Combining scenario planning and system dynamics: An application based study

Volume 1

Charles Featherston

A dissertation submitted for the degree of Doctor of Philosophy of The Australian National University

ANU College of Engineering and Computer Science
The Australian National University

October, 2013
Declaration

I certify that this dissertation does not incorporate any material that has been previously submitted for a degree or diploma at any university. To the best of my knowledge, no part therein has been previously published, or written by another person, except where due reference is made in the text. The work in this dissertation is my own, apart from contributions by colleagues as described in the Acknowledgements.

The following publications have been produced during the course of or as a result of this work:

Peer-reviewed conference papers


Conference papers
Featherston, Charles; Gregory, Mike; Gill, Andrew & O'Sullivan, Eoin (2012), High Value Manufacturing in the UK: A Study of its Challenges, Opportunities and Emerging Technologies, 11th Global Congress on Manufacturing and Management (GCMM 2012): Auckland University of Technology, Auckland, New Zealand.


Commissioned reports
Featherston, Charles & Doolan, Matthew (2011), L'Arche Scenario Analysis: The results of a scenario development project with L'Arche Genesaret ACT, a report commissioned by L'Arche Genesaret ACT.

Livesey, Finbarr; Frau, Ilaria; Oughton, Dominic & Featherston, Charles (2010), Future Scenarios for the UK Food & Drink Industry, A report to the Food and Drink Federation produced by the Institute for Manufacturing (IfM), University of Cambridge.

Papers currently being reviewed
Featherston, Charles & Doolan, Mathew (2013), Integrating Scenario Planning and System Dynamics: A Study.

Charles Featherston
For

My parents, Melissa and David, and my grandparents, Mary, Bob, Jo & John
Who taught me to value education and always supported my educational endeavours

And for

Jerome

‘Do the things you love’
Acknowledgements

First and foremost I would like to thank my primary supervisor Dr Matthew Doolan, his advice and constant encouragement was priceless for this dissertation to be completed. I would also like to thank Professor Michael Cardew-Hall who provided project oversight and always stayed focused on the big picture. My thanks also go to my other supervisors Marcelo Alves and Dr Finbarr Livesey for their guidance and nuggets of advice just when they were needed.

I would like to extend my gratitude also to the Institute of Manufacturing at the University of Cambridge. The Institute provided me with the latitude to complete two of the five studies in this dissertation and provided me with experience working and studying overseas during my candidature. I only hope that my contribution to the institute has been as much as it has been able to provide me. Particularly my thanks go to Professor Sir Mike Gregory, Dominic Oughton, Ilaria Frau-Hipps, Andrew Gill, and Jonathan Hughes.

I would also like to thank L’Arche Genesaret, ACT and the Australian National University’s System Dynamics Group and ANUEdge for their assistants in providing studies, people to participate in those studies, and resources to help run the studies. I would particularly like to thank Dominic Downie, Claire Lawler, James Sullivan, Tarlie Alcock, Valerie Spence, Alan Doolan, and the stakeholders who participated in the L’Arche study for their time and effort. Peter Stasinopoulos, Chris Browne, and the ANU’s System Dynamics Group were also of great assistance to this work.

I would like to thank my family and friends for their support throughout my candidature. My gratitude to my office for helping making going to university bearable and even a pleasure, these people being: Hamza, Chris, Peter, Eric, Jin, Oday, and, when present, the other Chris. I would like to thank Steph and Lauren for their emails and support; Anna for the lunches; Ash for the beers; and Luke and Ella for their warm hospitality and vital support on more occasions than I care to mention. Finally, my warmest gratitude to my family: my grandfather for his questions and provocation; my great-uncle Martin and great-aunt Eva for warm hospitality whenever I found myself in Cambridge, the fantastic home-brew, and revitalising discussions; Turo and my siblings – Ben, Josie, and Pippa – for their enduring support; and my grandmother and parents for their unwavering support throughout my education and provision of distractions when they were needed for sanity. Lastly, I will forever be in the debt of one person, Aleena, whose astounding endurance during this work was utterly unwavering and whose compassion is an inspiration.

