Frascati Manual 2015
Guidelines for Collecting and Reporting Data on Research
and Experimental Development

Chapter 2

Concepts and definitions for identifying R&D

This chapter provides the definition of research and experimental development (R&D) and of its components, basic research, applied research and experimental development. These definitions are essentially unchanged from those in previous editions of the manual. Where there are differences, they reflect changes in culture and the use of language. To provide guidance on what is and what is not an R&D activity, five criteria are provided which require the activity to be novel, creative, uncertain in it outcome, systematic and transferable and/or reproducible. Since the last edition, the treatment of R&D expenditure in the System of National Accounts (SNA) has changed from an expense to a capital investment. As a result, the language of this manual, and of the SNA, is closer and there are additional requirements for measurements of financial flows. While the manual has always applied to all scientific disciplines, there is more emphasis on the social sciences, humanities and the arts, in addition to the natural sciences and engineering. Measuring R&D activities through surveys, administrative data, or interviews raises questions about boundaries and what is and what is not included and this chapter provides examples to help answer those questions. The manual is used to interpret R&D data as part of policy development and evaluation, but the focus of this chapter is on definitions for measurement purposes.

2.1. Introduction

2.1 The *Frascati Manual* has provided the definition of research and experimental development (R&D) and of its components, basic research, applied research and experimental development, for more than half a century, and the definitions have stood the test of time. The definitions in this chapter do not differ in substance from those in previous editions. However, there is recognition of cultural change in the definition of R&D and of the use of language in the definition of experimental development.

2.2 Since the previous edition of this manual, the System of National Accounts (SNA) has changed the treatment of expenditure on R&D from an expense to a capital investment leading to a capital stock of knowledge created as a result of R&D. The SNA 2008 (EC et al., 2009) draws on this manual for the definition of R&D. A consequence of becoming a more integral part of the SNA is the use of its language in this manual. Such usage will be noted when it occurs.

2.3 R&D is found in the social sciences, humanities and the arts as well as in the natural sciences and engineering. This manual gives greater emphasis than past editions to the social sciences, humanities and the arts. This requires no changes in the definitions and conventions, but it does require greater attention to the boundaries that define what is and what is not R&D. Also, countries using this manual are at different stages of economic development, and this chapter tries to accommodate the differing needs.

2.4 The chapter provides definitions of R&D and its components, together with a set of criteria for identifying R&D. Examples of R&D, boundaries and exclusions are provided to illustrate how the definitions are applied. This is a statistical manual, and its fundamental purpose is to provide guidance for the measurement of R&D activities using various means of data-gathering from surveys, interviews and administrative sources. The manual is also used for interpreting R&D data as part of the development, implementation and evaluation of policy. However, users should note that the focus of this chapter is on definitions for measurement purposes.

2.2. Definition of research and experimental development (R&D)

2.5 **Research and experimental development (R&D) comprise creative and systematic work undertaken in order to increase the stock of knowledge – including knowledge of humankind, culture and society – and to devise new applications of available knowledge.**

2.6 A set of common features identifies R&D activities, even if these are carried out by different performers. R&D activities may be aimed at achieving either specific or general objectives. R&D is always aimed at new findings, based on original concepts (and their interpretation) or hypotheses. It is largely uncertain about its final outcome (or at least about the quantity of time and resources needed to achieve it), it is planned for and budgeted (even when carried out by individuals), and it is aimed at producing results that could be either freely transferred or traded in a marketplace. For an activity to be an R&D activity, it must satisfy five core criteria.

2.7 The activity must be:

- novel
- creative
- uncertain
- systematic
- transferable and/or reproducible.

2.8 All five criteria are to be met, at least in principle, every time an R&D activity is undertaken whether on a continuous or occasional basis. The definition of R&D just given is consistent with the definition of R&D used in the previous editions of the *Frascati Manual* and covers the same range of activities.

2.9 The term R&D covers three types of activity: basic research, applied research and experimental development. **Basic research** is experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundations of phenomena and observable facts, without any particular application or use in view. **Applied research** is original investigation undertaken in order to acquire new knowledge. It is, however, directed primarily towards a specific, practical aim or objective. **Experimental development** is systematic work, drawing on knowledge gained from research and practical experience and producing additional knowledge, which is directed to producing new products or processes or to improving existing products or processes. These three types of R&D are discussed further in Section 2.5.

2.10 This manual follows the System of National Accounts convention in which "product" refers to a good or a service (EC et al., 2009: para. 2.36). Throughout this manual, "process" refers to the transformation of inputs to outputs and their delivery or to organisational structures or practices.

2.11 The order in which the three types of R&D activity appear is not meant to suggest that basic research leads to applied research and then to experimental development. There are many flows of information and knowledge in the R&D system. Experimental development can inform basic research, and there is no reason why basic research cannot lead directly to new products or processes.

2.3. R&D activities and projects

2.12 An "R&D activity" is the sum of actions deliberately undertaken by R&D performers in order to generate new knowledge. In most cases, R&D activities can be grouped to form "R&D projects". Each R&D project consists of a set of R&D activities, is organised and managed for a specific purpose, and has its own objectives and expected outcomes, even at the lowest level of formal activity. The concept of an R&D project, while useful for understanding how R&D is done, is not likely to be applied in the same way in all the sectors used in this manual.

2.4. The five criteria for identifying R&D

2.13 For an activity to be classified as an R&D activity, five *core* criteria have to be jointly satisfied. A set of examples, which is by no means exhaustive, is used to illustrate how the five criteria can be effectively applied to identify R&D activities as well as specific R&D projects.

To be aimed at new findings (novel)

2.14 New knowledge is an expected objective of an R&D project, but it has to be adapted to different contexts. For example, research projects in universities are expected to pursue entirely new advancements in knowledge, and the same can be said for projects designed and managed by research institutes.

2.15 In the Business enterprise sector (*Frascati Manual* sectors are defined in Chapter 3), the potential novelty of R&D projects has to be assessed by comparison with the existing stock of knowledge in the industry. The R&D activity within the project must result in findings that are new to the business and not already in use in the industry. Excluded from R&D are activities undertaken to copy, imitate or reverse engineer as a means of gaining knowledge, as this knowledge is not novel.

2.16 Novelty could result from a project to reproduce an existing result that finds potential discrepancies. An experimental development project aimed at creating knowledge in support of the development of new concepts and ideas related to the design of new products or processes should be included in R&D. As R&D is the formal creation of knowledge, including knowledge embodied in products and processes, the measurement focus is on the new knowledge, not on the new or significantly improved products or processes resulting from the application of the knowledge. An example of R&D could be the integration of the "maintenance manual" of a very complex system (like a passenger aircraft) with additional material emerging from practical experience in ordinary maintenance and properly codified, so long as this was done as part of an R&D project. Another example is systematic testing to provide documentation of the potential use of a chemical reaction that has already been adopted in production processes (an existing technology) in order to achieve a new molecule, which has been considered an improbable outcome by the scientific literature.

To be based on original, not obvious, concepts and hypotheses (creative)

2.17 An R&D project must have as an objective new concepts or ideas that improve on existing knowledge. This excludes from R&D any routine change to products or processes and, therefore, a human input is inherent to creativity in R&D. As a result, an R&D project requires the contribution of a researcher (defined in Chapter 5). One area requiring care in assessment is the arts (Section 2.6): there is creativity, but the other criteria have to be confirmed for the activity to qualify as R&D. While routine activity is excluded from R&D, new methods developed to perform common tasks are included. As an example, data processing is not an R&D activity unless it is part of a project to develop new methods for data processing. Vocational training is excluded from R&D, but new methods to deliver training could be R&D. A new method to fix a problem, developed as part of a project, could be R&D if the outcome is original and the other criteria are met.

To be uncertain about the final outcome (uncertain)

2.18 R&D involves uncertainty, which has multiple dimensions. At the outset of an R&D project, the kind of outcome and the cost (including time allocation) cannot be precisely determined relative to the goals. In the case of basic research, which is aimed at extending the boundaries of formal knowledge, there is a broad recognition of the possibility of not achieving the intended results. For example, a research project may succeed in eliminating a number of competing hypotheses, but not all of them. For R&D in general, there is uncertainty about the costs, or time, needed to achieve the expected results, as well as about whether its objectives can be achieved to any degree at all. For example, uncertainty is a key criterion when making a distinction between R&D prototyping (models used to test technical concepts and technologies with a high risk of failure, in terms of applicability) and non-R&D prototyping (pre-production units used to obtain technical or legal certifications).

