

MIS775 Decision Modelling for Business Analytics

TOPIC 7: Building Stochastic Decision Models



Types of Decision Models

- Deterministic Decision Models (MODULE 1)
 - **Deterministic models are built on the assumption that all inputs to a model, apart from the decision variables, are fixed**
- Stochastic Decision Models (MODULE 2)
 - **Some inputs to these models are stochastic, i.e. they exhibit random behaviour**
 - **Instead of making a single “best guess” for each of these random inputs, we incorporate uncertainty into these models via probability distributions**
 - **This in turn produces random variation in model outputs, which we quantify in terms of probabilities and statistics**
 - **This information is then used to guide our decision-making**



Decision Modelling in Spreadsheets

- Spreadsheet-based decision models are useful for capturing the components of a business problem, modelling their inter-relationships, and helping to explore the possible outcomes of various decisions
- We use a case study to illustrate this, but the principal learning is in the process and methodology of modelling
- Decision modelling process involves three steps:
 - **Model formulation**
 - **Model solution**
 - **Model interpretation**
- This topic focuses on problem structuring and using of a framework for building spreadsheet-based decision models



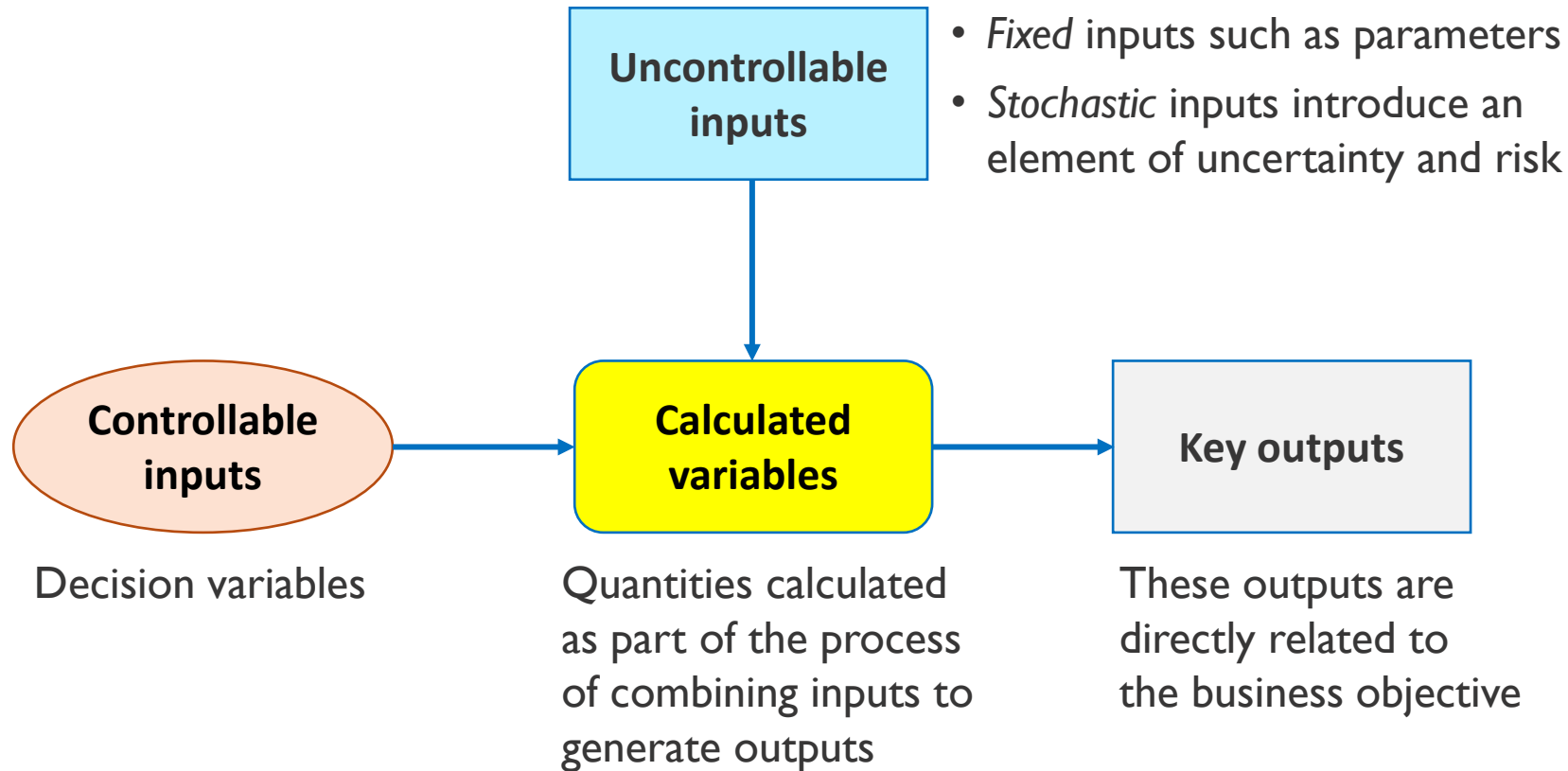
Learning Objectives

- Problem structuring for stochastic decision models
- Using a framework for building spreadsheet-based decision models
- Testing and validating a spreadsheet model
- Performing scenario analysis

