Scenario Modelling for Managers: A System Dynamics Approach

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Abstract

This paper presents an outline of scenario planning and some guidelines on developing and using scenarios. This is followed by a brief overview of scenario modelling. An example of scenario modelling is provided based on system dynamics. The system dynamics scenarios involve dynamic simulation modelling of business policy issues for a strategic business unit in a large organisation in the telecommunications industry in New Zealand. The data and situation are confidential but the case illustrates the scenario modelling process based on the approach developed by Paul Schoemaker. The scenarios in the paper are illustrated with the use of a Management Flight Simulator, developed with system dynamics software. Finally some reflections of the role of system dynamics in scenario planning, modelling and analysis are provided.

Key words: Scenario planning, scenario analysis, system dynamics, simulation, management flight simulator, scenario modelling.

1 Introduction

The term 'scenario' has entered the everyday language of managers in all sectors of the economy and it has been heavily popularised by the media. In earlier times, a scenario was a term more related to the theatrical scene than the business world. The Oxford Dictionary (1995) defines a scenario as "**1** an outline of the plot of a play, film, opera, etc., with details of the scenes, situations, etc. **2** a postulated sequence of imagined events." The author Jules Verne wrote futuristic stories (i.e. scenarios) of human beings travelling to the moon and into the depths of the ocean, well before such travel became possible. Similarly, social commentators such as Aldous Huxley and George Orwell wrote stories (scenarios) about the future state of society, with the intention of warning people how things could turn out if society developed along 'undesirable' paths.

During World War II, scenario planning became popular with military strategists analysing potential deployment of military resources, personnel and weapons. Scenario planning was further popularised in the 1950s by Herman Kahn, a well known futurist from the Rand Corporation and Hudson Institute. "Kahn was best known for his scenarios about nuclear war, in which he advocated that people should "think about the unthinkable" so that, if nuclear war did become imminent, society would be less vulnerable and less likely to slide into a holocaust" (De Geus, 1998, p57).

More recently, scenario planning was introduced to the business world by business planners at the Royal Dutch Shell Group. In the late 1960s and early 1970s, planners at Shell developed a process of preparing a range of stories about future potential states of the business environment, and communicating these stories and their implications to management within the Shell Group. This enabled Shell's management to be better prepared for the 1973 oil crisis than the other international oil companies. Also, scenario planning provided Shell management with substantial competitive insights again in 1981, "when other oil companies stockpiled reserves in the aftermath of the outbreak of the Iran-Iraq war, Shell sold off its excess before the glut became a reality and prices collapsed." (Wack,1995).

Scenario planning should not be confused with forecasting, or single path projections. Although forecasting does have its place in managerial decision analysis, history is littered with 'forecasts' from famous people and experts that have proved to be totally wrong. Cerf and Navasky (1984) summarise some of these:

'Heavier-than-air flying machines are impossible.'
Lord Kelvin, British mathematician, physicist, and president of the British Royal Society, c. 1895

'There is no likelihood man can ever tap the power of the atom.'
Robert Millikan, Physics Nobel Prize, 1923

'Who the hell wants to hear actors talk?'
Harry M. Warner, Warner Bros., 1927

'A severe depression like that of 1920–1921 is outside the range of probability.'
The Harvard Economic Society, 16 November 1929

'I think there is a world market for about five computers.'
Thomas J. Watson, chairman of IBM, 1943

'There is no reason for any individual to have a computer in their home.'
Ken Olson, president, Digital Equipment Corporation, 1977

'We don't like their sound. Groups of guitars are on the way out.'
Decca Recording Co. Executive, turning down the Beatles in 1962

These 'forecasts' almost provide sufficient reason to consider multiple futures! Scenario planning provides a framework to help managers understand the forces driving their businesses, rather than relying on forecasts presented to them with a hidden set of assumptions and judgements incorporated into a set of figures that become a substitute for thinking about the future. In short, scenario planning attempts to capture the richness and range of future possibilities, stimulating decision makers and managers to consider changes they would otherwise ignore. At the same time, it organises those possibilities into stories that are easier to grasp and use than huge volumes of data. Above all, however, scenarios are aimed at challenging managers' mental models and their prevailing mindsets.

In particular, organisations that face the following conditions will benefit from scenario planning (Schoemaker, 1995, p27):

- "uncertainty is high relative to managers' ability to predict or adjust;
- too many costly surprises have occurred in the past;

- the company does not perceive or generate new opportunities;
- the quality of strategic thinking is low (i.e. too routinised or bureaucratic);
- the industry has experienced significant changes or is about to experience such change;
- the company wants a common language and framework, without stifling diversity;
- there are strong differences of opinion, with multiple opinions having merit;
- competitors are using scenario planning."