Charles Featherston,
April 2013
Abstract

Informed policies and strategies (hereon policies) are important to any government or organisation. Information is used to inform policy development and make them more robust. Interventions can help identify and structure complex information and inform mental models to assist policy development. This work aims to explore if scenario planning and system dynamics, common interventions used to inform policy, can inform each other and produce more relevant and grounded results. In the past it has been demonstrated that these approaches separately benefit organisations. Together these approaches can inform each other’s output, helping to further inform mental models and structure complex information, potentially being interventions of greater benefit for organisations.

Scenario planning is an approach that collects and structures information to assist developing policies for the future. Scenario planning, however, has flaws that can lead to problems with the scenarios they develop and ineffective or even maladaptive policies. Such flaws include its subjective nature and dependence on informed mental models, for which the field provides little formal guidance to address.

System dynamics is an approach that aims to inform peoples’ mental models. It aims to uncover the endogenous causes behind the behaviour of a system. The approach employs techniques that encourage people to surface and question their mental models and formally tests them using mathematical models. System dynamics has flaws of its own: it is often misapplied, its goals and limitations miscommunicated, and its ability to address different systems questioned. This work aims to help scenario planning and system dynamics overcome their flaws by combining them in an applied approach.
Five studies were conducted to test if system dynamics could inform scenario planning and to test if the reverse was also true. The studies ranged from a predominantly scenario planning exercise with the Food and Drink Federation of the United Kingdom, which involved minimal systems mapping, to more complete integrations of the approaches applied to real situations.

The studies developed a workshop based scenario planning approach that executed a series of activities to generate scenarios. The studies demonstrated that preliminary system maps of the scenarios were often of little use for developing further using system dynamics and, according to participants, these maps assisted little with scenario development. The studies identified the need to educate participants about system dynamics and the need for a specific targeted problem for a system mapping exercise. The studies also exemplified how the two approaches can identify and provide novel information for the other. Mixed evidence was found regarding the mapping of systems observed in different scenarios and integrating these perspectives. These attempts to integrate the approaches also identified theoretical differences between the approaches, including system dynamics’ narrower scope (focus) and more specific view of causal relationships.

These studies highlighted how scenario planning and system dynamics can be used to inform each other. In practice, when executed effectively, the system mapping and system dynamics modelling helped surface and test peoples’ mental models, assisting scenario planning. Scenario planning, however, offered minimal assistance to system dynamics. The approaches offered each other mutual assistance, particularly with framing and preventing information filtering (exclusion), learning, communication, and with the mechanics of their execution. This work highlights the limitations and benefits of the integration of these approaches. With this understanding more work can now be conducted to take scenario planning and system
dynamics forward and develop them as co-informing and co-supporting structures of policies for governments and organisations, both for the present and the future.
## Contents

### Volume 1

**Chapter 1**  
Introduction ............................................................................................................. 1  
1.1  
Context for the research .......................................................................................... 2  
1.2  
Understanding the future by understanding the present ......................................... 4  
1.3  
This work .................................................................................................................. 6  
1.4  
Structure of this dissertation ..................................................................................... 6

**Chapter 2**  
A critical review of scenario planning ..................................................................... 9  
2.1  
Scenario planning ..................................................................................................... 9  
2.2  
Scenario planning, not strategic planning ................................................................. 15  
2.3  
Scenario planning (as scenario development) ............................................................ 19  
2.4  
Involvement ............................................................................................................... 35  
2.5  
Scenario interpretation and use ................................................................................ 37  
2.6  
Methodological techniques used to address the criticisms and implementation issues 41  
2.7  
Key conclusions ....................................................................................................... 46  
2.8  
This work .................................................................................................................. 47