Note: No textbook reading for this topic. However, we draw heavily upon Chapter 16 of Quantitative Methods for Business by Anderson et. al., available under Week 7 Learning Resources



General Structure of a Stochastic Decision Model



Case Study: SANOTRONICS*

- Sanotronics is a start-up company that manufactures medical devices for use in hospital clinics.
- The founders of the company have developed a prototype for a new device that limits health care workers' exposure to chemotherapy treatments while they are preparing, administering, and disposing of these hazardous medications.
- This new device features an innovative design and has the potential to capture a substantial market share.

*Case adapted from recommended textbook *Quantitative Methods for Business* by Anderson et. al., Edn 13e, p. 721.

Case Study: SANOTRONICS*

- Sanotronics would like an analysis of the first year profit potential of the device.
- Because of Sanotronics' tight cash flow situation, management is particularly concerned about the potential for making a loss.
- Sanotronics has identified the key inputs in determining the first-year profit:
 - selling price per unit (p)
 - first-year administrative and advertising costs (c_a)
 - direct labour cost per unit (c_l)
 - parts cost per unit (c_p)
 - first-year demand (d).

Define the Problem

- Clearly define the problem:
 - **What is its scope (i.e. where are the boundaries)?**
 - **What are the organisation's objectives?**
- Specify the model output(s) required to achieve the objectives
- Identify the inputs required to produce the model output(s)
 - **Which inputs are random/stochastic?**
 - **What parameter values are required?**
- What are the decision variables?
- What are the constraints, if any?