To be planned and budgeted (systematic)

2.19 R&D is a formal activity that is performed systematically. In this context "systematic" means that the R&D is conducted in a planned way, with records kept of both the process followed and the outcome. To verify this, the purpose of the R&D project and the sources of funding for the R&D performed should be identified. The availability of such records is consistent with an R&D project that is aimed at addressing specific needs and has its own human and financial resources. While the management and reporting structure just described is more likely to be found in large projects, it can also apply to small-scale activities where it would be sufficient to have one or more employees or consultants (providing that a researcher was included) charged with producing a specific solution to a practical problem.

To lead to results that could be possibly reproduced (transferable and/or reproducible)

2.20 An R&D project should result in the potential for the transfer of the new knowledge, ensuring its use and allowing other researchers to reproduce the results as part of their own R&D activities. This includes R&D that has negative results, in the case that an initial hypothesis fails to be confirmed or a product cannot be developed as originally intended. As the purpose of R&D is to increase of the existing stock of knowledge, the results cannot remain tacit (i.e. remain solely in the minds of the researchers), as they, and the associated knowledge, would be at risk of being lost. The codification of knowledge and its dissemination is part of the usual practice in universities and research institutes, although there may be restrictions for knowledge arising through contract work or as part of a collaborative undertaking. In a business environment, the results will be protected by secrecy or other means of intellectual property protection, but it is expected that the process and the results will be recorded for use by other researchers in the business.

Examples

2.21 To understand the aim of a project, it is essential to identify its R&D content and the institutional context in which R&D is performed. Some examples follow.

- In the field of medicine, a routine autopsy to determine the causes of death is the practice of medical care and is not R&D; a special investigation of a particular mortality to establish the side effects of certain cancer treatments is R&D (in fact, novelty and uncertainty about the final results of the study, as well as the transferability of the results for broader use, apply here).
- Similarly, routine tests such as blood and bacteriological tests carried out for medical checks are not R&D, whereas a special programme of blood tests for patients taking a new drug is R&D.
- Keeping daily records of temperatures or of atmospheric pressure is not R&D, but a standard procedure. The investigation of new methods of measuring temperature is R&D, as is the study and development of new models for weather prediction.
- R&D activities in the mechanical engineering industry often have a close connection with design. In small and medium-size enterprises (SMEs) in this industry, there is usually no special R&D department, and R&D performance is often included under the general heading “design and drawing”. If calculations, designs, working drawings and operating instructions are needed for setting up and operating pilot plants or prototypes, they should be included in R&D. If they are carried out for the preparation, execution and maintenance of production standardisation (e.g. jigs, machine tools)

or to promote the sale of products (e.g. offers, leaflets, catalogues of spare parts), they should be excluded from R&D. In this example, several R&D features can be identified: novelty in exploring the potential of new devices – by running prototypes; uncertainty, as prototype testing could yield unexpected results; creativity – emerging in the design of new devices to be produced; transferability – by producing technical documentation to translate the results of testing in information to be used at the product development stage; and a systematic approach, as far as a detailed organisation of the project can be identified behind the afore-mentioned technical activities.

2.22 Table 2.1 provides some practical examples of how R&D can be identified by using the five core criteria.

Table 2.1. **Examples of questions for identifying R&D projects**

Question	Comment
a. What are the objectives of the project?	The pursuit of original and challenging objectives through the creation of "new knowledge" (such as seeking previously undiscovered phenomena, structures or relationships) is a key criterion for R&D. Any use of already available knowledge (adaptation, customisation, etc.) which does not entail an attempt to expand the state of the art should be excluded (Novelty).
b. What is new about this project?	In addition to the development of "new knowledge", an R&D project should have a creative approach, such as devising new applications of existing scientific knowledge or new uses of available techniques or technologies (Creativity).
c. What methods are being used to carry out the project?	Methods used in scientific and technological research, as well as in research in the social sciences, humanities and the arts, are accepted provided that they address uncertainty about the project's final outcome. The uncertainty could be about how much time and resources will be needed to achieve the planned goal. The choice of method could be part of the project's creativity and a means of dealing with uncertainty (Creativity and uncertainty).
d. How generally applicable are the findings or results of the project?	To be generally applicable, the findings of an R&D project have to meet the criterion of being transferable/reproducible, in addition to the other four criteria. Transferring the results may for example be demonstrated by publication in the scientific literature and the use of instruments of intellectual property protection.
e. What types of staff are working on the project?	A range of skills is assumed to be required to undertake an R&D project (the R&D personnel issue is discussed in Chapter 5 of this manual). Research personnel in projects are classified as researchers, technicians and other supporting staff, but only researchers, working as researchers, are needed to identify an R&D activity which, implicitly, satisfies all five core criteria.
f. How should the research projects of research institutions be classified?	In selected cases, an "institutional approach" can be used to distinguish between R&D and non-R&D projects. For instance, most projects carried out in research institutes or research universities can be qualified as R&D projects. Projects launched in other domains – like business enterprises or institutions not totally devoted to R&D – should be checked against the five R&D criteria (see institutions in Chapter 3).

2.5. Distribution by type of R&D

2.23 A breakdown by type of R&D is recommended for use in all four of the sectors used in this manual and defined in Chapter 3: Business enterprise; Higher education; Government; and Private non-profit. For the purposes of international comparison, the breakdown could be based either on total R&D expenditure or on current expenditures only (see Chapter 4). It may be applied at project level, but some R&D projects may have to be further subdivided.

2.24 There are three types of R&D:

- basic research
- applied research
- experimental development.

Basic research

2.25 **Basic research is experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundations of phenomena and observable facts, without any particular application or use in view.**

2.26 Basic research analyses properties, structures and relationships with a view to formulating and testing hypotheses, theories or laws. The reference to no "particular application in view" in the definition of basic research is crucial, as the performer may not know about potential applications when doing the research or responding to survey questionnaires. The results of basic research are not generally sold but are usually published in scientific journals or circulated to interested colleagues. Occasionally, the publication of basic research may be restricted for reasons of national security.

2.27 In basic research, the researcher is expected to have some freedom to set goals. Such research is usually performed in the Higher education sector but also to some extent in the Government sector. Basic research can be oriented or directed towards some broad fields of general interest, with the explicit goal of a range of future applications. Business enterprises in the private sector may also undertake basic research even though there may be no specific commercial applications anticipated in the short term. Research on some kinds of energy-saving technologies may be described as basic according to the above definition if it does not have a specific use in view. However, it does have a specific direction: improved energy savings. Such research in this manual is referred to as "oriented basic research".

2.28 Oriented basic research may be distinguished from "pure basic research" as follows:

- Pure basic research is carried out for the advancement of knowledge, without seeking economic or social benefits or making an active effort to apply the results to practical problems or to transfer the results to sectors responsible for their application.

- Oriented basic research is carried out with the expectation that it will produce a broad base of knowledge likely to form the basis of the solution to recognised or expected current or future problems or possibilities.

Applied research

2.29 **Applied research is original investigation undertaken in order to acquire new knowledge. It is, however, directed primarily towards a specific, practical aim or objective.**

2.30 Applied research is undertaken either to determine possible uses for the findings of basic research or to determine new methods or ways of achieving specific and predetermined objectives. It involves considering the available knowledge and its extension in order to solve actual problems. In the Business enterprise sector, the distinction between basic and applied research is often marked by the creation of a new project to explore promising results of a basic research programme (moving from a long-term to a medium-short term perspective in the exploitation of the results of intramural [see Glossary] R&D).

2.31 The results of applied research are intended primarily to be valid for possible applications to products, operations, methods or systems. Applied research gives operational form to ideas. The applications of the knowledge derived can be protected by intellectual property instruments, including secrecy.

Experimental development

2.32 **Experimental development is systematic work, drawing on knowledge gained from research and practical experience and producing additional knowledge, which is directed to producing new products or processes or to improving existing products or processes.**

2.33 The development of new products or processes qualifies as experimental development if it meets the criteria for identifying R&D activity. An example is uncertainty about the resources needed to achieve the goal of the R&D project in which the development activity is taking place. In this manual the "D" in R&D refers to experimental development.

