresponse Adjusted Weight

The next component of the weight is the adjustment for total nonresponse. Although a high level of response is anticipated, it will surely not be 100%, and failure to make an adjustment for the actual amount of nonresponse would lead to underestimates of totals.

There is also, of course, the risk that nonrespondents as a group are different from respondents, with respect to some of the important survey variables, in which case adjusting the weights of respondents to represent nonrespondents could lead to bias.

The GHS team considers this risk carefully. The team methodologist points out that the nonresponse bias in any estimate is essentially the product of two factors: the amount of nonresponse, and the degree to which the nonrespondents are different from the respondents.

The team anticipates a fairly low level of nonresponse, so it is hoped that one component of that product will be reasonably small. They wonder whether the nonrespondents are really likely to be very different from respondents with respect to most of the important survey variables. It seems quite likely that nonrespondents may indeed have quite different characteristics from respondents. For example, the team fears that persons who have been laid off, who are recent migrants or who are very mobile may be much less likely to respond than persons with regular, stable employment in their place of permanent registration. This would lead to a significant contribution to nonresponse bias.

However, the team has no hard evidence, and decides that for the moment it must plan to adjust the weights as if nonresponse were random. At the same time, they agree to recommend follow-up studies of a sub-sample of nonrespondents to attempt to obtain a measure of the size of the bias which, they feel quite sure, should not simply be ignored. They also feel that another study should be put into place to examine partial nonresponse (where only some questions were answered), to see if a profile of reluctant respondents can be obtained in that way.

Given the sampling design used, there are several possible ways to make the weight adjustment for nonresponse. It could be made at the level of the cluster, the stratum or the city/district. It seems unreasonable to make a single adjustment for the entire country, since it is known that the population is not homogeneous; in fact, even adjusting at the level of each district or major city seems inadvisable for the same reason. Since the strata are usually counties, while clusters are quite small, the choice may be important. Clusters may be more homogeneous than entire strata, but are small enough that the

adjustments may not be too stable because of the small sample sizes and possibly quite variable response rates at that level.

Since the stratum sample is several times that of each cluster, and since the design weight is the same for both clusters in any case, the team feels that it is most sensible to apply the adjustment at the stratum level.

If the number of respondent households in the stratum is n_{rh}, the nonresponse adjusted weight will be equal to

$$w_{nr,h} = w_{d,h} \frac{n}{n_r}$$

$$= \frac{z_h}{k_h \times 40} \times \frac{k_h \times 40}{n_{r,h}}$$

$$= \frac{z_h}{n_{rh}}$$

and all respondent households and persons in the stratum again have the same weight.

It may be noted that this will only be strictly true as long as all eligible persons in a responding household are themselves respondents. For planning purposes, the GHS team has assumed that this will be true, but they are prepared to propose a further adjustment to the weights of individuals if not all individuals respond.

The team notes that the numerical values of the design weights will vary considerably from stratum to stratum, since the stratum sizes vary, and k may not be the same in all strata. The range of values may not be terribly wide, but is more than enough to prevent the design from being considered as self-weighting above the stratum level.

7.1.3   Final Post-Stratified Weight

The team proposes to include an adjustment to the weights to make sure that the estimates reproduce important known totals, and to improve the precision of the estimates by post-stratifying according to homogenous groupings. The most important of these from the point of view of labour force participation is the population size for each sex and for the major relevant age groups (15-24, 25-49, 50-64 and 65+ years of age), since these groups have markedly different labour force profiles.

The post-censal population estimates by age and sex are based on data from the most recent census, updated using housing registers and vital statistics on births and deaths. These figures are thought to be highly accurate for each major city or district, but because they take little account of internal migration and have been projected for nearly ten years, the GHS team is not sure whether they are very good at the stratum level.

They consult with officials of the BBS' Demographic Studies Division, and come to the conclusion that they should recommend adjusting only at the level of the district or city, but that the adjustment should be made at the stratum level once the next census results are available.

The final weight for each individual respondent will therefore be:

$$w_{f,hza} = w_{nr,h} \times \frac{N_{za}}{\hat{N}_{za}}$$

where N_{za} is the post-censal population estimate for age-sex group a in city or district z, and $\hat{N}_{za}$ is the sum of the (nonresponse-adjusted) weights over all respondents in area z who belong to age-sex group a, and corresponds to the direct survey estimate of the population in that age-sex group.

It may be noted that this now gives individuals in the same household different weights. However, the sample is now self-weighted within age-sex group and stratum.

7.2   Estimation of Sampling Variance

Standard textbooks contain formulae for stratified two-stage designs that are self-weighting at the stratum level, although these are somewhat complex. However, because of the adjustments being proposed for nonresponse and age-sex totals, the algebraic expressions will become complex, and the team resolves to undertake research into applying a computationally-intensive replication method such as the jackknife or the bootstrap. So far, they have not done much work on this aspect.

Review questions:

Is the GHS team correct in assuming that there is little risk of nonresponse bias? Consider the probable response rates for private households versus collective households, especially those containing many transient workers or recent migrants. Would it be possible to stratify by type of household (dwelling) before making the nonresponse adjustment within those strata?

Comment on the choice of level for making the nonresponse adjustment. In your opinion, did the team make the right decision regarding weight adjustment for nonresponse? Would it be best to adjust the weights at the level of the cluster, the stratum or the city/district? Give your reasons.

Do similarly with regard to the post-stratified adjustment for age and sex.

Chapter 8 - Sample Size Determination and Allocation

8.0   Sample Size Determination and Allocation

Having established the general structure of the sample design, the team begins to work out the details of the design, namely the sample size, the allocation of the sample across strata and the numbers of clusters per stratum.

The team considers the most important variables to be measured: these are percentages or proportions, such as the proportion of adults who are in the labour force, the proportion holding jobs, the proportion of persons aged 55+ who are still economically active, and so forth.

The team, in consultation with the Steering Committee, considers what factors should be taken into account in determining the sample size and its allocation among regions. The Steering Committee indicates that, while a high degree of precision is required at the national level, it is very important to control the precision for each region, since it is at the regional level that planning decisions will primarily be made.

There is some discussion of using an optimal allocation function to take account of differential costs or variances between regions. However, no good indication of relative differences in the variances is available, and it is felt that the data collection costs, the largest single component of the survey's total cost, will not vary greatly from region to region. Also, optimum allocation may not ensure adequate precision for regional estimates. Therefore, it is decided to aim for the same margin of error for all regions.

The methodology representative on the Steering Committee points out that, if good precision is obtained for each of the eleven regions, in terms of small margin of error for the most important estimates, then the margin of error for the national estimates will be no more than about one third of the regional margins of error, implying a very good degree of precision.

The stated precision requirements indicate that the margin of error (at the 95% level of confidence) should be no more than 2.5% for the key variables, for each of the 11 regions. Since each region has a large population, this means that the sample size should be the same in each region.

8.1   Sample Size Determination by Region

1. Initial Sample Size in Each Region

A preliminary estimate of the sample size, n_1, is:

$$n_1 = \frac{z^2 \hat{P}(1-\hat{P})}{e^2}$$

where e is the margin of error (.025) and $\hat{P}$ is the targeted proportion (assume P=.5).

$$n_1 = \frac{(1.96)^2 \times .5 \times (1 - .5)}{(.025)^2}$$
$$= 1{,}537$$

2. The methodologist notes that there is probably no need to adjust the sample size for the size of the population since the smallest region – City B – is very large (over 2 million people). Thus, $n_2 = n_1$.