Define the Problem

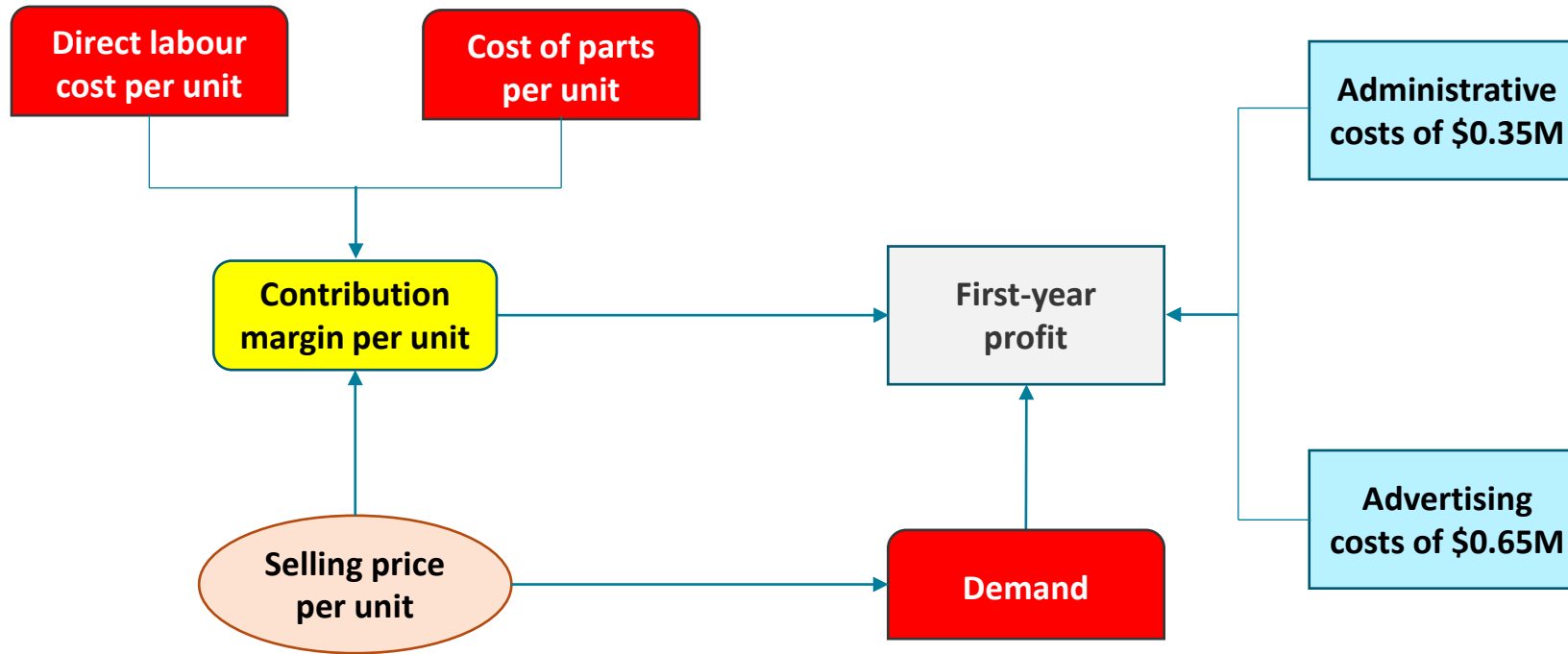
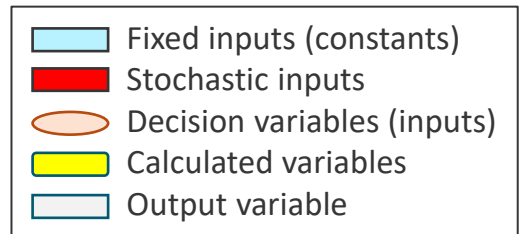
- Objective is to maximise profit in the first year
- Output required is the first-year profit of the new device
- Stochastic (i.e. random) inputs required to produce the output
 - **Cost of direct labour**
 - **Cost of parts**
 - **First-year demand**
- Fixed parameter inputs:
 - **Administrative costs**
 - **Advertising costs**
- Decision variable: **Selling price per unit**

Acquire Data

- Sanotronics commissioned market research to estimate demand at two price points, \$249 and \$299, under the assumption that it used all of its available funds on first-year administrative and advertising costs, at \$0.35 million and \$.65 million, resp.
- The research findings for the first year are as follows:
 - a selling price of \$249 per unit will result in an average demand of 15,000 units
 - a selling price of \$299 per unit will result in an average demand of 11,000 unitsthough the actual demand is subject to random variation
- Sanotronics is also uncertain about the values for the cost of direct labour and the cost of parts. At this stage of the planning process, Sanotronics's base estimates of these inputs are \$45 per unit for the direct labour cost, and \$90 per unit for the parts cost per unit.