Not "product development"

2.34 The concept of experimental development should not be confused with "product development", which is the overall process – from the formulation of ideas and concepts to commercialisation – aimed at bringing a new product (good or service) to the market. Experimental development is just one possible stage in the product development process: that stage when generic knowledge is actually tested for the specific applications needed to bring such a process to a successful end. During the experimental development stage new knowledge is generated, and that stage comes to an end when the R&D criteria (novel, uncertain, creative, systematic, and transferable and/or reproducible) no longer apply. As an example, in a process aimed at developing a new car, the option to adopt some technologies could be taken into consideration and tested for use in the car under development: this is the stage when experimental development is performed. It will lead to new results by dealing with new applications of some general knowledge; it will be uncertain, because testing could give rise to negative results; it will have to be creative, as the activity will focus on the adaptation of some technology to a new use; it will be formalised, by needing the commitment of a specialised workforce; and it will involve a codification, in order to translate the results of the tests into technical recommendations for the further stages of the product development process. However, there are cases of product development without R&D that are discussed in the economics literature, especially in the case of SMEs.

Not "pre-production development"

2.35 The concept of experimental development should not be confused with "pre-production development", which is the term used to describe non-experimental work on a defence or aerospace product or system before it goes into production. Similar cases apply in other industries. It is difficult to define precisely the cut-off point between experimental development and pre-production development; the distinction between these two categories requires "engineering judgement" as to when the element of novelty ceases and the work changes to routine development of an integrated system.

2.36 For example, once a fighter bomber has successfully passed through the stages of research, technology demonstration, project design and initial development to the flight-testing of a pre-production aircraft, up to ten additional airframes may be required in order to ensure full operational integration of the vehicle into air offence/defence systems. This would be a two-stage process. The first stage is development of the integrated air offence/defence system, which involves bringing together developed components and subsystems that have not previously been integrated in this context. It requires a large flight test programme for the aircraft, which is potentially very expensive and the main cost element prior to production. While much of the work commissioned during this stage is experimental development (R&D), some does not have the element of novelty necessary for classification as R&D and is instead pre-production development (non-R&D). The second stage covers trials of the integrated air offence/defence system. Once the system is proven to work at stage one, the development project may move on to produce a trial production batch for operational trials (low-rate initial production). The full production order depends on their success. According to this manual, this work is not R&D but pre-production development. However, problems may arise during the trials, and new experimental development may be needed to solve them. This work is described in this manual as "feedback R&D" and should be included as R&D.

How types of R&D can be differentiated

2.37 A key criterion guides the classification of R&D activities by type: the expected use of the results. In addition, two questions can help identify the type of an R&D project:

- how far ahead in time is the project likely to lead to results that can be applied
- how broad is the range of potential fields of application for the results of the R&D project (the more fundamental the research, the broader the potential field of application).

2.38 The relationship between basic research, applied research and experimental development has to be seen within a dynamic perspective. It is possible that applied research and experimental development could adapt fundamental knowledge arising from basic research directly for general application. However, the linearity of such a process is affected by the feedback that takes place when knowledge is used to solve a problem. This dynamic interaction between knowledge generation and the solution of problems links basic and applied research and experimental development.

2.39 With reference to the organisations where R&D is performed, a clear-cut separation of the three types of R&D rarely exists. All three types may sometimes be carried out in the same unit by essentially the same staff, but some research projects may genuinely straddle categories. For instance, the search for a new medical treatment for people affected by an epidemic disease may involve both basic and applied research. It is recommended to undertake an evaluation of the type of R&D at the project level, by classifying the project's expected results according to the two "indicators" described above. Some examples are provided in the next paragraphs.

Examples of how to differentiate types of R&D in the natural sciences and engineering

2.40 The following examples illustrate general differences between basic and applied research and experimental development in the natural sciences and engineering.

- The study of a given class of polymerisation reactions under various conditions is basic research. The attempt to optimise one of these reactions with respect to the production of polymers with given physical or mechanical properties (making it of particular utility) is applied research. Experimental development then consists of "scaling up" the process that has been optimised at the laboratory level and investigating and evaluating possible methods of producing the polymer as well as products to be made from it.
- The modelling of a crystal's absorption of electromagnetic radiation is basic research. The study of the absorption of electromagnetic radiation by this material under varying conditions (for instance, temperature, impurities,

concentration, etc.) to obtain given properties of radiation detection (sensitivity, rapidity, etc.) is applied research. Testing a new device using this material in order to obtain a better detector of radiation than those already existing (in the spectral range considered) is experimental development.

- The development of a new method for the classification of immunoglobulin sequences is basic research. Investigations undertaken in an effort to distinguish between antibodies for various diseases is applied research. Experimental development then consists of devising a method for synthesising the antibody for a particular disease on the basis of knowledge of its structure and clinical tests of the effectiveness of the synthesised antibody on patients who have agreed to accept an experimental advanced treatment.
- A study about how the properties of carbon fibres could change according to their relative position and orientation within a structure is basic research. The conceptualisation of a method to allow for processing carbon fibres at industrial level with a degree of precision at the nano-scale could be the outcome of some applied research. Testing the use of new composite materials for different purposes is experimental development.
- Controlling material processes in the domain where quantum effects occur is an objective to be pursued through basic research. Developing materials and components for inorganic and organic light-emitting diodes for improved efficiency and cost reduction is applied research. Experimental development could be aimed at identifying applications for advanced diodes and incorporating them in consumer devices.
- Searching for alternative methods of computation, such as quantum computation and quantum information theory, is basic research. Investigation into the application of information processing in new fields or in new ways (e.g. developing a new programming language, new operating systems, program generators, etc.) and investigation into the application of information processing to develop tools such as geographical information and expert systems are applied research. Development of new applications software and substantial improvements to operating systems and application programmes are experimental development.
- The study of sources of all kinds (manuscripts, documents, monuments, works of art, buildings, etc.) in order to better comprehend historical phenomena (the political, social, cultural development of a country, the biography of an individual, etc.) is basic research. Comparative analysis of archaeological sites and/or monuments displaying similarities and other common characteristics (e.g. geographic, architectural, etc.) to understand interconnections of potential relevance to teaching material and museum displays is applied research. The development of new instruments and methods for studying artefacts and natural objects recovered through archaeological endeavours (e.g. for the age-dating of bones or botanic remains) is experimental development.

- In agricultural sciences and forestry:
  - Basic research: Researchers investigate genome changes and mutagenic factors in plants to understand their effects on the phenome. Researchers investigate the genetics of the species of plants in a forest in an attempt to understand natural controls for disease or pest resistance.
  - Applied research: Researchers investigate wild potato genomes to locate the genes responsible for resistance to potato blight in an effort to improve the disease resistance in domestic/crop potatoes. Researchers plant experimental forests where they alter the spacing and alignment of the trees to reduce the spread of disease while ensuring the optimum arrangement for maximum yield.
  - Experimental development: Researchers create a tool for gene editing by using knowledge of how enzymes edit DNA. Researchers use existing research on a specific plant species to create a plan for improving how a company plants its forests to achieve a specific goal.
- In nanotechnology:
  - Basic research: Researchers study the electrical properties of graphene by using a scanning tunnelling microscope to investigate how electrons move in the material in response to voltage changes.
  - Applied research: Researchers study microwaves and thermal coupling with nanoparticles to properly align and sort carbon nanotubes.
  - Experimental development: Researchers use research in micro-manufacturing to develop a portable and modular micro-factory system with components that are each a key part of an assembly line.
- In computer and information sciences:
  - Basic research: Research on the properties of general algorithms for handling large amounts of real-time data.
  - Applied research: Research to find ways to reduce the amount of spam by understanding the whole structure or business model of spam, what spammers do, and their motivations in spamming.
  - Experimental development: A start-up company takes code developed by researchers and develops the business case for the resulting software product for improved on-line marketing.

Examples of how to differentiate types of R&D in the social sciences, humanities and the arts

2.41 Another set of examples can be provided with reference to the social sciences, humanities and the arts where, as discussed above, the blurring of boundaries could affect the distinction between basic and applied research. Examples of experimental development in these domains can also be difficult to identify, because of the role played by other domains in the natural sciences and engineering. It should be noted that these examples must also meet the basic criteria identified in this chapter to be considered as R&D.