A scenario is not a forecast or an intention to describe a certain future state, but it is intended to provide a possible set of future conditions. As Becker (1983, p96) outlines:
"A scenario can present future conditions in two different ways. It can describe a snapshot in time, that is, conditions at some particular instant in the future. Alternatively, a scenario can describe the evolution of events from now to some point of time in the future. In other words, it can present a "future history". This latter approach is generally preferred by those engaged in policy analysis and choosing strategy, because it provides cause-and-effect information. Indeed, preparing scenarios as a future history requires that a possible evolution of events and trends be described as an integral part of the scenario".

2 Methodology

2.1 Scenario construction

Pierre Wack (1985, p140) stresses that "scenarios must help decision makers develop their own feel for the future of the system, the forces at work within it, the uncertainties that underlie the alternative scenarios and the concepts useful for interpreting key data."

The main building blocks for constructing scenarios are illustrated in Figure 1 and more detailed steps in scenario construction are provided in Table 1. It should be noted that there are many alternative ways of constructing scenarios (eg see Schwartz, 1996; van den Heijden, 1997) but the method outlined here appears the most consistent with the subsequent use of simulation modelling for testing the assumptions, internal consistency and future implications of the scenarios.

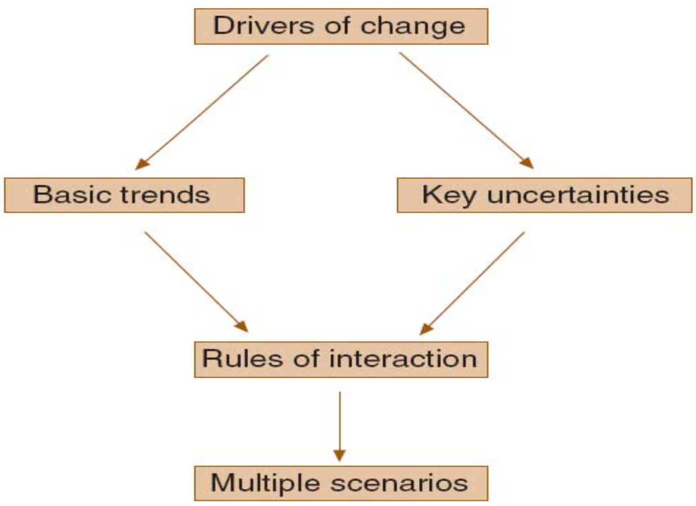

Figure 1. Building blocks for scenarios (Schoemaker, 1995)

Table 1. Steps in scenario construction

1	Define the issues you wish to understand better in terms of time frame, scope and decision variables… Review the past to get a feel for degrees of uncertainty and volatility.
2	Identify the major stakeholders or actors who would have an interest in these issues, both those who may be affected by it and those who could influence matters appreciably (*perhaps prepare a stakeholder map*). Identify their current roles, interests and power positions.
3	Make a list of current trends or predetermined elements that will affect the variable(s) of interest. Briefly explain each, including how and why it exerts an influence. Constructing a diagram may be helpful to show interlinkages and causal relationships (*e.g. a causal loop diagram*).
4	Identify key uncertainties whose resolution will significantly affect the variables of interest to you. Briefly explain why these uncertain events matter, as well as how they interrelate.
5	Construct two forced scenarios by placing all positive outcomes of key uncertainties in one scenario and all negative outcomes in the other. Add selected trends and predetermined elements to these extreme scenarios.
6	Next assess the internal consistency and plausibility of these artificial scenarios. Identify where and why these forced scenarios may be internally inconsistent (in terms of trends and outcome combinations).
7	Eliminate combinations that are not credible or are impossible, and create new scenarios (two or more) until you have achieved internal inconsistency. Make sure these new scenarios bracket a wide range of outcomes.
8	Assess the revised scenarios in terms of how the key stakeholders would behave in them. Where appropriate, identify topics for further study that would provide stronger support for your scenarios, or might lead to revisions of these learning scenarios.
9	After completing additional research, re-examine the internal consistencies of the learning scenarios and assess whether certain interactions should be formalised via a quantitative model… (*such as a system dynamics simulation model*).
10	Finally, reassess the ranges of uncertainty of the dependent (i.e. target) variables of interest, and retrace Steps 1 through 9 to arrive at decision scenarios that might be given to others to enhance their decision making under uncertainty (*or used to test strategies and generate new ideas*).