Develop the Conceptual Model



Develop the Algebraic Model

- We seek to maximise the first-year profit, calculated by:

$$Profit = (p - c_l - c_p) \times d - c_a$$

where c_a is fixed at \$1M

Spreadsheet Design

- Make best use of the multiple worksheets by allocating specific tasks to separate worksheets
- Use multiple worksheets or regions of a worksheet to separate:
 - **Key inputs and outputs, i.e. the most important/relevant aspects of the decision model (“Manager page” and Conceptual model worksheets)**
 - **Constants (things you can’t control but impact on the outcome)**
 - **Calculations and computed values**
 - **Charts (optional) : Useful to have dynamic charts which automatically update with any changes to the model**



Build the Spreadsheet Model

	A	B	C	D	E	F	G	H
1								
2		COMPUTED VALUES AND OUTPUT					INPUTS	
3							Stochastic inputs	
4		Contribution margin per unit	\$114				Direct labour cost per unit	\$45 Best guess
5							Cost of parts per unit	\$90 Best guess
6		First-year profit	\$710,000				Demand	15000 Best guess
7								
8								
9							Decision variables	
10							Selling price per unit	\$249
11								
12								
13							Fixed inputs	
14							Administrative costs (\$M)	\$0.35
15							Advertising costs (\$M)	\$0.65

General Rules for Spreadsheets

- Include a worksheet that explains the model and identifies and names the quantities/variables involved
- Always **use a single point of entry for all input values**. “One version of the truth”. Other cells that require the input should copy the cell reference
- **Never use an explicit value within a formula**, however fixed it may be. A formula should only contain cell references and mathematical operations/functions

Testing Spreadsheet Models

- Debugging spreadsheets can be monotonous and laborious
- Testing and auditing the model regularly at various stages of its development is usually the only way to avoid having a long-winded debugging session at the end
- The following types of tests provide a reasonable foundation for identifying possible programming errors:
 - **Zero tests:** Set each key input to zero and confirm the resulting output value is as it should be
 - **Logical tests:** Increase and decrease the key inputs in a systematic manner and confirm the change in outputs is logical
 - **Manual tests:** Do a full manual calculation of all formulas
 - **Audit formulas:** confirm the inputs involved are correct
- **COMMON-SENSE TEST:** Is the model output reasonable?



Developing a Solution

Approach 1: Decision analysis: tree-like model of decision alternatives and their possible consequences, including chance event outcomes, resource costs, and payoffs. This was discussed in Topic 6

Approach 2: Scenario analysis (the range of possible outcomes from ‘what-if’ input values is used to understand the risks of undesirable outcomes)

- With Scenario analysis (What-if analysis) each scenario is considered in the model to see what impact it has on outputs

Approach 3: Simulation modelling is when distributions are used for stochastic variables. This will be discussed in Topics 8 & 9



Scenario Analysis

- When dealing with uncertainty it is useful to consider a range of scenarios that may eventuate, and consider strategies that would be effective in each situation
- The scenarios need to be developed by someone with domain knowledge so they are reasonable and cover situations that are worth worrying about!
- Excel's Scenario Manager (within Data > What-If Analysis) allows the modeller to capture scenarios and resulting outcomes

Scenario Analysis

- By changing the values of input variables we can see what happens to the values of output variables

Advantages:

- **Easy to carry out in a spreadsheet**
- **By changing the value of each variable one at a time, we determine the sensitivity of outputs to each input variable**

Disadvantages:

- **The modeller must decide the values for the stochastic inputs or get a domain expert to work alongside**
- **There may be dozens/hundreds of scenarios to consider**

Inputs

INPUTS

Stochastic inputs

Direct labour cost per unit	\$45	Best guess
Cost of parts per unit	\$90	Best guess
Demand	15000	Best guess

Decision variables

Selling price per unit	\$249
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Fixed inputs