- In economics and business:
  - Basic research: A review of theories on the factors determining regional disparities in economic growth. Economists conducting abstract research in economic theory that focuses on whether a natural equilibrium exists in a market economy. The development of new risk theories.
  - Applied research: The analysis of a specific regional case for the purpose of developing government policies. Economists investigating the properties of an auction mechanism that could be relevant to auctioning the telecommunications spectrum. The investigation of new types of insurance contracts to cover new market risks or new types of savings instruments.
  - Experimental development: The development of operational models, based upon statistical evidence, to design economic policy tools to allow a region to catch up in terms of growth. The development by a national telecommunications authority of a method for auctioning the telecommunications spectrum. The development of a new method to manage an investment fund is experimental development as long as there is sufficient evidence of novelty.
- In education:
  - Basic research: Analysis of the environmental determinants of learning ability. The investigation by researchers of the effect of different types of manipulatives on the way first graders learn mathematical strategy by changing manipulatives and then measuring what students have learned through standardised instruments
  - Applied research: The comparative evaluation of national education programmes aimed at reducing the learning gap experienced by disadvantaged communities. The study by researchers of the implementation of a specific math curriculum to determine what teachers needed to know to implement the curriculum successfully.
  - Experimental development: The development of tests for selecting which educational programme should be used for children with specific needs. The development and testing (in a classroom) of software and support tools, based on fieldwork, to improve mathematics cognition for student special education.
- In social and economic geography:
  - Basic research: Researchers seek to understand the fundamental dynamics of spatial interactions.
  - Applied research: A research study analyses the spatial-temporal patterns in the transmission and diffusion of an infectious disease outbreak.

- In history:
  - Basic research: Historians study the history and human impact of glacial outburst floods in a country.
  - Applied research: Historians examine past societies' responses to catastrophic natural events (e.g. floods, droughts, epidemics) in order to understand how contemporary society might better respond to global climate change.
  - Experimental development: Using previous research findings, historians design a new museum exhibit on the adaptations of past human societies to environmental changes; this serves as a prototype for other museums and educational installations.
- In language/linguistics:
  - Basic research: Linguists study how different languages interact as they come into contact with one another.
  - Applied research: Speech therapists examine the governing neurology of languages and how humans acquire language skills.
  - Experimental development: Linguists develop a tool for diagnosing autism in children based on their language acquisition, retention and use of signs.
- In music:
  - Basic research: Researchers develop a transformational theory that provides a framework for understanding musical events not as a collection of objects that have particular relationships to each other but as a series of transformational operations applied to the basic material of the work.
  - Applied research: Researchers use historical records and the techniques of experimental archaeology to recreate an ancient and long-disappeared musical instrument and to determine how it would have been constructed, how it was played and the types of sounds it would have produced.
  - Experimental development: Music educators and theorists work to produce new pedagogical materials based on new discoveries in neuroscience that change our understanding of how humans process new sounds and information.

2.6. Classification and distribution by Fields of Research and Development (FORD)

2.42 For a number of reasons, survey practitioners and data users often find it helpful and relevant to classify R&D-performing units and distribute their R&D resources according to the knowledge domain in which they operate. This manual proposes the use of the OECD Fields of Research and Development (FORD) classification for such purposes. This classification, developed for R&D

measurement purposes, follows primarily a content approach. Where the content of the R&D subject matter is closely related, subjects are grouped together to form the broad (one-digit) and narrower (two-digit) fields of the classification. While the classification can be applied to a broader range of science and technology (S&T) and knowledge-based activities, its formulation by the OECD is focused on R&D as defined in this manual.

2.43 The aim is to distribute R&D efforts and classify the units that undertake such efforts. Two R&D projects can be said to belong to the same field if their content is the same or sufficiently similar. The following criteria give rise to the FORD classification and can help inform the assessment of the degree of similarity of the subject matter content:

- The knowledge sources drawn upon for the R&D activity carried out. The application of developments in some technology fields often gives rise to new scientific efforts, in the same way that scientific knowledge provides a basis for new technological developments.
- The objects of interest – the phenomena to be understood or the problems to be solved as part of R&D.
- The methods, techniques and professional profiles of the scientists and other R&D workers – different domains can be distinguished sometimes on the basis of the methodological approaches to the study of a given phenomenon or question.
- The areas of application. For example, in the FORD classification, the medical sciences and agricultural sciences are specifically defined by their applications to human health and agricultural activities.

2.44 This classification is closely related to and consistent with UNESCO's "Recommendation concerning the International Standardisation of Statistics on Science and Technology" (UNESCO, 1978), which provided the initial basis for the OECD classification of R&D by the field of S&T in previous versions of this manual. There is also a degree of relationship with the ISCED Fields of Education and Training (ISCED-F), which is aimed at the classification of study and training programmes and reflects to a large extent the way in which schools, departments, etc., organise their activities and award credentials to students who successfully complete these programmes. It is recognised that FORD and the ISCED-F have different purposes, and it is not feasible to ensure a direct correspondence between the two classifications (UNESCO-UIS, 2014, p. 17).

2.45 In light of ongoing changes in the way R&D is conducted and the progressive emergence of new domains, the FORD classification will be subject to continuing revision after the publication of this manual's edition. For more up-to-date versions, the reader should consult the online annexes to this manual where more detail can be found on this classification and its use.

Table 2.2. **Fields of R&D classification**

Broad classification	Second-level classification
1. Natural sciences	1.1 Mathematics 1.2 Computer and information sciences 1.3 Physical sciences 1.4 Chemical sciences 1.5 Earth and related environmental sciences 1.6 Biological sciences 1.7 Other natural sciences
2. Engineering and technology	2.1 Civil engineering 2.2 Electrical engineering, electronic engineering, information engineering 2.3 Mechanical engineering 2.4 Chemical engineering 2.5 Materials engineering 2.6 Medical engineering 2.7 Environmental engineering 2.8 Environmental biotechnology 2.9 Industrial biotechnology 2.10 Nano-technology 2.11 Other engineering and technologies
3. Medical and health sciences	3.1 Basic medicine 3.2 Clinical medicine 3.3 Health sciences 3.4 Medical biotechnology 3.5 Other medical science
4. Agricultural and veterinary sciences	4.1 Agriculture, forestry, and fisheries 4.2 Animal and dairy science 4.3 Veterinary science 4.4 Agricultural biotechnology 4.5 Other agricultural sciences
5. Social sciences	5.1 Psychology and cognitive sciences 5.2 Economics and business 5.3 Education 5.4 Sociology 5.5 Law 5.6 Political science 5.7 Social and economic geography 5.8 Media and communications 5.9 Other social sciences
6. Humanities and the arts	6.1 History and archaeology 6.2 Languages and literature 6.3 Philosophy, ethics and religion 6.4 Arts (arts, history of arts, performing arts, music) 6.5 Other humanities

2.7. Examples of R&D, boundaries and exclusions in different areas

R&D and innovation activities and borderline cases

2.46 Innovation is currently defined for measurement purposes in the third edition of the Oslo Manual (OECD/Eurostat, 2005) with a sole focus on the Business enterprise sector (see a definition for this sector in Chapter 3). In summary, it has to do with putting new or significantly improved products on the market or finding better ways (through new or significantly improved processes and methods) of getting products to the market. R&D may or may not be part of the activity of innovation, but it is one among a number of innovation activities. These activities also include the acquisition of existing knowledge, machinery, equipment and other capital goods, training, marketing, design and software development. These innovation activities may be carried out in-house or procured from third parties.

2.47 Care must be taken to exclude activities that, although part of the innovation process, do not satisfy the criteria required to be classified as R&D. For example, patent application and licensing activity, market research, manufacturing start-up, and tooling up and redesign for the manufacturing process are not in their own right R&D activities and cannot be assumed to be part of an R&D project. Some activities, such as tooling up, process development, design and prototype construction, may contain an appreciable element of R&D, making it difficult to identify precisely what should or should not be defined as R&D. This is particularly true for defence and large-scale industries such as aerospace. Similar difficulties may arise in distinguishing public technology-based services such as the inspection and control of food and drugs from related R&D.

Examples of what is or is not R&D in innovation processes

2.48 Table 2.3, and the examples that follow, provide more information on what should and what should not be counted as R&D.

Prototypes

2.49 A prototype is an original model constructed to include all the technical and performance characteristics of the new product. For example, if a pump for corrosive liquids is being developed, several prototypes are needed for accelerated life tests with different chemicals. A feedback loop exists so that if the prototype tests are not successful, the results can be used for further development of the pump.

2.50 The design, construction and testing of prototypes normally falls within the scope of R&D. This applies whether only one or several prototypes are made and whether they are made consecutively or simultaneously. However, when any necessary modifications to the prototype(s) have been made and testing has been satisfactorily completed, the end-point of R&D has been reached. The construction of several copies of a prototype to meet a temporary commercial, military or medical need after successful testing of the original, even if undertaken by R&D staff, is not part of R&D. The virtualisation of prototyping could follow the same rules, and it will be included in R&D as far as the testing activity is part of an R&D project and is aimed at collecting evidence essential for achieving the objectives of the project.