3. The best estimate of the overall design effect is *deff=2* (based on similar surveys conducted in other countries):

$$n_3 = deff \times n_2$$
$$= 2 \times 1{,}537$$
$$= 3{,}074$$

4. The sample size is adjusted for the nonresponse rate, which is expected to be no more than 20% (again based on similar surveys conducted elsewhere). This nonresponse also accounts for a modest percentage of vacant or unoccupied dwellings and a reasonable level of nonresponse due to families being temporarily absent or simply difficult to locate. The final sample size per regions is estimated at:

$$n = \frac{n_3}{r}$$
$$= \frac{3{,}074}{.8}$$
$$= 3{,}843$$

So, across all regions, the total sample size is 11 x 3,843 = 42,473 people to survey. Because the team has assumed approximately two adults per household, this means 21,237 households across Belleterre (1,922 per region).

Several team members do not understand the significance of the assumption of two adults per household. The methodologist explains that the sample unit for the survey is the dwelling, however, all estimation will be done for the adult population of the country, since it is they, not dwellings, who comprise the labour force. Therefore, since the precision requirements are related to adults, these calculations must first be done based on the number of adults required then translated to the number of dwellings required in the sample.

The methodologist confirms that there is no need to consider the finite population correction since for City B (the smallest region) it is 3,843 divided 2 million, which is 0.0019.

The team is planning to monitor response rates for every selected cluster, noting the type of household and other relevant information, in order to detect any differences in response rates by household type, or by region or other variables that could be taken into account in developing a revised nonresponse weight adjustment strategy in subsequent years.

8.2   Definition of Second Stage Stratification and Clusters

The country's population as of 2005 is estimated to be approximately 44 million people, and the team has been advised to assume an average of 4 persons per dwelling (allowing for children, elderly relatives, and a small percentage of multi-household dwellings other than collectives). This translates into a total of about 11 million dwellings, taken for planning purposes to correspond to 11 million households.
With a sample size of 21,237 households, this would indicate an average sampling fraction of 1 in 518. This may appear very low, but the sample size is still quite a large number. At the regional level, the populations vary widely, and therefore so do the sampling fractions dictated by the targeted regional sample size of 1,922 dwellings. Among the regions, the sampling fractions will range from about 1 in 268 in City B to 1 in 754 in the most populous region, District J.

The sample design has been set up to allow for the definition of a large number of strata, each of which will have a substantial number of primary sampling units (PSUs) referred to as clusters. Two (occasionally three) clusters will be selected per stratum to facilitate use of simple variance estimation techniques.

Of course, there will be differences in strata and cluster sizes within each region, so that the sampling fractions in each stratum within a region will vary somewhat. Also, the team keeps in mind that it is not desirable for the within-cluster sampling fractions to become too small, as that would lead to undue geographic dispersion, at least in the rural areas.

As mentioned earlier, the strata within each region were defined by administrative, municipal boundaries.

Table 8.1: Stratification

Region	Counties	Municipalities	Strata
City A	3	21	21
City B	3	17	17
City C	3	16	19
District D	11	23	23
District E	11	26	26
District F	13	29	28
District G	10	26	26
District H	7	21	23
District I	11	26	26
District J	13	34	34
District K	11	28	30
Total	**96**	**267**	**273**

N-proportional Allocation Across Strata within each Region

The regional sample will be allocated across strata using N-proportional allocation. Recall that with N-proportional allocation,

$$n_h = n \times \frac{N_h}{N}$$

where here n=1,922.

Within each stratum, clusters are created. Considerations related to the efficiency of field operations limit the ranges of options in determining cluster sizes. A team of 3 interviewers and 1 supervisor should be

able to do between 75 and 100 interviews in a week. To allow for unforeseen circumstances, it is decided to make the sample size in each cluster 40, so that the team can cover the expected two clusters in a stratum within a week's work, for a total of 80 interviews if there is a 100% response rate. For strata with three selected clusters, it is planned to have 4 interviewers on the team, and perhaps take one or two days longer to cover the assignment.

The cluster creation and sample allocation for City A results in the following:

Table 8.2: Allocation of Sample Across Strata in City A

Stratum	County	Population of Dwellings (N_h)	Number of Clusters in Stratum	Average Cluster Size (Dwellings)	Sample Size Of Dwellings (n_h)
1	1	39,836	52	766	75
2	1	42,481	50	849.6	80
3	2	58,411	43	1,358.4	110
4	2	52,039	45	1,156.4	98
5	3	55,800	48	1,162.5	105
…	…	…	…	…	…
21	9	50,900	52	978.8	96
Total		**1,020,600**	**1,092**	**934.6**	**1,922**

Notice that the sampling fractions in each stratum are roughly equal (because the strata are roughly equal in size). Within City A, sampling fractions vary from 1 in 529 to 1 in 535.

Because in each cluster we want to sample 40 dwellings and since we can only select an integer number of clusters, the expected sample size in City A is 2,000 (i.e., 50 clusters with 40 households per cluster), as shown in the table below.

Table 8.3: Number of Clusters to Sample In Order to Satisfy Above

Stratum	Population of Dwellings (N_h)	Number of Clusters in Stratum	Number of Clusters Sampled	Sample Size Of Dwellings (n_h)
1	39,836	52	2	80
2	42,481	50	2	80
3	58,411	43	3	120
4	52,039	45	3	120
5	55,800	48	3	120
…	…	…	…	
21	50,900	52	3	120
Total	**1,020,600**	**1,092**	**50**	**2,000**

District D has 11 counties, in which a total of 23 strata have been defined. The structure is somewhat more complicated than City A, since the counties vary widely in population, and it is desirable that stratum boundaries should not cross county lines. In one case, two small counties are merged to make a single stratum, and in another the county is itself a stratum. In most cases, the county becomes two or three strata (broken down by municipal boundaries).

One team member, an economist, has pointed out that within any county, the economic and labour force characteristics of the urban and rural parts are likely to be quite different and that cluster sampling may be very inefficient. The methodologist considers this problem and suggests forming the two or three strata within a county so that one contains the most urban areas and the other (or other two) contains the most rural parts. Since then two or three clusters will be selected in each resulting stratum, the other team members agree that the sample should be reasonably well balanced.

The resulting stratum sizes now range from 19,400 to 37,600 dwellings, averaging 28,300 dwellings per stratum. The clusters are on average somewhat smaller than in City A, the number of clusters per stratum from 24 to 44 with again 2 or 3 clusters to be selected per stratum to yield 80 or 120 dwellings per stratum.

The following table shows the sample for District D allocated across its 23 strata using N-proportional allocation.

Table 8.4: Allocation of Sample Across Strata in District D

Stratum	County	Population of Dwellings (N_h)	Number of Clusters in Stratum	Average Cluster Size (Dwellings)	Sample Size Of Dwellings (n_h)
1 Urban	1	22,400	25	896	66
2 Rural	1	26,200	32	818.8	77
3 Urban	2	30,200	25	1,208	89
4 Rural	2	24,400	28	871.4	72
5 Rural	2	30,600	38	805.3	90
…	…				…
9 Urban	4	21,800	26	838.5	64
10 Rural	4	28,900	32	903.1	85
11 Rural	4	32,200	36	894.4	95
12 Rural	5	19,400	24	808.3	57
13 Rural	6+7	24,200	26	930.8	72
14 Urban	8	28,900	34	850	85
15 Rural	8	29,400	41	717.1	87
….					
22 Urban	11	30,800	44	700	91
23 Rural	11	22,900	29	789.7	68
Total		**650,100**	**856**	**759.4**	**1,922**

Table 8.5: Allocation of Sample Across Strata in District D

Stratum	Population of Dwellings (N_h)	Number of Clusters in Stratum	Number of Clusters Sampled	Sample Size Of Dwellings (n_h)
1	22,400	25	2	80
2	26,200	32	2	80
3	30,200	25	3	120
4	24,400	28	2	80
5	30,600	38	3	120
…				…
9	21,800	26	2	80
10	28,900	32		
11	32,200	36	3	120
12	19,400	24	2	80
13	24,200	26	2	80
14	28,900	34	3	120
15	29,400	41	3	120
….				
22	30,800	44	3	120
23	22,900	29	2	80
Total	**650,100**	**856**	**50**	**2,000**

So, the overall expected sample size of adults is 4,000 for City A and District D. Performing the allocation for all cities and districts, the methodologist finds the expected overall sample size to be 22,000.