(Source: Schoemaker, 1993, p97. Words added in italics.)

2.2 System dynamics

The general modelling approach used in this paper to illustrate the Schoemaker approach to scenario construction and analysis is system dynamics. The main phases are summarised in Table 2, following the five phase integrated approach outlined by Maani & Cavana (2007). For further details of the general approach to system dynamics, see for example Forrester (1961), Coyle (1996) or Sterman (2000).

Table 2. Systems Thinking, System Dynamics Methodology

Phases	
1	Problem Structuring
2	Causal Loop Modelling
3	Dynamic Modelling
4	Scenario Planning and Modelling
5	Implementation & Organisational Learning

Source: Maani & Cavana (2007).

The main focus of this paper is on the application of phase 4 ‘scenario planning and modelling’. In this phase, various policies and strategies are formulated and tested. Here ‘policy’ refers to changes to a single internal variable such as hiring, quality, or price. Strategy is the combination of a set of polices and as such deals with *internal* or *controllable* changes. When these strategies are tested under varying *external* conditions, this is referred to as scenario modelling. This stage involves working closely with all major stakeholders. Chapter 5 of Maani & Cavana (2007) outlines the scenario planning and modelling approach more fully.

2.3 Scenario modelling

The process outlined by Schoemaker (1993, p197) for developing scenarios is summarised in Table 2. A dynamic simulation model is most useful during stages 6, 9 and 10 of the process, i.e. to test the internal consistency and consequences of a range of scenarios. In addition, a dynamic simulation model can be used to design and analyse the implications of policies and strategies against the backdrop of the scenarios developed. In the next section, we briefly outline a case study involving scenario modelling and strategy development for a business unit in the telecommunications industry in New Zealand.

3 Case: scenario analysis for a telecommunications business unit

3.1 Case overview

This case is based on a consultancy project for a business unit of a telecommunications company operating in a small city in New Zealand (Cavana & Hughes, 1995). However, the issues, data and names have been changed to preserve client confidentiality. The major issues dealt with are how to design policies, and test strategies to help managers turn around a business unit that is experiencing a declining market share and eroded profitability (see Figure 2).

The operations of the telecommunications business unit (called TBU for the purposes of this case) include replacing, maintaining and installing telecommunications lines and connections to commercial and residential sites in the small city in which it works. The processes involve the design and planning of these connections, as well as undertaking the work to deliver the services. These are known as ‘jobs’ in the industry and we will refer to the whole process from design to delivery as a ‘job’ in this case.

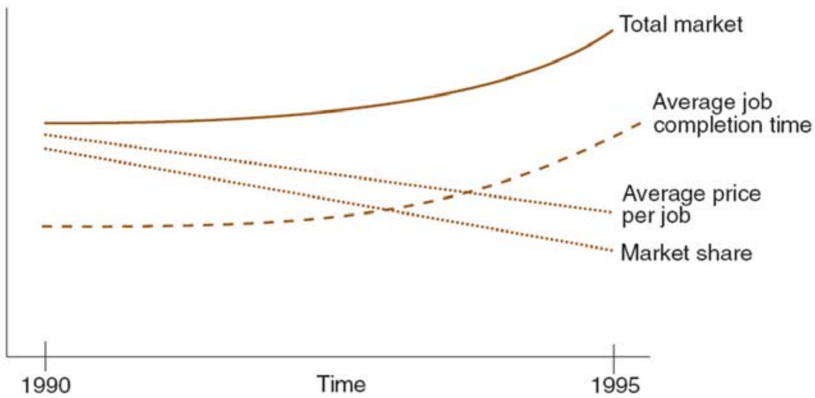

Figure 2. Behaviour over time chart for the TBU strategy case

After a number of meetings with the project team (two consultants, the finance manager and CEO of the TBU, and two members of the head office (HO) strategy support staff), a causal loop diagram (CLD) was developed. This development was iterative, and a whiteboard was used. This CLD became the basis for the development of the telecommunications business unit (TBU) strategy model, using the *ithink* computer simulation software (Richmond & Petersen, 1997). The model contains four sectors: a market sector which includes variables for price, quality, market share, and the total market; an operations sector that deals with the processing of the services provided by the business unit, and relative productivity factors; a human resources sector that incorporates natural attrition, replacement and hiring decisions; and a finance sector that calculates costs, revenues, profit margins, cash flow and net present value for the business unit over a five-year period.