Table 2.3. **Borderline between R&D, innovation and other business activities**

Item	Treatment	Remarks
Prototypes	Include in R&D	As long as the primary objective is to make further improvements.
Pilot plant	Include in R&D	As long as the primary purpose is R&D.
Industrial design	Split	Include design required during R&D. Exclude design for production process.
Industrial engineering and tooling up	Split	Include "feedback" R&D and tooling up industrial engineering in innovation processes. Exclude for production processes.
Trial production	Split	Include if production implies full-scale testing and subsequent further design and engineering. Exclude all other associated activities.
Pre-production development	Exclude	
After-sales service and trouble-shooting	Exclude	Except "feedback" R&D (to be included).
Patent and licence work	Exclude	All administrative and legal work needed to apply for patents and licences (delivering documentation as an outcome of R&D projects is R&D). However, patent work connected directly with R&D projects is R&D.
Routine tests	Exclude	Even if undertaken by R&D personnel.
Data collection	Exclude	Except when an integral part of R&D.
Routine compliance with public inspection control, enforcement of standards, regulations	Exclude	

Pilot plants

2.51 The construction and operation of a pilot plant is a part of R&D as long as the principal purposes are to obtain experience and to compile engineering and other data to be used in:

- evaluating hypotheses
- writing new product formulas
- establishing new finished product specifications
- designing special equipment and structures required by a new process
- preparing operating instructions or manuals on the process.

2.52 If, as soon as this experimental phase is over, a pilot plant switches to operating as a normal commercial production unit, the activity can no longer be considered R&D even though it may still be described as a pilot plant. As long as the primary purpose in operating a pilot plant is non-commercial, it makes no difference in principle if part or all of the output is sold. Such receipts should not be deducted from the cost of R&D activity (Chapter 4).

Large-scale projects

2.53 Large-scale projects (in areas like defence, aerospace or big science) usually cover a spectrum of activity from experimental to pre-production development. Under these circumstances, the funding and/or performing organisation often cannot distinguish between R&D and other elements of expenditure. The distinction between R&D and non-R&D expenditure is particularly important in countries where a large proportion of government R&D expenditure is directed to defence.

2.54 It is important to look closely at the nature of costly pilot plants or prototypes, such as the first of a new line of nuclear power stations or of icebreakers. They may be constructed almost entirely from existing materials and use existing technology, and they are often built for simultaneous use for R&D and for providing the primary service concerned (power generation, ice breaking). The construction of such plants and prototypes should not be wholly credited to R&D. Only the additional costs due to the experimental nature of these products should be attributed to R&D.

Trial production

2.55 After a prototype has been satisfactorily tested and any necessary modifications made, the manufacturing start-up phase may begin. This is related to full-scale production; it may consist of product or process modification or retraining personnel in the new techniques or in the use of new machinery. Unless the manufacturing start-up phase implies further design and engineering R&D, it should not be counted as R&D, since the primary objective is no longer to make further improvements to the products but to start the production process. The first units of a trial production run for a mass production series should not be considered as R&D prototypes even if they are loosely described as such.

2.56 For example, if a new product is to be assembled by automatic welding, the process of optimising the settings on the welding equipment in order to achieve maximum production speed and efficiency would not count as R&D.

Trouble-shooting

2.57 Trouble-shooting occasionally shows the need for further R&D, but more frequently it involves the detection of faults in equipment or processes and results in minor modifications of standard equipment and processes. It should not, therefore, be included in R&D.

"Feedback" R&D

2.58 After a new product or process has been turned over to production units, there will still be technical problems to be solved, some of which may demand further R&D. Such "feedback" R&D should be included.

Tooling up and industrial engineering

2.59 In most cases, the tooling up and industrial engineering phases of any project are considered to be part of the production process, and not of R&D. Three phases of tooling up can be identified:

- the first-time use of components (including the use of components resulting from R&D efforts)
- the initial tooling of equipment for mass production
- installing equipment linked with the start of mass production.

2.60 If the tooling up process results in further R&D work, such as improvements in the production of machinery and tools or changes to the production and quality control procedures or the development of new methods and standards, these activities are classified as R&D. "Feedback" R&D resulting from the tooling up phase should be defined as R&D.

Clinical trials

2.61 Before new drugs, vaccines, devices or treatments can be introduced onto the market, they must be tested systematically on human volunteers to ensure that they are both safe and effective. These clinical trials are divided into four standard phases, three of which take place before permission to manufacture is granted. For the purposes of international comparison, by convention, clinical trial phases 1, 2 and 3 can be treated as R&D. Phase 4 clinical trials, which continue testing the drug or treatment after approval and manufacture, should only be treated as R&D if they bring about a further scientific or technological advance. Moreover, not all activities undertaken prior to permission to manufacture are considered to be R&D, especially when there is a significant wait after the completion of phase 3 trials, during which activities related to marketing and process development may be started.

R&D and design

2.62 Design and R&D activities are difficult to separate. Some design activities are an integral part of R&D projects, and R&D can be an input to new design efforts. There are similarities and linkages. However, not all design meets the functional novelty and uncertainty tests as captured in this chapter's five core R&D criteria. Design plays a key role in the development and implementation of innovations. As an agreed definition of design for statistical purposes does not yet exist, design can be described as a potential multi-faceted innovation activity aimed at planning and designing procedures, technical specifications and other user and functional characteristics for new products and processes. Among these activities are initial preparations for the planning of new products or processes, and work on their design and implementation, including adjustments and further changes. This description emphasises the creative role of design within an innovation process, a feature potentially shared with the R&D performed in the same context. Some design-related activities may be considered R&D to the extent that they play a role in a product development process, which is aiming at something "new" (but not necessarily at new knowledge), is creative and original, can be formalised (performed by a dedicated team), and leads to a codified output to be passed on to the development team. The main difference with R&D is that no uncertainty is likely to be found when skilled designers are asked to contribute to an innovation project. This leads to a view that design is not R&D and that it has to be kept distinct from R&D for any statistical purpose.

2.63 While an R&D project involves uncertainty about whether an expected outcome will be delivered within an agreed time schedule, a design project's uncertainty will be directly influenced by the clarity and the feasibility of its original goals. As an example, designing a standard building does not involve major uncertainty about the final outcome; yet the more challenging the concept of the building, the adding of new features, for example, the higher the uncertainty about the time and costs needed to complete the project. R&D activity, complementing the use of existing design tools, may be required to address the uncertainty.

R&D and artistic creation

2.64 Design sometimes tends to be characterised by the use of artistic methods. This is another potential area of overlap. In order to address the discussion of R&D and artistic creation, it can be useful to make a distinction between research for the arts, research on the arts and artistic expression.

Research for the arts

2.65 Research for the arts consists in developing goods and services to meet the expressive needs of artists and performers. There are enterprises in this line of business that devote a significant part of their resources to R&D in this area. For instance, they engage in experimental development to produce new electronic musical instruments to suit the needs of a group of performers. Other types of R&D organisations (mainly universities and technical institutes) also play a role in exploring new technologies for performance art (to improve audio/video quality, for instance). The activity aimed at supporting the introduction of new organisational or marketing methods by art institutions (advertising, financial management, etc.) may qualify as R&D, but caution should be exercised in making this decision. This area of R&D performance is already covered by existing data collection.

Research on the arts (studies about the artistic expression)

2.66 Basic or applied research contributes to most of the studies of the arts (musicology, art history, theatre studies, media studies, literature, etc.). Public research institutions could have a role in selected research domains (as some relevant research infrastructures – like libraries, archives, etc. – are often attached to arts institutions, such as museums, theatres, etc.). As far as preservation and restoration activities are concerned (if not to be included in the group above), it is recommended to identify the providers of such technical services as R&D performers (employing researchers, publishing scientific works, etc.). This area of R&D performance is largely covered by existing data collection.

Artistic expression versus research

2.67 Artistic performance is normally excluded from R&D. Artistic performances fail the novelty test of R&D as they are looking for a new expression, rather than for new knowledge. Also, the reproducibility criterion (how to transfer the additional knowledge potentially produced) is not met. As a consequence, arts colleges and university arts departments cannot be assumed to perform R&D without additional supporting evidence. The existence of artists attending courses in such institutions is not relevant to the R&D measurement. Higher education institutions have, nevertheless, to be evaluated on a case-by-case basis if they grant a doctoral degree to an artist as a result of artistic performances. The recommendation is to adopt an "institutional" approach and only to take account of artistic practice recognised as R&D by higher education institutions as potential R&D (to be further used by data collectors).

R&D and software development

2.68 Information technology has a pervasive role in almost every innovation activity, and largely relies on R&D activities but also influences the ability of enterprises and institutions to perform R&D effectively. Software development is an innovation-related activity that is sometimes connected with R&D and incorporates, under specific conditions, some R&D. For a software development project to be classified as R&D, its completion must be dependent on a scientific and/or technological advance, and the aim of the project must be the systematic resolution of a scientific and/or technological uncertainty.