Review questions:

Discuss the GHS team's assumption of 'one household, two adults'. Can they do better than this, before obtaining data from the first round of the GHS?

How will the inclusion of collective dwellings affect the assumption made in the previous point and your response to it?

Can you give some practical arguments why the within-cluster sample size should be larger, or smaller, than has been suggested by the GHS team? (Consider the field conditions in which the interviewing teams will be working). Would it not be better to make smaller clusters and then smaller samples of dwellings within clusters, combining several selected clusters to make an interviewing team's assignment? Comment on the advantages and disadvantages of such a modification.

Given that the sample size determination targets a margin of error of 2.5% for each of the 11 regions, with widely varying populations, approximately what margin of error would you expect at the national level?

Comment on the assumption of an average of 4 persons per household. How will this vary between rural and urban areas?

Chapter 9 - Data Collection Operations

9.0 Data Collection Operations

As soon as it was decided to use personal interviewing for data collection for the GHS, the project team began to prepare for the data collection operations.

The use of a two-stage sample design requires that the definition of the clusters and the allocation of sample size to strata and to clusters be statistically efficient, while at the same time being both cost-effective and feasible from an operational point of view. Because of these considerations, much of the preparatory work for the data collection operations was done in parallel with the development of the sample design.

9.1 Regional Organisation of the GHS Project

The BBS is responsible for the overall design and management of the GHS. However, in order to conduct data collection and processing, they require the active collaboration of the statistical organisations at the district and sub-district levels.

In each of the three major cities there is a district statistical office. These offices will be intensively involved in data collection and the first stages of data processing, working under the general direction of the BBS. Each of the other 8 regions (Districts D-K) also has a district and in some cases sub-district office(s). Each district has between 7 and 13 counties and most of these counties correspond to two or three strata. Thus, it is still practical to organise the data collection teams at the level of the county, under the co-ordination of the district office and, of course, the BBS. Data collection costs will be reduced since members of the interviewing teams will likely reside in the areas in which they will be interviewing, or at least live quite nearby.

The BBS, functioning as the survey's head office, is primarily responsible for establishing the data collection timetable and target response rates. As well, the BBS, in collaboration with the district statistical offices, designs the reporting system and control forms required to guarantee the correct listing and selection of sampling units, and the timely flow of completed questionnaires back to the statistical offices.

In similar fashion, the BBS team prepares the training and operations manuals for interviewers and supervisors, sharing the drafts of these documents with the district offices for comment and revision. Training exercises and other materials are also designed by the BBS, although most of the training sessions will be held and district or sub-district offices. Once finalised, the manuals and other forms will be printed by the BBS, and distributed through the district and sub-district offices.

Because of the scope of the activities to be conducted and co-ordinated, each of the district offices has named a GHS regional project manager. This person is responsible for much of the organisation of the office's work on the GHS, and is the principal point of contact for the main GHS team at the BBS. Since it has been decided that the data capture will also be conducted in the district offices, the regional manager is also responsible for co-ordinating these activities (see Case Study Chapter 10). The regional managers will be responsible for the flow of materials from the BBS to the local offices, as well as the return of completed questionnaires to their own offices for data capture, and of the electronic files to the BBS for final processing (editing and imputation, outlier detection).

Using the guidelines developed in conjunction with the BBS team, the regional managers will work with their local counterparts to identify suitable candidates for hiring and training as interviewers and supervisors. To ensure consistency, these steps will be monitored and observed by the BBS team, who will also receive regular progress reports from the regional managers.

In most cases, a team of one supervisor and three or four interviewers hired at the county level (or sub-district office level) will be responsible for data collection in the clusters in its GHS stratum. In some cases, an interviewing team will cover more than one stratum, but given the plan to conduct all interviewing in little more than a week, this is not expected to happen in many cases. The team will work together in a cluster until it has been completed and then move on to the next cluster.

The GHS project team notes that this requires a total of nearly 275 supervisors (one for each of the 25 strata in each of the 11 regions), and close to 900 interviewers altogether.

9.2   Public Relations

Because the GHS is an important new survey and the BBS intends to obtain the highest possible quality of data, including data from population groups that may have reason to be wary of answering questions, the team decides, with the approval of the GHS Steering Committee, to invest in an extensive public relations campaign across the country.

For this purpose, a staff member of the BBS' Communications Division is assigned to work with the GHS project team to prepare suitable informative material. This will include an introductory letter explaining the objectives and the importance of the GHS. The letter will be signed by the Director General of the BBS, and a suitable public figure at the community level, either the manager of the district or sub-district statistical office, or a well-known representative of the municipal administration.

The first draft of the letter follows:

Dear respondent,

Your household has been selected to participate in the Belleterre General Household Survey. This important new public survey will provide essential information on the work activities of the population of our country, and how families are doing in the current time of rapid economic change.

This survey is being conducted by the Belleterre Bureau of Statistics. The confidentiality of the information gathered by this survey is protected by the law. Your answers to the survey questions will be kept strictly confidential. All the data obtained from this survey will be used for statistical purposes only. Your answers will be combined with those of many other citizens to provide a statistically reliable picture of conditions in the country.

The interview will take approximately 20 minutes to complete. If it is not convenient for you to take that much time when our interviewer first calls on you, he/she will be happy to make an appointment to conduct the interview at a time more convenient to you.

The Belleterre Bureau of Statistics recognises the important contribution that you and other citizens make in taking the time to provide your share of this vital information. We thank you in advance for your valuable contribution.

If you have any questions that the interviewer is unable to answer, please feel free to contact the local GHS representative at the branch/county statistical office, located at --------------------------; or by telephone at 1-23-456-7899.

J. Doe   *P. Smith*
Director, BBS   *Responsible Officer*
                                           (Local Office Name)

A carefully worded press release is also prepared, to be sent to all local newspapers, radio stations and police offices, as well as the offices of municipal administration, informing them of the upcoming GHS activities and requesting collaboration in informing the general public. To facilitate this task, several key paragraphs are written that can be read by news announcers or printed verbatim in newspaper reports. In this way, the same message will be used throughout the country.

9.3   Preparing for Collection

The GHS survey team must develop three manuals: one for listing of dwellings, one for interviewing, and one for the supervisors who will oversee both operations.

In order to write the interviewers' and supervisors' manuals, the GHS team consults manuals used for other household surveys in the past and extracts whole sections to include in the GHS manuals. Much of the listing manual, however, has to be developed from scratch since the BBS has not done listing before. The team is able to refer to manuals from countries that frequently use area frames in order to help develop the manual.

As mentioned above, the supervisors will be hired first and trained. Supervisors should preferably have previous survey experience. They must also have the necessary personal qualities and skills to effectively manage a team of several interviewers during the listing and interviewing activities and to deal with difficult respondents, while at the same time ensuring that data and other information are transmitted reliably and in timely fashion back to the responsible statistical office. All staff hired must be reliable and trustworthy – to get the job done as prescribed and to preserve confidentiality of the data collected.

Approximately 275 supervisors are needed who will be trained by the regional project managers. The GHS team plans to make an intensive effort to train the regional project managers thoroughly in the survey objectives, concepts, collection procedures, etc., so that they can work with small groups of district or sub-district representatives to interview candidates for supervisors' positions, and then to train those who are hired. Subsequently, those hired as supervisors will join with the district and sub-district office representatives, under the direction of the GHS team and the regional managers, to interview and hire a sufficient number of qualified interviewers.