The case is outlined in Cavana & Hughes (1995) and fully discussed in Maani & Cavana (2007, Case 5, pp.225-270). The documented equations are provided, and an electronic version of the *ithink* and Vensim versions of the model are provided in the CD-rom accompanying the book (Maani & Cavana, 2007).

3.2 Model development

The analysis was done on a monthly basis as records and data were available on that basis, and the planning horizon (or length of the simulation run) was five years (60 months). This was TBU's usual planning horizon for strategic analysis and planning. Data were collected from interviews with TBU and HO staff, and where data were not readily available, estimates were made – typically in collaboration with, and with the endorsement and/or approval of, the financial manager and CEO of TBU. An example of one of the model sectors is provided in Figure 3.

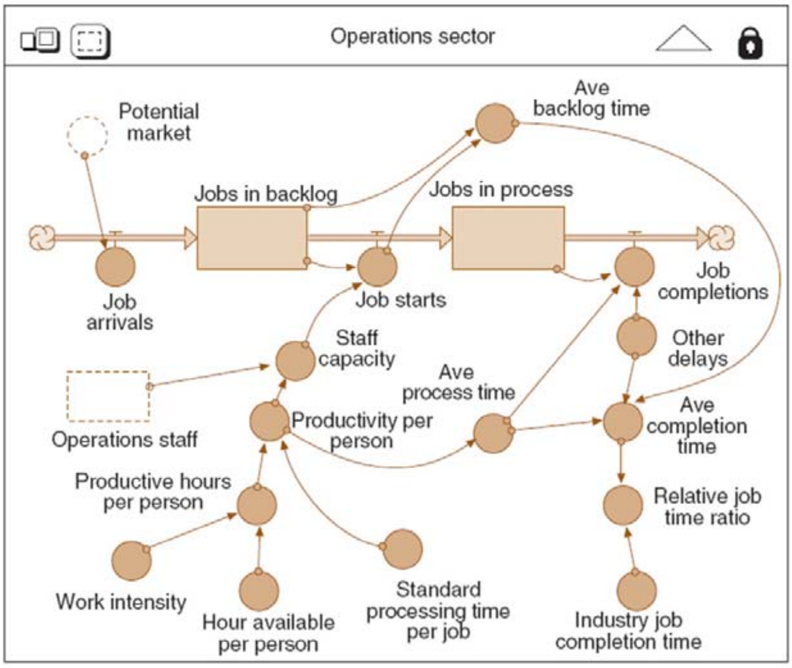

Figure 3. Stock flow diagram for the TBU operations sector

3.3 Base case behaviour

The base case model behaviour for some of the main variables is summarised in Figure 4.

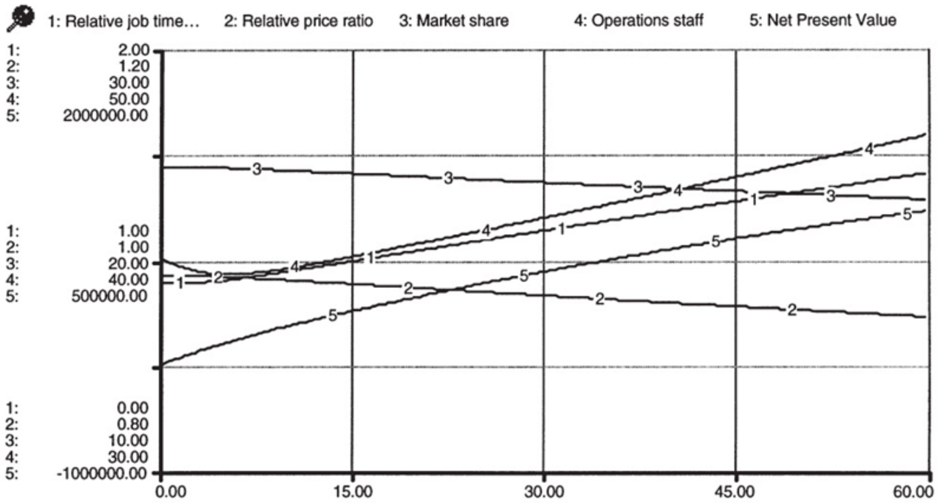

Figure 4. Base case behaviour of the TBU strategy model

The detailed model validation, sensitivity testing, policy analysis and strategy development was facilitated by the construction of a user friendly Management Flight Simulator for the model. An example of a simple control panel for the market sector input parameters, graphs and main outputs is provided in Figure 5.