2.69 In addition to the software that is part of an overall R&D project (to record and monitor its different stages, for instance), the R&D associated with software as an end product or software embedded in an end product could also be classified as R&D when the R&D criteria apply.

2.70 The nature of software development is such that it is difficult to identify its R&D component, if any. Software development is an integral part of many projects that in themselves have no element of R&D. The software development component of such projects, however, may be classified as R&D if it leads to an advance in the area of computer software. Such advances are generally incremental rather than revolutionary. Therefore, an upgrade, addition or change to an existing program or system may be classified as R&D if it embodies scientific and/or technological advances that result in an increase in the stock of knowledge. The use of software for a new application or purpose does not by itself constitute an advance.

2.71 The following examples illustrate the concept of R&D in software and should be included in R&D:

- the development of new operating systems or languages
- the design and implementation of new search engines based on original technologies
- the effort to resolve conflicts within hardware or software based on the process of re-engineering a system or a network
- the creation of new or more efficient algorithms based on new techniques
- the creation of new and original encryption or security techniques.

2.72 Software-related activities of a routine nature are not to be considered R&D. Such activities include work on system-specific or program-specific advances that were publicly available prior to the commencement of the work. Technical problems that have been overcome in previous projects on the same operating systems and computer architecture are also excluded. Routine computer and software maintenance are not included in R&D.

Examples of other software-related activities to be excluded from R&D are:

- the development of business application software and information systems using known methods and existing software tools
- adding user functionality to existing application programs (including basic data entry functionalities)
- the creation of websites or software using existing tools
- the use of standard methods of encryption, security verification and data integrity testing
- the customisation of a product for a particular use, unless during this process knowledge is added that significantly improves the base program
- routine debugging of existing systems and programs, unless this is done prior to the end of the experimental development process.

2.73 In the systems software area, individual projects may not be considered as R&D, but their aggregation into a larger project could generate some technological uncertainty, the resolution of which will need R&D. Alternatively, a large project can be aimed at developing a commercial product by adopting available technologies and not include R&D in its planning, but there may be some elements in the project that would need some additional R&D activity to assure the smooth integration of different technologies.

2.74 Starting in the 1993 SNA (EC et al., 1994), total expenditure on software (including R&D for software development) was regarded as capital investment. In the 2008 SNA (EC et al., 2009), total expenditure on R&D is regarded as capital investment. According to the *Handbook on deriving capital measures of intellectual property products* (OECD, 2009), which further developed the 2008 SNA guidance on intangibles, capitalised software R&D remained in software investment. It is important to be able to identify explicitly R&D expenditure devoted to software to better inform both R&D and SNA statisticians and users of the overlap between software and R&D. This is discussed further in Chapter 4.

R&D and education and training

2.75 Educational and training institutions below the tertiary level focus their resources on teaching and, as a result, have a very low likelihood of being involved in R&D projects. On the other hand, in higher education institutions research and teaching are always very closely linked, as most academic staff undertake both, and many buildings, as well as much equipment, serve both purposes.

2.76 Because the results of research feed into teaching, and because the information and experience gained in teaching can often result in an input to research, it is difficult to define where the education and training activities of higher education staff and their students end and R&D activities begin, and vice versa. R&D's elements of novelty distinguish it from routine teaching and other work-related activities. The adoption of the key R&D criteria can be supplemented, in this sector, by a consideration of the institutional role played by some actors:

- doctoral students and master's students meeting specific conditions (Chapters 5 and 9)
- supervisors of students (included in the university staff)
- providers of specialised health care in university hospitals.

2.77 Since the research activity performed by doctoral students should be included in the overall R&D performed by the Higher Education sector, both they and the university staff acting as their instructors or supervisors should be included in R&D personnel totals (see Chapter 5). Of course, the time spent by the university staff to undertake tasks that are not related to research should be excluded from the estimation of the actual R&D performance. This applies to all scientific disciplines.

2.78 Similarly, in university hospitals where the training of medical students is an important activity in addition to the primary activity of health care, the activities of teaching, R&D and advanced, as well as routine, medical care are frequently closely linked. Personnel and students providing specialised health care in university hospitals, when they can be safely assumed to be part of an overall R&D effort, should be included in R&D personnel. Any routine activity undertaken to provide health care in the same context should be excluded from R&D.

R&D in service activities

2.79 The 2008 SNA defines services as the result of a production activity that changes the conditions of the consuming units, or facilitates the exchange of products or financial assets. Among the former, service providers can affect changes in the condition of the consumer's goods, in the physical and mental conditions of persons (e.g. through health or transportation, as well as through the provision of information, education, etc.). The SNA also defines a separate hybrid product category that has features of both goods and services, namely "Knowledge-capturing products". These concern the provision, storage, communication and dissemination of information, advice and entertainment in such a way that the consuming unit can access the knowledge repeatedly. The industries that produce these products are those concerned with the provision, storage, communication and dissemination of information, advice and entertainment in the broadest sense of those terms (EC et al., 2009).

2.80 The provision of services entails a high degree of proximity and interaction with customers. In addition, industries that specialise in the production of goods may be actively involved in the delivery of services. Firms in the service industries may in turn control several aspects of goods production, including for example the experimental development of new goods that are part of their service delivery.

2.81 Defining the boundaries of R&D in service activities is therefore difficult, for two main reasons: first, it is difficult to identify projects involving R&D that is specific to a service and not embedded in a good or knowledge-capturing product; and, second, the line between R&D and other innovation activities is not always clear.

2.82 Among the many projects in services, those that constitute R&D result in new knowledge or the use of knowledge to devise new applications, in keeping with the definition of R&D.

2.83 Identifying R&D is more difficult in service activities than in goods-producing industries because the R&D is not necessarily specialised in a field of research, although there may be specialisation reflecting the market served. R&D covers several areas: technology-related R&D, and R&D in the social sciences, humanities and arts, including R&D relating to the knowledge of behaviour and organisations. This last notion is already included in the criterion "knowledge of humankind, culture and society", but it is particularly important in the case of service activities. Because these forms of R&D may be combined in a project, it is important to define clearly the various forms of R&D involved. If the analysis is confined to technology-related R&D, for example, R&D may be understated. In many cases, R&D findings in service industries may be part of service delivery activities.

2.84 Also, in service companies, R&D is not always organised as formally as in goods-producing companies (i.e. with a dedicated R&D department, researchers or research engineers identified as such in the establishment's personnel list, etc.). The concept of R&D in services is still less specific and sometimes goes unrecognised by the enterprises involved. As more experience becomes available on the collection of R&D data in services, the criteria for identifying R&D and examples of service-related R&D may require further development.

Criteria for identifying R&D in services

2.85 In addition to the five core criteria, the following are indicators that may help to identify the presence of R&D in service activities:

- links with public research laboratories
- the involvement of staff with doctoral degrees or doctoral students
- the publication of research findings in scientific journals, the organisation of scientific conferences or involvement in scientific reviews.

Examples of R&D in selected service activities

2.86 The R&D activities listed below may serve as examples of R&D in service activities. The general and supplementary criteria for distinguishing R&D presented in Section 2.4 also have to be taken into account.

2.87 The general boundaries of R&D as defined above largely apply to service activities. The element of novelty is a basic criterion for distinguishing R&D from related activities.

Examples of R&D in banking and insurance

- mathematical research relating to financial risk analysis
- the development of risk models for credit policy
- the experimental development of new software for home banking
- the development of techniques for investigating consumer behaviour for the purpose of creating new types of accounts and banking services
- research to identity new risks or new characteristics of risk that need to be taken into consideration in insurance contracts
- research on social phenomena with an impact on new types of insurance (health, retirement, etc.), such as on insurance cover for non-smokers
- R&D related to electronic banking and insurance, Internet-related services and e-commerce applications
- R&D related to new or significantly improved financial services (new concepts for accounts, loans, insurance and saving instruments).

Examples of R&D in some other service activities

- analysis of the effects of economic and social change on consumption and leisure activities
- the development of new methods for measuring consumer expectations and preferences
- the development of new methods to deliver and measure social service outcomes that can be adapted in a variety of different socioeconomic or cultural settings
- the development of new survey methods and instruments
- the development of tracking and tracing procedures (logistics)
- research into new travel and holiday concepts.