If possible, the GHS would prefer to assign existing supervisory and interviewing staff to the project. However, in case some positions cannot be filled from within the various regional offices, announcements will be made on the radio, in the local newspaper and in community halls, inviting applications and stating the essential qualifications for the work.

Thorough training will be conducted to prepare the interviewers for their tasks. In each case, they must first study their manuals at home and do several written exercises. Next, they will undergo several days of in-class training, during which they will study interviewing skills and techniques and will familiarise

themselves with the questionnaire. During training, the supervisors will discuss and correct the written exercises completed at home by the interviewers and practice interviews will be done, both with other interviewers and with respondents who will not be in the GHS sample.

9.4   Listing

Because the sample design is based on clusters which have been delineated on maps, the first task for the interviewing teams is to identify the selected clusters and go into the field to list the dwellings in them with a sufficiently detailed description that they can be uniquely identified and easily found again if selected for interviewing. The teams proceed on foot, by bicycle or by car, depending on the geographic size of the cluster.

Once the lists are completed, the supervisor and the district or sub-district office representative (following the instructions received from the GHS team through their regional managers) select the appropriate number of dwellings, using systematic sampling from the lists, with sampling intervals and random starts communicated to them by the regional managers.

9.5   Data Collection

Having identified the selected dwellings, data collection starts. Interviewers contact the households or individuals living in those dwellings and, if possible, interview the eligible household members. When no one eligible to be interviewed is home, the interviewer asks when he/she should call back; if no one at all is there, he/she leaves a note saying that he/she will call again later. If someone is present but unable to proceed with the interview, the interviewer attempts to arrange to do the interview within the next few days, reiterating the importance of that person's contribution to the survey. In the case that the householder refuses the interview outright, the interviewer makes one more attempt at persuasion, but then withdraws and brings the case to the attention of his/her supervisor, who is responsible for further attempts at conversion to a complete response.

At the end of each day, the interviewer checks that all interview documents are complete, and that the status of each interview is correctly entered on the control forms. Some field edits are applied and if any errors are detected, the household is contacted the following day to resolve any inconsistencies or omissions. Following their completion, the forms are returned to the office.

To ensure high-quality data collection, the supervisor observes a certain proportion of the interviews conducted by each interviewer, particularly at the beginning of the data collection period. In addition, members of the municipal office staff and of the GHS team from the BBS observe some interviews in various areas of the district. Supervisors provide feedback to the interviewers so they can correct any errors and improve their interviewing skills.

The GHS team also implements a reinterview program whereby a subsample of sampled units are recontacted the week after data collection to verify critical information on the questionnaire. Any discrepancies with the original information are clarified with the help of the respondent. The resulting reinterview data will be used to estimate the extent of various types of nonsampling error (such as coverage error, measurement error, nonresponse error or processing errors) in the data.

The supervisors also check that the questionnaires have been completed properly and that the correct status codes have been assigned. They must also ensure that all questionnaires and other forms are accounted for and in order before being forwarded to the office for processing.

When interviewing is completed, the supervisor and municipal office staff debrief the interviewers to gain valuable feedback both for processing the data and for revising the questionnaire and manuals for the next round of the GHS.

Review questions:

Is it practical to hire such a large number of interviewers and supervisors to work for such a short period of time each quarter? What would be the implications of using fewer teams, and spreading out the interviewing over several weeks? (Consider aspects such as costs, data quality, and the other operations associated with data collection such as listing and counting.)

Can you suggest any improvements to the draft letter to respondents, to help them understand how important the survey is, and to reassure them that their answers will be kept confidential?

It was stated that data capture would be done at the district offices. Is this the most effective arrangement, or would it be preferable to do the data capture at head office?

Chapter 10 - Processing

10.0 Processing

After the questionnaires are returned to the sub-district or district branch offices, they are processed to obtain a datafile so that tables may be produced and the survey results analysed. The steps to be carried out at this stage of the survey include coding, data capture, editing and imputation, outlier detection and treatment, and database creation. In addition, a variety of quality control and quality assurance procedures are developed and put into effect.

10.1 Coding and Data Capture

The closed questions are pre-coded on the questionnaire, so that the data capture operators simply need to key in the code numbers found beside the circles or boxes corresponding to the response. The open questions dealing with quantities (respondent's age in years, number of hours worked, wages, etc.) can also be captured directly from the questionnaire.

On the other hand, the questionnaire contains several questions, such as type of work done, which have so many possible answers that the categories and codes cannot be included on the questionnaire. In these cases, the list of codes has been prepared and given to office personnel who write the appropriate code on the questionnaire prior to data capture. For example, question JD6 asks the respondent in which industry his/her employer conducts its principal economic activity. Therefore, a code list of economic sectors had to be provided to the office staff to use to assign the most appropriate value to the response before data capture.

There are also a few cases of 'other, please specify' questions that cannot be precoded. In these cases, the GHS team has developed a preliminary list of the most likely topics that will appear in the responses and assigned codes to them. A team member studies a number of questionnaires (perhaps about 100) to see if any other topics appear often enough to warrant a code of their own. All responses that can be coded using the revised list are. (Data capture personnel are instructed to key the actual response into a text field for all responses that cannot be coded prior to data capture.) These cases are studied once the data have been captured, and further attempts are made to develop a complete code list. Any cases that can still not be coded will then be given a default code for 'other'.

After coding is complete, batches of questionnaires are sent to the data capture operator who keys the coded responses into the computer to create the preliminary datafile. This is done using data capture screens prepared by the GHS team's informatics support team.

Throughout the survey, from data collection to table production, the survey team implements a number of procedures for quality control and quality assurance. A quality control program is put in place to verify a percentage of the work of each data entry operator, and to re-check all his/her work if the number of errors exceeds a predetermined limit. A similar procedure is used to verify coding. In both cases, acceptance sampling is implemented, with each operator's daily production being treated as a batch.

Feedback from the results of acceptance sampling are provided to each operator, and where necessary, additional training is provided (or, if targets not reached, the operator released). The relevant indicators are also shared with supervisors and survey managers.

10.2   Editing

Editing began when the interviewers, and then their supervisors, groomed the questionnaires to check that they were properly completed, and to see whether follow-up with the respondent was needed. Some further grooming is done in the office prior to coding and data capture.

More editing occurs during data capture, since the capture screens were programmed to detect certain errors at the time of keying. These edits include validity checks for out-of-range codes. For example, keying of any value from 3 through 8 for sex of respondent causes the computer to 'beep' and wait for a correction since that variable should only be coded as 1 for male, 2 for female or 9 for nonresponse.

The data capture programs also include consistency checks for invalid skip patterns. For example, in the job description section, only self-employed workers are supposed to answer questions JD2-JD4. If the person is not self-employed, questions JD2-JD4 should be skipped, and a code indicating inapplicability (such as '8') should be entered. If the data capture operator attempts to enter a response to one of these questions for a person who is not self-employed, the data capture screen beeps so that the operator can verify the data.

Once the data are in electronic format, more complete editing is done. As soon as the questionnaire was finalised, the team began preparing edit rules to check for unreasonable combinations of codes for groups of related questions (two, three or more questions). For example, a record would fail an edit rule, if the wages seem too high or low given the number of hours worked. These edit rules are applied automatically to the datafile. However, since the team has been warned of the dangers of over-editing and the need to make only the minimum necessary changes to data provided by the respondent, edit failures will be imputed only if the record has a significant impact on the estimate. For each question, therefore, special 'flag' fields are created to indicate whether the field failed an edit and whether it should enter into the imputation system.

Because of the grooming and manual edit steps, very few records have so many remaining edit failures at this stage that they will have to be declared unusable. Any such case is treated as a total nonresponse. As in the case of refusals and other instances of total nonresponse at the data collection stage, these cases are compensated for by adjustment to the survey weights.