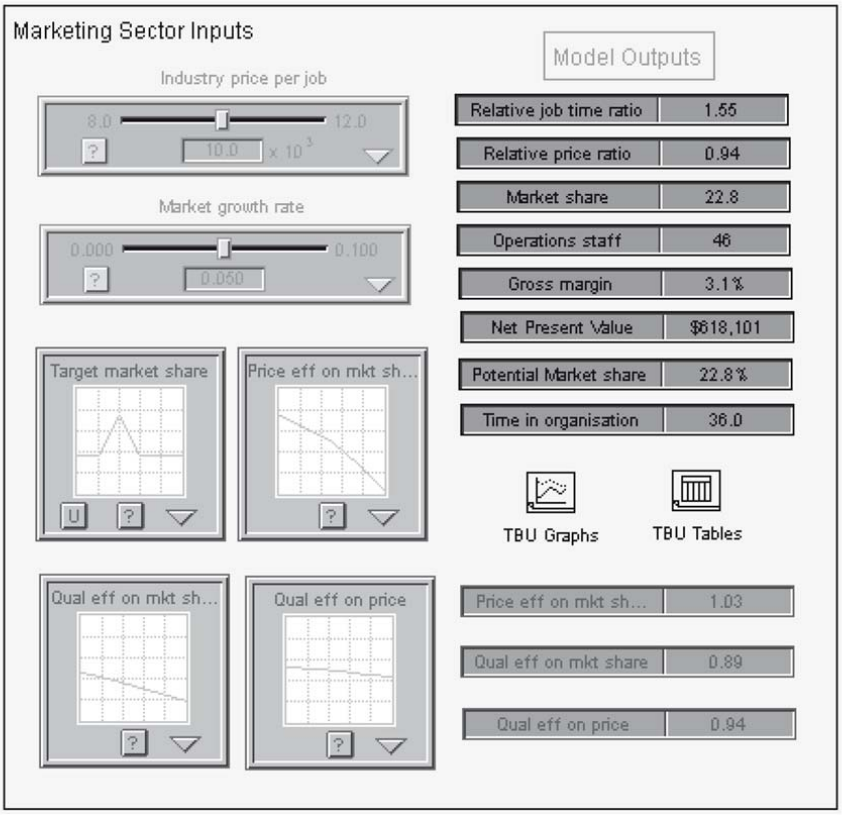

Figure 5. A simple control panel for the market sector of the TBU strategy model

4 Scenario analysis

In this section we present a range of scenarios for the TBU strategy case and then test the redesigned strategies against these alternative futures (i.e. scenarios). Initially we indicate the scope of the major uncertainties that could have an impact on the TBU, then we present two 'forced' scenarios. These form the basis for the 'learning' scenarios, which we analyse with the dynamic simulation model to test the robustness of our redesigned strategies.

4.1 Uncertainties

There are a large number of uncertainties that could have an impact on the future of the TBU. These include the factors summarised in Table 3.

Table 3. Factors potentially affecting the future of TBU

Market factors • Market – stagnation and decline, slow growth, rapid growth • Competitors – major new competitors, some competitors departing • Technological changes in market – nature of telecommunications greatly different, remains the same • Prices – remain constant in real terms, declining
Operations factors • Operations – big changes in delays (logistic, workers, regulatory authorities, etc.) – improvements and deterioration in relationships causing increased or decreased delays. • Technological changes in equipment used – no change, substantial changes • Equipment – continue leasing from market, purchase own equipment

However, to undertake scenario analysis, we cannot consider every possible change that may take place in the future. Instead, we need to identify the changes that are likely to happen, or could have the biggest impact on the organisation (i.e. the TBU). Also we need to consider the variables, parameters and factors that are most uncertain, or are most important to the organisation.

4.2 Forced scenarios

Having identified a range of uncertainties and factors that could have an impact on the TBU, the project team then developed the forced scenarios which are summarised in Table 4. The base case was taken as the 'surprise-free' scenario, and all the negative external parameter changes were 'dumped' into the 'pessimistic' scenario and all the positive external changes to the parameters were 'dumped' into the 'optimistic' scenario.

The 'surprise-free' scenario is the one based on the existing model parameters that TBU management expected would continue into the future (i.e. the 'business as usual' scenario). These forced scenarios then needed to be checked for internal consistency and some extra research was necessary to determine realistic boundary values for the parameters and graphical relationships, so that 'learning' scenarios could be developed.