Administrative costs (\$M)	\$0.35
Advertising costs (\$M)	\$0.65

- What values do we use for Stochastic inputs?
 - **Is it reasonable to use best guesses?**
 - **How do we build random variability into a decision model?**
- Decision variables are controlled by the decision maker
- Fixed inputs of admin & advert costs are given

Best/Worst-case Analysis

- Establish a range of possible outcomes by setting the value of each stochastic input to their most likely value (base case), most optimistic value (best case), and most pessimistic value (worst case)

	Best	Base	Worst
Direct labour cost	\$43	\$45	\$47
Cost of parts	\$80	\$90	\$100
Demand at price of \$249	30,000	15,000	0
Demand at price of \$299	22,000	11,000	0

Advantages:

- Provides the range of values for the output(s) covering best, base and worst cases**
- Recommendations can then be supported by best/worst scenarios**

Disadvantages:

- Does not indicate the likelihood of the best or worst case happening. The worst case may be unlikely to happen, while the best case may be quite likely to happen, yet this is not considered**



Example 1 of Scenario Analysis

Suppose we want to see how changing demand affects output (profit) when selling price is \$249: what is the best/worst case scenario?

Scenario Summary				
	Current Values:	Best case	Base case	Worst case
Changing Cells:				
Demand	15000	30000	15000	0
Result Cells:				
First_year_profit	\$710,000	\$2,420,000	\$710,000	-\$1,000,000

Notes: Current Values column represents values of changing cells at time Scenario Summary Report was created. Changing cells for each scenario are highlighted in gray.



Example 2 of Scenario Analysis

Suppose we want to see how direct labour cost affects profit when selling price is \$249: what is the best/worst case scenario?

Scenario Summary				
	Current Values:	Best case	Base	Worst case
Changing Cells:				
Direct_labour_cost_per_unit	\$45	\$43	\$45	\$47
Result Cells:				
First_year_profit	\$710,000	\$740,000	\$710,000	\$680,000

Notes: Current Values column represents values of changing cells at time Scenario Summary Report was created. Changing cells for each scenario are highlighted in gray.



Example 3 of Scenario Analysis

Suppose we want to see how cost of parts affects profit when selling price is \$249: what is the best/worst case scenario?

Scenario Summary				
	Current Values:	Best case	Base case	Worst case
Changing Cells:				
Cost_of_parts_per_unit	\$90	\$80	\$90	\$100
Result Cells:				
First_year_profit	\$710,000	\$860,000	\$710,000	\$560,000

Notes: Current Values column represents values of changing cells at time Scenario Summary Report was created. Changing cells for each scenario are highlighted in gray.



Possible Problems in Developing Decision Models

- We often face roadblocks in defining a problem
 - **Problems do not exist in isolation and often span multiple departments. The problem therefore needs to be examined from several points of view**
 - **The problem statement should include inputs from all concerned departments**
 - **“a good solution to the right problem is much better than an optimal solution to the wrong problem”**
- Often difficult to access reliable data
 - **Results of a model are only as good as the input data used**
- Complex decision models tend to give solutions that are not intuitively obvious
- Once the model solution has been tested, the results must be analysed in terms of how they will affect the entire company



Summary

- With stochastic decision models, some inputs are random and, as a result, outputs are also random. This uncertainty introduces risk into these models
- Our case study illustrates how to structure a problem, and how to use a framework for building a spreadsheet model
- Scenario analysis is one of three approaches for developing a solution for a stochastic decision model. It involves changing the values of stochastic inputs (preferably one at a time) to examine the impact on the model's outputs



Next Class

Topic 8: Simulation Modelling

- **We show how randomness/uncertainty can be explicitly captured in a model, enabling the decision maker to consider the likelihood of a range of possible outcomes**
- **In preparation for this class, refresh your knowledge of probability distributions (Normal, Binomial, Poisson)**
- **Pre-read section 10.2 of the text, pages 518-527 (excluding reference to @RISK software on p. 527)**
- **Read section 16.2 of Quantitative Methods for Business by Anderson et. al., available under Week 7 Learning Resources**