10.3   Imputation

For useable questionnaire records, all fields failing an edit rule and all item nonresponses are analysed for possible imputation. Depending on the type of question, the method of imputation varies.

For a few fields, there is redundancy in the questions that permits deterministic imputation. For example, the section on household composition includes a field for total household size as well as the names, ages, etc. of all household members. If, despite previous checking, there is still an inconsistency among these fields, the total household size is flagged as being incorrect, and the value is imputed deterministically as the number of persons named in the remaining fields.

On the other hand, if a respondent declares income from the sale of agricultural products but does not provide an amount, the value is imputed by the random hot-deck method, using all other respondents in the same stratum, having income from this activity, as potential donors. If there are no suitable donors, the pool of potential donors is expanded to include all respondents in the same region.

Once imputation has been completed, the datafiles may be again passed through the edit programs, to ensure that the data are fully consistent. Imputation must be run again on the file, to eliminate the few remaining records which fail the edit rules, and the file is then edited again to be sure of consistency.

At the same time, diagnostic indicators such as the number of cases imputed for each field, the type of imputation used, the number of eligible donors and the frequency of their use, and other measures, are recorded as input to the survey evaluation process. At the evaluation stage, these indicators will be used to calculate edit failure rates and imputation rates for the key survey variables and those variables that showed the greatest number of problems. The edit and imputation flags will also be maintained on the file to aid in diagnosing the overall quality of the final database.

10.4   Outlier Detection and Treatment

Because of the nature of the questions, relatively few fields on the GHS datafile are outliers, that is extreme or influential observations. However, there are several variables, such as earnings, and even hours worked, for which extreme but possible values occur. For example, one person declared having worked 96 hours last week, and indeed this could be true. Another respondent reported earning $75,000 last week and this too could be true, but would be a very rare case – especially since that same respondent gave her occupation as elementary-school teacher. In this case, likely her true income was closer to $750.00. Even if true, this response could have an undue influence on the survey estimates if, for some reason, her household had an unusually high sampling weight (for example, due to nonresponse weight adjustments).

To detect and deal with cases like the above, the GHS team developed systematic approaches to outlier detection and treatment based on the sample quantiles (quartiles and median). They were unsure what to use as the critical values, so they chose fairly low values (that is, likely to detect too many 'outliers'). The analysts then examine all the flagged values to get a better understanding of the data distributions, before making any final decisions as to what cases should be defined as outliers and how they should be treated. Using this experience, the team will then develop a more systematic approach to outlier detection and treatment for the second round of the GHS.

10.5   Creating the Database

The last steps in processing are to create a flat file to serve as the basic survey datafile, and to compute the weights and add them to the file. The GHS file then stores the file in a suitable format for the BBS' main statistical processing software (to speed up production of tables and other survey outputs).

Review questions:

It is stated above that questions with many possible answer categories needed to be coded manually before data capture. Can you suggest another way of dealing with these cases? Would it likely be more or less efficient than manual coding? Explain why.

Is it feasible to implement the suggested acceptance sampling for quality control of coding and data entry as described above, given that the approximately 300 coders and data entry operators are scattered across the various district offices? Can you suggest another approach to data processing and quality control that would be more effective? What would be its disadvantages?

Suggest other imputation approaches that could be used for the GHS.

What auxiliary variables should be considered in the creation of imputation classes?

Chapter 11 - Data Analysis

11.0 Data Analysis

Having obtained a complete and clean database, the GHS team must analyse the data in order to provide useful information to users to help them answer the questions that gave rise to the survey.

11.1 Summary Measures

The preliminary analysis is mainly descriptive including univariate frequency distributions, estimated totals, averages and proportions for all the variables generated directly from the questionnaire, or derived from them during processing. The estimates are accompanied by their estimated standard errors. There are also a substantial number of cross-tabulations, many of them pre-planned but some developed as a result of the preliminary data analysis. For example, as a result of the preliminary analysis, one analyst decided to study the type of jobs that men and women are working in. An excerpt of his analysis follows:

What types of jobs are men and women working in?

There is a large difference in the occupation distributions for men and women. Despite a perceived movement by women to management occupations and men to sales and service jobs, women and men still retain traditional occupation structures:

i.   *Women are more likely than men to be working in: sales and service; business, finance and administrative; social science, education, government service and religion; art, culture, recreation and sport; and health jobs.*

ii.   *Employed men, on the other hand, are more likely than women to be working in blue collar and management and natural and applied science jobs.*

Table 11.1a: Employment by Occupation and Sex

Occupation	Distribution across Occupations (%)	
	Men	**Women**
Management	11.9	8.6
Business, finance and administrative	9.5	26.9
Natural and applied sciences	8.6	2.4
Health	2.0	9.1
Social science, education, government service and religion	4.8	8.9
Art, culture, recreation and sport	2.4	3.2
Sales and service	19.6	31.5
Trades, transport and equipment operators	24.5	2.2
Primary industry	6.0	2.0
Processing, manufacturing and utilities	10.5	5.2
Total	**100.0**	**100.0**

Table 11.1b: Employment by Occupation and Sex

Occupation	Disribution across Men and Women	
	Men	**Women**
Management	62.6	37.4
Business, finance and administrative	29.8	70.2
Natural and applied sciences	81.4	18.6
Health	20.7	79.3
Social science, education, government service and religion	39.5	60.5
Art, culture, recreation and sport	47.4	52.6
Sales and service	42.6	57.4
Trades, transport and equipment operators	93.0	7.0
Primary industry	78.1	21.9
Processing, manufacturing and utilities	70.7	29.3
Total	**54.5**	**45.5**

11.2   Testing Hypotheses About the Population

Although summary measures are necessary as a starting point for analysis, most users and analysts wish to test certain hypotheses about the population. For example, one analyst wants to analyse the difference in wages by sex for employees between 15 and 65. Her hypothesis is that men are paid more than women. She initially examines the estimate of average hourly wages for both and notices a substantial difference – $19 for men and $15 for women. In addition, by graphing the data, she can see that the distributions are quite skewed – the median for men being $17 and the median for women being $13. For more information see Figure 11.1.

Figure 11.1: Hourly Wages for Men (1) and Women (2)
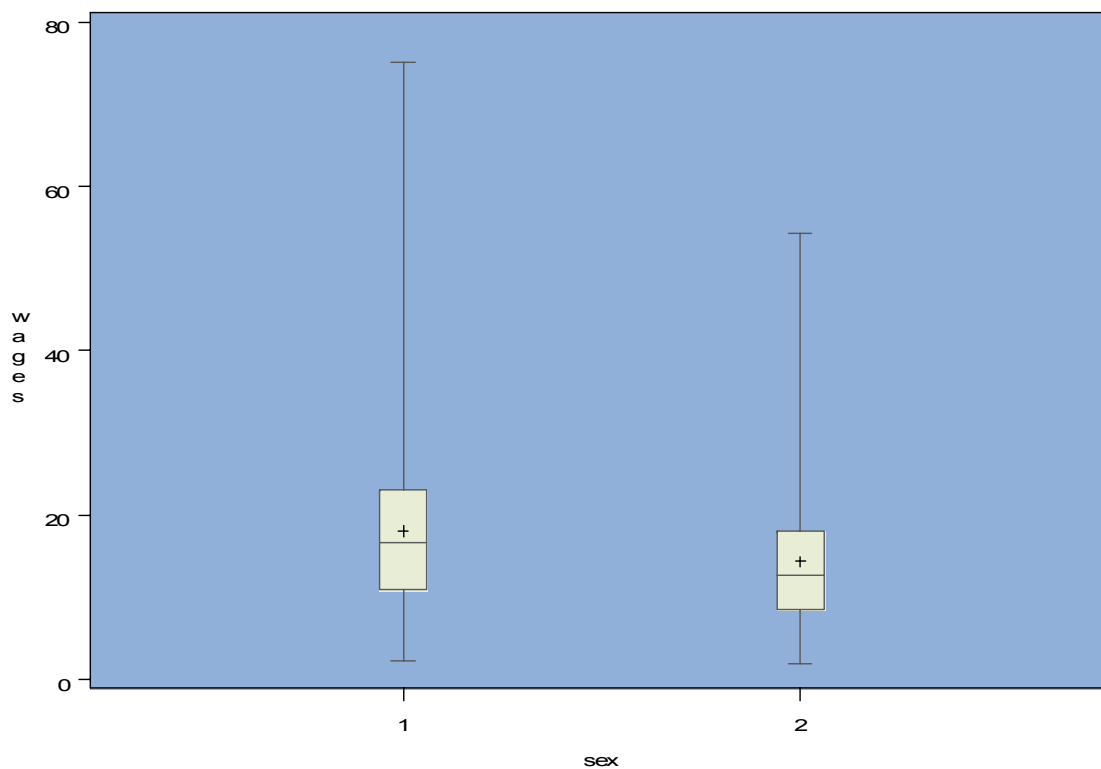
The analyst tests the null hypothesis that the mean wages for men and women are the same versus the alternative hypothesis that they are different. She finds that at the 95% confidence level, they are different.