Table 4. Forced scenarios for the TBU strategy case

	Forced scenarios		
	Major influence	Pessimistic	Optimistic
Market sector			
Industry price per job	External	-15%	+10%
Market growth rate	External	0%	+10%
Target market share	Internal	Decline to 20%	Increase to 30%
Price effect on market share	External	Deteriorate by 20%	Improve by 10%
Quality effect on market share	External	Deteriorate by 25%	Improve by 10%
Quality effect on price	External	Deteriorate by 20%	Improve by 10%
Operations sector			
Industry job completion time	External	-15%	+10%
Other delays	Both	+25%	-20%

We discussed these forced scenarios with TBU management and realised that there were some inconsistencies and some assumptions that were most unlikely to occur, or would affect the whole industry so the TBU would be no better off. This led to the development of the 'learning scenarios' against which the new redesigned policies and strategies could be tested.

4.3 Learning scenarios

A number of the combinations included under the positive and pessimistic scenarios were not logically consistent. For example, the assumption that costs would decrease by between 10 and 20%, while the market is growing at 10% p.a., is probably not consistent with economic logic. An increase in demand for the final product or service is likely to result in an increase in the demand for the factor inputs and cause costs to rise rather than fall, unless there are some other compensating changes.

Similarly, TBU management was of the opinion that it was unlikely there would be any significant changes in the tax rate over the next five years, and most of the costs were expected to remain at about the same level. Some of the ranges for the parameter changes shown in the forced scenarios were also considered rather extreme.

Finally we generated some 'learning scenarios' for testing our strategies for the TBU. These are summarised in Table 5. We considered three scenarios: base case (i.e. 'business as usual'); 'bleak outlook' (a combination of 'consistent' negative parameters in the external environment); and a 'rosy picture' scenario (based on a feasible combination of positive factors that could occur in the external environment).

Table 5. Learning scenarios for the TBU strategy case

External parameter or behavioural relationship	Base case scenario	'Bleak outlook' scenario	'Rosy picture' scenario
Industry price per job	$10 000	$9500	$10 300
Market growth rate	5% p.a.	2% p.a.	8% p.a.
Price effect on market share	1.5/1.25/1/0.6/0.1	1.2/1.1/1/0.4/0.05	1.6/1.3/1/0.7/0.2
Quality effect on market share	1.2/1.1/1/0.9/0.8	1.1/1.05/1/0.8/0.6	1.3/1.15/1/0.95/0.9
Quality effect on price	1.1/1.05/1/0.95/0.9	1.05/1.025/1/0.8/0.6	1.2/1.1/1/0.975/0.95
Industry job completion time	2.5 mths	2.2 mths	2.8 mths
Time in organisation[10] (mths)	60/48/36/20/0	45/36/27/15/0	75/60/45/25/0

We inputted each of these scenarios into the model using the control panel features of the *ithink* computer simulation software (eg see Figure 5), and tested each strategy against the scenarios. The results of some of these scenario tests are presented in Table 6.

Table 6. Selected results of the 'learning' scenario tests

Strategy	Base case scenario	'Bleak outlook' scenario	'Rosy picture' scenario
Relative job time ratio			
1 'Base case'	1.17	1.33	1.04
2 'Tightening up ops'	1.05	1.20	0.94
Relative price ratio			
1 'Base case'	0.98	0.87	1.00
2 'Tightening up ops'	0.99	0.92	1.01
Market share (%)			
1 'Base case'	23.7	22.1	23.8
2 'Tightening up ops'	24.1	23.1	24.2
Net present value ($m)			
1 'Base case'	1.12	0	2.35
2 'Tightening up ops'	1.53	0.30	2.87

5 Conclusions

This analysis indicates strategy 2 (tightening up operations) is robust, when the alternative plausible future scenarios are taken into consideration. Strategy 2 performs better than the base case strategy under each of the performance measures, i.e. lower relative job times; higher relative price ratio; greater market share; and higher net present value. Overall, strategy 2 would help TBU's management address the strategic issues that were outlined at the beginning of this case.

The system dynamics and scenario modelling approach outlined in this paper provided considerable insights and learning for the whole TBU project team, including the managers from the TBU and the strategy support staff from the head office holding company. In addition, the paper demonstrates the value of utilising Schoemaker's (1993, 1995) scenario construction process with system dynamics modelling.

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