R&D and related scientific and technological activities

2.88 Difficulties in separating R&D from other scientific and technological activities (STA) arise when several activities are performed in the same institution. In data collection practices, criteria are usually applied on the basis of a direct knowledge of the performing institutions. As general guidelines:

- Institutions or units of institutions and firms whose principal activity is R&D often have secondary, non-R&D activities (e.g. scientific and technical information, testing, quality control, analysis). Insofar as a secondary activity is undertaken primarily in the interests of R&D, it should be included in R&D; if the secondary activity is designed essentially to meet needs other than R&D, it should be excluded.
- Institutions whose main purpose is an R&D-related scientific activity often undertake some research in connection with this activity. Such research should be isolated and included when measuring R&D.

2.89 In some sectors, the key criteria for distinguishing between R&D and related scientific and technological activities are particularly difficult to apply. General-purpose data collection, testing and standardisation, big data projects, space exploration, and mineral exploration and evaluation are all areas involving large amounts of resources, and any variations in their treatment will have important effects on the international comparability of the resulting R&D data. Large-scale projects also pose problems for the identification of their R&D. As this edition is being finalised, UNESCO is updating its definitions of STA for statistical purposes (UNESCO, 1978; UNESCO, 1984), and the outcome of that process is expected to provide further guidance on the boundaries between R&D and other STA activities. Such guidance will be made available in due course as part of the online annex material to this manual.

General-purpose data collection and documentation

2.90 General-purpose data collection is undertaken generally by government agencies to record natural, biological or social phenomena that are of general public interest or that only the government has the resources to record. Examples are routine topographical mapping; routine geological, hydrological, oceanographic and meteorological surveying; and astronomical observations. Data collected solely or primarily as part of the R&D process are included in R&D (e.g. data collected by a detector that is part of an elementary particle scattering experiment at CERN). The same reasoning applies to the processing and interpretation of the data. The social sciences, in particular, are very dependent on an accurate record of facts relating to society in the form of censuses, sample surveys, etc. When these are specially collected or processed for the purpose of scientific research, the cost should be attributed to research and should cover the planning and systematising of the data. R&D can also be identified when a specific project is aimed at developing totally new statistical methods (e.g. conceptual and methodological work in relation to the development of completely new or substantially modified surveys and statistical systems, work on sampling methodologies, small area statistical estimates and advanced data-capturing techniques) or data collection methodologies and techniques. However, data collected for other or general purposes, such as quarterly sampling of unemployment, should be excluded from R&D even if exploited for research (unless the researcher had to pay for the right to use such data in the research). Market surveys should also be excluded.

2.91 The activities of a scientific and technical information service or of a research laboratory library that is maintained predominantly for the benefit of the research workers in the laboratory should be included in R&D. The activities of a firm's documentation centre open to all the firm's staff should be excluded from R&D even if it shares the same premises as the business research unit (the need to avoid an over-evaluation of R&D-related activities applies here). Similarly, the activities of central university libraries should be excluded from R&D. These criteria, which will have to be applied also to electronic libraries and data repositories, apply only when it is necessary to deal with the activities of an institution or a department in their entirety. Where more detailed accounting methods are used, it may be possible to impute part of the costs of the excluded activities to R&D overheads. Whereas the preparation of scientific and technical publications is, generally speaking, excluded, the preparation of the original report of research findings should be included in R&D.

Testing and standardisation

2.92 Public bodies and consumer organisations often operate laboratories that are intended mainly to test products and verify that standards are met. In addition to standard testing and benchmarking activities – which are not R&D – the staff of these laboratories may also spend time devising new or substantially improved testing methods. Such activities should be included in R&D.

Big data projects

2.93 The advent of new instruments and methods of data-intensive exploration is facilitating the process of data-intensive scientific discovery and data-driven innovation. These activities are R&D if and only if they meet the five core criteria, in particular the general requirement that the activity or project should be undertaken in a systematic way – i.e. by clearly identifying the original knowledge gap and focusing specific resources on addressing it. An example is the "Human Genome Project", which attracted researchers and institutions from 18 countries to co-operate in a 13-year-long research effort to sequence and map out the human DNA code. Through digitisation, the R&D codification criterion plays a major part in big data projects, as the usability of the data arising from "big data" science projects depends on its ability to convey knowledge about specific phenomena for which the data have been gathered. These data may or may not be made widely accessible or usable for research purposes. The concept of open science commonly refers to efforts to make the output of publicly funded research more widely accessible in digital format to the scientific community, the business sector or society more generally (OECD, 2015). In some cases, efforts to make research data openly accessible to the broad scientific community, including developing specific tools that facilitate the reproducibility of the research, will be an integral part of an R&D project, provided that they are explicitly formulated as such within the R&D project's objectives and are budgeted. In other cases, these should be treated as separate dissemination efforts and not counted as R&D.

Space exploration

2.94 A difficulty with space exploration is that, in some respects, much space activity may now be considered routine; certainly, most costs are incurred for the purchase of goods and services that are not R&D. It may be necessary to separate the activities associated with space exploration, including the development of vehicles, equipment, software and techniques, from those involved in the routine placing of orbiting satellites or the establishment of tracking and communication stations.

Mineral exploration and evaluation

2.95 Mineral exploration and evaluation is defined in the 2008 SNA as a category of activity leading to the creation of an intellectual property asset, separate from R&D (EC et al., 2009; OECD, 2009). The activity of mineral exploration and evaluation adds to the knowledge of subsoil deposits in specific locations for the purpose of their economic exploitation. It includes the acquisition of exploration rights as well as topographical, geological, geochemical and geophysical studies, and trenching, sampling and evaluation activities.

2.96 This manual also makes a strict separation between R&D and mineral exploration. However, some links with R&D can be found. For example, a number of geological tests undertaken in the context of R&D projects can provide initial evidence for exploration and mining companies to follow up with exploitation-driven exploration efforts, which are not R&D. R&D may also be required to develop new test and drilling techniques that the mining industry can draw on for its exploration and routine activities. Mining and prospecting sometimes cause problems owing to a linguistic confusion between research for new or substantially improved resources (food, energy, etc.) and the search for existing reserves of natural resources, a confusion that blurs the distinction between R&D and surveying and prospecting. In theory, in order to establish accurate R&D data, the following activities should be identified, measured and summed:

- the development of new surveying methods and techniques
- surveying undertaken as an integral part of a research project on geological phenomena
- research on geological phenomena, undertaken as a subsidiary part of surveying and prospecting programmes.

2.97 In practice, the last of these presents a number of problems. It is difficult to frame a precise definition that would be meaningful to respondents to national surveys. For this reason, only the following activities should be included in R&D:

- the development of new or substantially improved methods and equipment for data acquisition and for the processing and study of the data collected and for the interpretation of these data
- surveying undertaken as an integral part of an R&D project on geological phenomena, including data acquisition, processing and interpretation undertaken for primarily scientific purposes.

2.98 It follows that the surveying and prospecting activities of commercial companies will be almost entirely excluded from R&D. For example, the sinking of exploratory wells to evaluate technological services is not R&D.

R&D and the management of science and technology (S&T) activities

Technology readiness levels

2.99 The classification of large R&D projects is discussed in Chapter 8, with an emphasis on the defence and aerospace industries. In some jurisdictions, classifications of the technology readiness level (TRL) are used in procurement and in the description of projects. As there are a number of such classifications, the recommendation is that, if there is one in use in the jurisdiction of interest, it can be assessed to determine whether it could make a contribution to improving the collection of R&D statistics.

Demonstration projects

2.100 Two concepts of demonstration have already been adopted in R&D statistics: “user demonstration”, which takes place when a prototype is operated at or near full scale in a realistic environment to aid the formulation of policy or the promotion of its use, which is not R&D; and “technical demonstration” (including the development of “demonstration projects” and “demonstration models”) which, because it is an integral part of an R&D project, is an R&D activity.

2.101 With reference to its broad use in the management of large research projects, “technology demonstration” is seen as a step in the process of evaluating, *ex-ante* or *ex-post*, the implementation of new technologies. This meaning was originally adopted in the information and communication sector and has evolved to mean the activity carried out to show to potential investors and customers the expected potentiality of a technology under development. In this respect, the use of this concept is not recommended in association with the R&D concept, unless a clear role of a demonstration activity in an R&D project can be identified.

R&D in the social sciences, humanities and the arts

2.102 In the definition of R&D in this manual, the phrase “knowledge of humankind, culture and society” includes the social sciences, humanities and the arts. Also for the social sciences, humanities and arts, the use of clear criteria to identify R&D, such as having an appreciable element of novelty and dealing with uncertainty, is extremely helpful for defining the boundary between R&D and related (routine) scientific activities as well as non-scientific investigations. The conceptual, methodological and empirical components of the project concerned have to be taken into consideration to identify an R&D activity.