However, after thinking about the relationship between sex and wages, the analyst wonders whether other variables might also have an impact. She suspects that age, education, industry and occupation may also be related to earnings. She decides to conduct an analysis of variance using wages as the outcome variable but first she must decide how to handle some of the independent variables.

First, age is of the wrong data type to use in an analysis of variance; therefore, before she can run the analysis of variance, she must first group the age variable. She decides to group the age variable into 10-year age groups and create a derived variable on the database called age group which will contain the value 1 for someone less than 25, 2 for someone between 25 and 34, etc.

Next, she must decide what to do with the industry and occupation variables. Both industry and occupation are based on standard classification systems that consist of a 4-digit code. The first digit indicates the broad industry or occupation group and each subsequent digit offers more detail. In total there are thousands of groups for each coding system – too many to use in an analysis of variance. Also, there are too few respondents in some groups to provide meaningful results. Also, the coding systems are quite subjective and it is felt that the error rates are quite high at the 4-digit level. As a result of all these issues, the analyst decides to truncate the codes to a single digit for analysis.

After creating the necessary derived variables, the analyst runs an analysis of variance using wages as the dependent variable and age group, sex, education, industry and occupation as the independent variables. The model turns out to be significant, meaning it explains a significant amount of the variation in wages and each of the independent variables also turns out to be significant contributors to the variation of wages.

However, the analyst suspects that there may be some interaction between independent variables. For example, what if the effect that sex has on wages depends on the age of the person? In order to examine this issue, the analyst decides to add all the interaction effect into the model to examine their effect on wages. She finds that all the interaction effects are significant except for age group by industry. This means that, not only do wages depend on age group, sex, education, industry and occupation but wages also depend on most combinations of these variables.

The analyst realises that this is a very complicated issue and it deserves much more research.

11.3   Other Analysis

In addition, to the analysis already done, the GHS analysts wish to analyse certain characteristics over time and to eventually do seasonal adjustments once enough data are available.

Review questions:

What type of data are the variables age and age group?

What other variables could be used in an analysis of variance?

What other types of analyses would you suggest?

Chapter 12 - Data Dissemination

12.0 Data Dissemination

Having analysed the data, the GHS team must now report the results to users to help them answer the questions that gave rise to the survey. At the same time, the team will evaluate the data in terms of the survey's objectives.

12.1 Main Survey Report

The body of the report begins with an introduction giving a brief description of the GHS's objectives, the various organisations involved in its design and execution, the principal expected users, and an overview of the methodology adopted.

The bulk of the main survey report consists of the pre-planned tables derived directly from the database of questionnaire responses. In order for these tables to be most useful for the users, however, the team prepares a textual report summarising the most important results with discussion of their meaning in terms of the survey's original objectives, and commentary on the data's strengths and weaknesses. The text of the report includes a number of graphs and tables to illustrate the main points. This report also includes comments on points other than the data in the main database; for example, it mentions particular problems encountered during the fieldwork, or items requiring unusually high rates of imputation. Mention is also made of other planned reports to be released at a later date (Section 12.3).

The last main section of the report draws conclusions about the overall labour market situation in Belleterre and includes recommendations for further study of several key points not covered thoroughly in this first GHS round.

The tables in the appendices present the univariate frequency distributions as well as the relevant estimated totals, averages and proportions for all the variables generated directly from the questionnaire, or derived from them during processing. The estimates are accompanied by their estimated standard errors.

12.2 Data Quality Report

The GHS project team is also in the process of producing a comprehensive report on the quality of the data from the first survey round, to help with survey development for subsequent years. The report will include measures of sampling variability such as coefficients of variation or design effects. It will also include vacancy rates, response rates (both total and item) and many of the measures and indices generated by the quality control steps put in place for coding, data capture and other survey phases. It will also describe the editing and imputation process and discuss the imputation rates and any other problems found in the data during this process. Finally, it will comment on the advisability of comparing GHS results with other available data sources, emphasising the comparability or differences in the concepts and measurement tools used and whether any calibration to more reliable source has been used for some of the data.

The following is a list of some of the values examined in the report:
- coefficients of variation by region;

- design effects by region;
- vacancy rates by urban/rural;
- nonresponse rates by region and urban/rural within region;
- nonresponse rates by type of nonresponse;
- data used for poststratification;
- edit failure rates by question;
- imputation rates by question;
- coding error rates;
- data capture error rates;
- average number of contacts to finalise a response case;
- average number of contacts to finalise a nonresponse case;
- average interview time for response cases.

12.3   Other Reports

The GHS team will likely produce several additional reports including:

i.   Survey Evaluation Report. It will provide the team's recommendations for improvements to the survey process so that the next GHS round will function even more smoothly and efficiently.

ii.   Detailed Analysis Reports. The GHS team plans to produce a series of analytical reports to be written in collaboration with various user agencies.

iii.   Technical Reports. These reports will provide details on the survey methodology, sampling plan, estimation method, data collection and processing procedures, etc.

12.4   Confidentiality and Disclosure Control

As far as the final survey results are concerned, disclosure control is an important issue. Since there will be no public-use microdatafiles, disclosure control focuses on the published tables and other summary measures. (However, the BBS will likely grant microdata access to certain authorised analysts after they have been sworn in as if they were BBS employees. They would then be subject to all the penalties for breach of confidentiality.)

With respect to the data published in the main survey report, the team is studying the available restriction-based methods for tabular data. Much of the GHS data are categorical, but some variables are continuous, and therefore harder to deal with. Several methods are under study, but no conclusion has yet been reached as to which will be adopted. However, since one of the main purposes of the first GHS round is to obtain improved information for fine-tuning the ongoing GHS, the general strategy adopted is to be very conservative. Thus, the team is willing to suppress too much information if necessary, while doing detailed evaluations of the data quality and disclosure risk for subsequent implementation of disclosure rules that will maximise the amount of publishable information in the future.

For this reason, the team has established a preliminary cut-off rule that there must be a minimum of ten respondents in any cell of a table before it is published. This, together with the associated residual suppression, is felt to be sufficient for most cases, and probably quite conservative overall. When possible, the team prefers to collapse sensitive cells with neighbouring cells, rather than simply

suppressing them, as this will help to minimise the otherwise large amounts of complementary cell suppression.

Review questions:

Should the main survey report be made available to the general public, as part of the BBS' regular series of publications, or should the report on this first round be restricted to BBS personnel and the known data users in other ministries?

Recommend other possible disclosure control methods that could be considered for the GHS.

Chapter 13 - Survey Planning and Management

Belleterre's General Household Survey (GHS)
Project Manager's Personal Evaluation of Planning and Management Practices

13.0 Introduction

The goal of this report is to describe and evaluate the planning and management practices used to conduct Belleterre's General Household Survey (GHS) in order to learn from the experience. These are personal notes that will not be circulated to the project team or the Steering Committee. As project manager, I will however, include some of the points that are covered in this report in the official survey evaluation report so that the questionnaire and procedures can be improved for the next round of the GHS.

13.1 Background

The Belleterre Bureau of Statistics (BBS), fully aware of the increasingly urgent need for up-to-date information on the state of the economy and the socio-economic situation of its population, has begun efforts to modernise its statistical program. In particular, the BBS recognises the need to obtain relevant data on the situation of households in both the urban and the rural areas of the country.

Support was received from the national government to proceed with a proposal for a survey on the socio-economic conditions of households in the urban and rural areas of the country. Broad topics to be covered by the survey were socio-demographic characteristics, labour market activity, income and expenditure patterns, as well as indicators of living conditions. A number of important national ministries requested that additional information be collected by the GHS on the population's health status, household agricultural activities in both rural and urban areas and small business.

In the context of these objectives, a Steering Committee was appointed to oversee the management of the survey. The Steering Committee was composed of directors representing the fields of labour and household statistics, methodology, informatics, and data collection. The goal of the Steering Committee was to represent the information needs of the BBS as well as to approve important decisions such as the statement of objectives, budget, schedule, etc.

One of the first steps in the planning process was the identification of an information gap and the preparation of a survey proposal. An interim project manager was appointed who provided initial information on alternatives to a survey (e.g., data available from another survey or administrative source), and on cost and feasibility of a survey. This preliminary examination was based on consultation with experts from the various disciplines that were expected to be involved in the survey team (although these experts were not, in the end, members of the actual survey team). As a result of the survey proposal, the Steering Committee decided to proceed with more substantive development towards a statement of objectives and a survey plan.

13.2 Planning the GHS

The next decision made by the Steering Committee was my appointment as the project manager of the GHS. I was provided with the broad objectives of the survey and with contact names for the external

agencies interested in information (e.g., the Ministry of Health). Finally, I was told to form a project team and quickly develop a rough statement of objectives and survey plan.

The formation of the project team was an important consideration. Like any manager, my goal was to find experienced people with whom I had worked successfully on previous occasions. I contacted the director of the methodology division to request the services of Mr. X who had served as the methodologist on a previous project team that I had managed. I was informed, not only that Mr. X had left the BBS, but that due to the changing market conditions, the division was understaffed and was particularly lacking in experienced personnel. I was assigned a methodologist (Mr. M) who had only a few years experience. However, I was assured that all decisions made by the methodologist would be reviewed by his supervisor. I had more success recruiting the other members of the team:
- a subject matter co-ordinator (Ms. S) and a team of subject matter experts in the fields of economics, labour statistics, etc.;
- a computer systems expert (Mr. P) who was said to be an extremely capable programmer;
- a data collection and operations officer (Ms. D) with whom I had worked before.

Once established, the survey team began to develop the statement of objectives and to confirm feasibility of the survey. The first project team meeting was convened, the goal being to introduce the members of the project team to each other, explain the roles of the team members, the reporting structure and to discuss the goals of the project. For the benefit of the inexperienced members of the project team, I made it clear that it was expected that their work would be reviewed by their line supervisors.

The goal of the second project team meeting was to begin work on the statement of objectives. After some discussion, it became clear to me that detailed information could not be collected on so many diverse topics in one survey. To do so, would place too much of a burden on respondents and possibly compromise the quality of the data. I returned to the Steering Committee with the suggestion that they consider scaling back the scope of the survey and/or conduct a formal feasibility study to test the collection procedures before proceeding with a full-scale survey. I was told they would consider my suggestions.

Meanwhile, the team began to identify the specific information needs of the various users. I contacted the Ministry of Health, the Ministry of Agriculture and the economic ministries that had requested information to define their information needs. In addition, I began refining the draft budget and schedule that had been prepared for the survey proposal. Using my previous experience, and after consulting with various members of the project team, I estimated the resource requirements to plan, develop, implement and evaluate the survey. The estimated resource requirements were quite high given the scope of the survey. However, since the survey was to be ongoing, the costs of planning and development could be thought of as being spread over several years (even though the resources would be spent up-front). Only the costs of survey implementation and evaluation (and occasional redesigns) would occur regularly. I met again with the interested ministries to inform them of the estimated costs. Given the high start-up costs, the ministries' enthusiasm for the project was much more subdued than in previous meetings.

On behalf of the project team, I met with the Steering Committee again to present the draft budget, schedule (Table 13.1) and statement of objectives. The Steering Committee decided that planning should continue only on the four core themes and the other interested ministries could be approached again after the first cycle of the survey. Even though the budget, schedule and statement of objectives were only in rough draft form, the Steering Committee approved the budget and gave its formal approval to design and develop the survey.

Having been through the planning process on numerous occasions, I knew that substantial work was still needed on the statement of objectives (as well as the budget and schedule) before beginning the design of

the actual survey. Therefore, the project team continued to develop the statement of objectives. I met with the interested ministries to inform them that the GHS would be narrowing its focus during the first cycle, but that in subsequent years, they would be invited to propose additions to the survey.

Shortly thereafter, the Steering Committee informed the project team that the budget had been cut in half and that the team should focus its efforts on one of the core themes while preparing a survey infrastructure that could be readily expanded in the second year. The Steering Committee and the project team considered what had been learned to date and decided to concentrate on the labour market component, leaving aside the remainder of the list of subjects until the following year. Although this announcement was initially disappointing to the project team members (especially those who had worked on the themes that were cut), they quickly came to realise that, in the long run, this was for the best. It would allow time to concentrate effort on producing a quality product to collect quality data. The statement of objectives was quickly finalised and submitted to the Steering Committee for approval.

The project team then began writing a draft planning report to present and discuss options for the frame, sample design, data collection, processing, analysis, dissemination, etc. This planning report was presented to the Steering Committee and the project team requested advice on several issues, including defining the target and survey populations, what sampling frame to use, collection methodologies, etc. Little substantive advice was provided by the Steering Committee and, for the most part, the project team was told to make these decisions.

13.3   Design and Development

Once the major decisions had been made, each team member began preparing component plans associated with his/her responsibility within the team.

i.   Subject matter

Having developed the concepts and definitions for the Statement of Objectives, Ms. S began developing the questionnaire. Ms. S, supervising a group of new recruits, understandably wanted them to experience the project team environment. Her subject matter team, having no previous survey experience, were enthusiastic although sometimes unrealistic in their expectations. Many project team meetings were spent (and substantial time was wasted) discussing proposals brought forth by the junior members of the subject matter team. A more effective procedure would have been for the subject matter team to discuss the proposals among themselves, come to a consensus on their preferred option and present that to the project team. Ultimately, I did suggest this procedure and the questionnaire design, and subsequent steps, proceeded much more smoothly and quickly.

ii.   Methodology

The survey methodologist, although inexperienced, completed his work quickly and effectively. The methodologist was also responsible for the design of the quality control systems for data capture and coding. Initially, Mr. M was quite inflexible in compromising on the amount of quality control inspection to be done. He insisted that the outgoing error rates for both data capture and coding be almost 0%. However after several discussions, I was able to convince him that a compromise between cost and quality was necessary.

iii.   Programming

Even though the systems analyst received all specifications on time, the systems were not ready to go to testing on time. I am still unclear as to the exact problem. I believe that the programmer was overloaded with other work and was unable to effectively manage his time. This had major consequences on the implementation phase (discussed in the next section).

iv.   Data collection and operations

The data collection and operations officer effectively managed the recruitment, training, monitoring and control of data collection staff such as interviewers and supervisors, as well as data capture and coding staff. All manuals were produced on time and were of high quality. The data collection and operations officer visited several of the regional statistical offices to observe recruitment and training.