2.103 In the social sciences – e.g. sociology, economics or political science – data collection activities, e.g. statistical surveys on specific populations, can only be included in R&D if they are undertaken as an integral part of a specific research project or for the benefit of a specific research project. Therefore, projects of a routine nature, in which social scientists bring established social science methodologies, principles and models to bear on a particular problem, cannot be classified as research. For example, a project using labour force survey data to identify long-term unemployment trends should exclude the data collection activity as an R&D component (as those data are regularly collected by using an existing methodology). On the other hand, a case-study on unemployment in a specific region, if applying original techniques in interviewing survey respondents could include such data collection in its R&D effort. From a broader perspective, to the extent that the social sciences are using empirical data, the same guidelines have to be applied as for the natural sciences (although excluding the testing of their results on an experimental basis).

2.104 For the humanities, the same approach could be used as for the arts (studies on literature, music, visual arts, theatre, dance and other performing arts). Their historical or comparative nature can be pointed out as well as the relevant role played by universities or other specialised institutions in developing scientific guidelines to be followed by the scholars in the field.

2.105 The broad range of sources used in history, archaeology, languages and legal studies and the different methods used by researchers are possible areas of R&D. The adoption of the five core criteria for R&D should be recommended, mainly with reference to novelty, creativity and transferability and/or reproducibility.

2.106 In the fields of philosophy and religious studies, for instance, historical and comparative studies undertaken in line with current academic standards are included in R&D. As a general rule cannot be given, beyond that of strictly applying the R&D criteria, the use of the institutional approach is also recommended (i.e. potentially excluding research-related activities on philosophy and religion conducted outside recognised research institutions).

2.107 In conclusion, research in the humanities and the arts can be included in R&D in so far as their own internal requirements for identifying the "scientific" nature of such research are met. Additional practical guidelines follow.

- Context of performance (institutional criterion). Research carried out within the framework of a university or an officially recognised research institution (including museums, libraries, etc.) can be included in R&D.
- Adoption of recognised procedures. Research requires formalisation, and this applies to the humanities. Research activities could be identified and their results made available to the scientific community through their publication in scientific journals. In so far as these features can be identified and a scientific community is actively developing some rules to identify its own members, the same rules can be applied for identifying R&D performance.
- Research in the humanities may deal with the systematic development of theories or interpretations of texts, events, material remains or any other available evidence. By convention, research activities carried out outside the fields of R&D listed in Chapter 3 have to be excluded from R&D.

R&D and traditional knowledge

2.108 A cross-cutting research domain with some overlap with the humanities and medicine is that dealing with "traditional knowledge". Traditional knowledge has been defined to be a largely tacit "cumulative body of knowledge, know-how, practices and representations maintained and developed by peoples with extended histories of interaction with the natural environment […] a cultural complex that encompasses language, naming and classification systems, resource use practices, ritual, spirituality and worldview" (ICSU and UNESCO, 2002: 9). The issue of the relationship between traditional knowledge and R&D is particularly relevant in developing countries where the existence of a valuable stock of traditional knowledge can be a powerful incentive for domestic and foreign organisations to set up R&D activities.

2.109 As a general rule, where activities associated with traditional knowledge form part of an R&D project, the effort (financial and in terms of human resources) should be counted as R&D. Otherwise they should be excluded.

Examples of different types of activities involving traditional knowledge that should be counted as contributing to R&D are as follows:

- An R&D project may entail a scientific-based approach to establishing the content of traditional knowledge, in disciplines such as ethno-science (ethno-botany, ethno-pedology, ethno-forestry, ethno-veterinary medicine, and ethno-ecology) or cognitive anthropology. In this case, R&D methods within established disciplines are used to study traditional knowledge.
- The application of scientific methods to identify the active ingredient of local health remedies and/or their effectiveness for certain medical conditions. In this case, R&D methods are applied directly to traditional knowledge products with the purpose of expanding the stock of scientific knowledge.
- Activities undertaken by traditional knowledge practitioners to expand the stock of traditional knowledge, through the combined use of traditional and other, scientific methods. These activities must meet the standard criteria for being countable as R&D or must be carried out in universities.

2.110 Examples of traditional knowledge activities that would be excluded from R&D include the following:

- the regular/continued use of traditional knowledge by practitioners, for example, in treating ailments or managing crops
- the routine development of products based on traditional knowledge
- the storage and communication of traditional knowledge in traditional ways (by the test of novelty)
- the traditional handing down of religious or cultural beliefs and practices.

2.8. Activities to be excluded from R&D

2.111 For survey purposes, R&D must be distinguished from a wide range of related activities with a scientific and technological basis. These other activities are very closely linked to R&D both through flows of information and in terms of operations, institutions and personnel, but as far as possible they should be excluded when measuring R&D.

Scientific and technical information services

2.112 The specialised activities of:

- collecting
- coding
- recording
- classifying
- disseminating
- translating

- analysing
- evaluating

by:

- scientific and technical personnel
- bibliographic services
- patent services
- scientific and technical information, extension and advisory services
- scientific conferences

are to be excluded, except when conducted solely or primarily for the purpose of R&D support (e.g. the preparation of the original report of R&D findings should be included in R&D) or in the context of R&D projects, as defined earlier in this section.

Testing and standardisation

2.113 This concerns the maintenance of national standards, the calibration of secondary standards and the routine testing and analysis of materials, components, products, processes, soils, atmosphere, etc. These activities are not R&D.

Feasibility studies

2.114 The investigation of proposed engineering projects, using existing techniques to provide additional information before deciding on implementation, is not R&D. In the social sciences, feasibility studies are investigations of the socio-economic characteristics and implications of specific situations (e.g. a study of the viability of a petrochemical complex in a certain region). However, feasibility studies on research projects are part of R&D.

Specialised health care

2.115 This concerns the routine investigation and normal application of specialised medical knowledge. Usually this is not R&D; there may, however, be an element of R&D in what is usually called "specialised health care", when it is carried out, for example, in university hospitals.

Policy-related studies

2.116 In this context, "policy" refers not only to national policy but also to policy at regional and local levels, as well as the policy of business enterprises in the pursuit of their economic activity. Policy-related studies cover a range of activities, such as the analysis and assessment of the existing programmes, policies and operations of government departments and other institutions; the work of units concerned with the continuing analysis and monitoring of external phenomena (e.g. defence and security analysis); and the work of legislative commissions of inquiry concerned with general government or departmental policy or operations.

2.117 Any activity aimed at providing close support to policy actions, as well as to legislative activity, should be excluded from R&D. This includes policy advice and relations with the media, legal advice, public relations or even technical support for the administrative activity (e.g. accounting).

2.118 It has to be pointed out that, on the other hand, research activities aimed at providing the decision makers with a thorough knowledge of social, economic or natural phenomena have to be included in R&D. These R&D activities are usually performed by skilled personnel – researchers – in small teams of experts and consultants and meet the standard academic criteria for scientific work (in addition to the R&D criteria).

Programmatic evaluations

2.119 R&D efforts may underpin the decision-making process within government and other institutions. While these efforts may be outsourced to external organisations, some institutions may have dedicated teams actively involved in carrying out analyses such as ex-ante and ex-post appraisals or evaluations, on an ad hoc or even formalised basis. These activities may in some cases meet the criteria for an R&D project. However, this is not always the case, and not all intelligence or evidence-building efforts associated with policy or programmatic advice can be correctly described as R&D. It is relevant to consider in some detail the expertise of those involved in the activity, how knowledge is codified within the organisation, and how quality standards are assured with regard to the research questions and the methodology applied. There is a significant risk that some types of socio-economic consultancy (internal or external) are inaccurately presented as R&D.

2.120 Scientific advisors play an important role within government. However, the application of established decision-making criteria to policy making does not represent R&D. Efforts aimed at developing improved methodologies for science-based decision making can be considered as R&D.

Purely R&D-financing activities

2.121 The raising, management and distribution of R&D grants to performers by ministries, research agencies, foundations or charities is not R&D.

Indirect supporting activities

2.122 This covers a number of activities that are not R&D but which provide support for R&D. By convention, R&D personnel data cover R&D proper but exclude indirect supporting activities, whereas an allowance for these is included under overheads in the R&D expenditure of performers. Typical examples are transportation, storage, cleaning, repair, maintenance and security activities. Administration and clerical activities undertaken not exclusively for R&D, such as the activities of central finance and personnel departments, also come under this heading.

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