During the design and development phase of the survey, project team meetings were held less frequently to allow more time for the project team members to work on their component plans and to review the plans of other team members. The Steering Committee was informed of all decisions made by the project team. However, we rarely received feedback.

13.4   Implementation

During implementation, the focus shifted from deciding what to do to doing it. The questionnaire was printed, the sample was selected, training was conducted in the regions, clusters were listed and interviewing took place. Once the data returned, they were captured, coded, edited and imputed. Estimation and analysis followed. The frequency of project team meetings was increased again in order to deal with any problems arising during implementation.

Several problems occurred during the implementation stage.

i.   The achieved response rate was lower than expected. The planned response rate was 80% but the achieved rate was only 68%. This caused two concerns.

    a.   First, the higher level of nonresponse could introduce bias into the survey results. To examine this issue, a nonresponse follow-up study is planned to examine the characteristics of nonrespondents compared to respondents. This study will be used to plan nonresponse follow-up procedures for subsequent survey occasions.

    b.   Secondly, the precision of regional estimates was less than targeted during the sample size determination. Therefore, it was necessary to recalculate the achievable precision, given the response rate and present this to the Steering Committee and the users. It was decided that more resources would be put into nonresponse follow-up and refusal conversion in an attempt to increase the response rate, and, where necessary, data would be published at a more aggregate level.

ii.   As a result of the late delivery of the computer applications (mentioned above), specifically that for data capture, a group of clerical staff sat idle while the project team tested the computer programs. I must admit that, because I was aware of the clerks sitting idle (yet being paid), I placed pressure on the project team to cut corners during the application testing. Unfortunately, as a result, the application still contained errors when it was finally implemented. The resulting

delays and shutdowns caused by critical program errors likely cost more time and money than if we had spent sufficient time testing the program before its implementation.

iii.   It became evident from review of the comments in the 'Other (specify)' portion of Question E3 that either respondents or interviewers did not understand the answer categories. Since these comments were reviewed during collection, it was possible to send instructions to the interviewers to clarify the question and answer categories so that the data collected from that point forward would be correct. For the questionnaires already received, the data for the question were reviewed by the subject matter experts and recoded when necessary.

13.5 Evaluation

In evaluating the planning and management of the GHS survey, I have several observations:

i.   It became evident early on that the Steering Committee was not involved enough in the decision making process. They seemed content to allow the project team to make all the decisions, even those having far-reaching consequences. I should have expressed my concern in this regard to the Steering Committee. Instead, I took those decisions back to the project team, some of whom were too inexperienced to provide useful input.

ii.   In retrospect, there are several things that I could have done to remedy the situation involving the late delivery of the data capture system. I should have more closely monitored the schedule in order to identify earlier that there was a problem. Once I realised that there was a problem, I should have taken action immediately to replace the programmer or acquire additional programming resources. At the time, I was reluctant to do so because I believed it would waste too much additional time to familiarise a new programmer with the specifications and the existing programs. Also, I should have allowed sufficient time for proper testing.

iii.   The original schedule was too strict – more time should have been allowed between deliverables to avoid problems. Given the inexperience and heavy workload of several project team members, I should have created a more conservative schedule. Alternatively, I could have left the schedule constant and instead increased the number of persons working on certain key tasks, notably programming.

iv.   Nonresponse is an issue that must be dealt with in the GHS. For the current GHS survey, the potential for nonresponse bias (particularly for certain subgroups of the population) should be assessed. For subsequent implementations of the GHS, I would recommend that improved nonresponse follow-up procedures be implemented to ensure a high response rate. Currently, only very aggregate information is available to the users. The data would be much more useful if they could be provided at a more detailed level.

v.   There were a large number of temporary dwellings occupied by recent migrants. These may cause some problems if the same dwellings are to be included in more than one phase of the survey.

Table 13.1: GHS Schedule

Milestones	Responsible	Start Date	End Date
Statement of Objectives	Management, Subject Matter	January 1	January 31
Survey Plan	All	February 1	February 28
Budget	Management	January 1	January 31
Questionnaire Design	Subject Matter	March 1	March 31
Analysis Plan	Subject Matter	April 1	April 30
Specifications – Sample Design	Methodology	March 1	April 30
Specifications – Data Collection Method	Data Collection	March 1	March 31
Specifications – Edit and Imputation	Methodology, Subject Matter	April 1	April 30
Specifications – Quality Control	Methodology	May 1	May 31
Specifications – Data Capture	Data Collection	April 1	April 30
Specifications – Estimation, Variance	Methodology	June 1	June 30
Computer System Development	Programming	June 1	August 15
Computer System Testing	All	July 15	August 31
Field Manuals	Data Collection	June 1	July 31
Public Relations	Management, Data Collection	August 1	August 31
Interviewer training	Data Collection	August 15	August 31
Listing	Data Collection	September 1	September 12
Data Collection	Data Collection	September 15	September 30
Training – Coding	Data Collection	September 26	September 30
Coding	Data Collection	October 1	October 14
Training – Data Capture	Data Collection	October 10	October 14
Data Capture	Data Collection	October 15	October 31
Editing and Imputation	Data Collection	November 1	November 14
Estimation	Methodology, Subject Matter	November 15	November 30
Analysis	Subject Matter	December 1	December 14
Data Quality Evaluation	Methodology, Subject Matter	December 1	December 25
Disclosure Control	Methodology	December 15	December 25
Dissemination	Management, Subject Matter	December 31	December 31
Documentation	All	January 1	December 31

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- **acceptance control:** see *quality – quality control – acceptance control*

- **acceptance sampling:** see *quality – quality control – statistical product control – acceptance sampling*

- **accuracy**: see *estimator – accurate estimator*

- **administrative data**: 4.3.3 and Appendix A; see also *data collection- other methods of data collection – administrative data*
    - o **sources of administrative data**: Appendix A
    - o **usefulness of administrative data**: Appendix A
    - o **uses of administrative data**: Appendix A

- **analysis of variance (ANOVA):** see *data analysis – hypothesis testing for continuous variables – simple survey data – testing many means- ANOVA*

- **area frame:** see *frames (survey frame/ sampling frame) – area frame*

- **bias**: see also *estimator – unbiased estimator*; see also *estimation – estimating the sampling variance – estimating confidence intervals – in the presence of bias.*

- **bootstrap**: see *estimation –estimating the sampling variance - estimating variance using replicated sampling / jackknife / bootstrap*

- **calibration and generalised regression:** see *weights – using auxiliary information to adjust weights – calibration and generalised regression*

- **CAPI/CASI/CATI:** see *data collection – computer assisted.*

- **census**: see *sample design - sample versus census*

- **chi-square test statistic**: 11.4.1; 11.5.1.1; 11.5.1.2; 11.5.1.3; 11.5.2. See also *data analysis - hypothesis testing for discrete/categorical variables.*

- **cluster sampling:** see *sample design – probability sampling – cluster sampling*

- **coding:** see *processing – coding*

- **coefficient of variation (CV):** See *estimation - estimating a coefficient of variation (CV)*

- **confidentiality:** see *data dissemination – disclosure control;* see also *data dissemination - other confidentiality considerations;* see also 5.1.3; 5.5.1; 9.2.2; 9.3.1.1; 9.4; 9.4.2.

- **contingency tables**: see *data analysis – hypothesis testing for discrete/categorical variables – testing for independence*

- **control charts:** see *quality - quality control - statistical process control - control charts*