**Chapter 3**  
A critical review of system dynamics ................................................................... 49  
3.1  
System dynamics ....................................................................................................... 49  
3.2  
Critiquing system dynamics ...................................................................................... 52  
3.3  
Applications of system dynamics ............................................................................ 53  
3.4  
Mimicry, validity, comparison & prediction ............................................................... 57  
3.5  
Complexity: Richness, reductionism, pluralism, and social systems ....................... 65  
3.6  
Determinism: Dehumanising, 'grand' theory, and austere ....................................... 73  
3.7  
Hierarchy ................................................................................................................... 76  
3.8  
Discussion .................................................................................................................. 78  
3.9  
This work and system dynamics .............................................................................. 82  
3.10  
Previous work with scenario planning and system dynamics .................................. 83  
3.11  
This work .................................................................................................................. 89

**Chapter 4**  
Method ....................................................................................................................... 91  
4.1  
Method of evaluation for thesis ............................................................................... 92
4.2 Scenario planning process.................................................................................................. 94
4.3 System dynamics approach............................................................................................... 111
4.4 Workshops: Data capture ................................................................................................. 120
4.5 Techniques ....................................................................................................................... 129
4.6 Method of process evaluation ......................................................................................... 131
4.7 Summary .......................................................................................................................... 135

Chapter 5  Future Scenarios for the Food and Drink Industry .................................................... 137
5.1 Key structure elements ........................................................................................................ 137
5.2 Context ............................................................................................................................... 138
5.3 Aim and premise ................................................................................................................ 139
5.4 Method, results, and observations .................................................................................... 142
5.5 Discussion .......................................................................................................................... 170
5.6 Chapter conclusions .......................................................................................................... 176

Chapter 6  High Value Manufacturing Study ......................................................................... 179
6.1 Key structure elements ........................................................................................................ 179
6.2 Context ............................................................................................................................... 179
6.3 Aim and premise ................................................................................................................ 181
6.4 Method and results ............................................................................................................. 183
6.5 Discussion .......................................................................................................................... 196
6.6 Chapter conclusions .......................................................................................................... 204

Chapter 7  China Futures Study ............................................................................................ 207
7.1 Key structure elements ........................................................................................................ 207
7.2 Context ............................................................................................................................... 208
7.3 Premise and aim .................................................................................................................. 209
7.4 Method and results ............................................................................................................. 212
7.5 Discussion .......................................................................................................................... 222
7.6 Chapter conclusions .......................................................................................................... 228

Chapter 8  The Grass-Rabbits-Foxes Study ............................................................................ 231
8.1 Key structure elements ........................................................................................................ 231
8.2 Context ............................................................................................................................... 232
8.3 Premise and aim .................................................................................................................. 232
8.4 Method summary ................................................................. 234
8.5 Method, results, and observations ..................................... 236
8.6 Discussion of methodology and theory .............................. 274
8.7 Chapter conclusions ............................................................ 283
Chapter 9 L’Arche Genesaret Study ........................................ 285
  9.1 Key structure elements .................................................... 285
  9.2 Context ........................................................................... 285
  9.3 Premise and aim ............................................................... 289
  9.4 Method summary ............................................................. 289
  9.5 Pre-workshops .................................................................. 292
  9.6 Workshop 1: Uncertainty identification ............................ 294
  9.7 Workshop 2: Scenario development .................................. 297
  9.8 Inter-workshop period: scenario narrative development .... 301
  9.9 Workshop 3: System dynamics .......................................... 304
  9.10 Inter-workshop period: Dynamic model development ....... 304
  9.11 Workshop 4: Scenario & Systems Analysis ..................... 312
  9.12 Dynamic modelling and taking a system dynamics approach 322
  9.13 System dynamics ............................................................. 324
  9.14 Study closeout ................................................................. 336
  9.15 Survey results ................................................................. 336
  9.16 Discussion ....................................................................... 344
  9.17 Chapter conclusions ......................................................... 354
Chapter 10 Discussion ............................................................... 359
  10.1 Major conclusions from the studies in brief ..................... 360
  10.2 Contrasting and comparing scenario planning and system dynamics 362
  10.3 Developing scenarios through system dynamics: an exclusion 372
  10.4 How system dynamics informed scenario planning .......... 373
  10.5 How scenario planning informed system dynamics ........... 380
  10.6 Mutual assistance ............................................................. 382
  10.7 Integration ....................................................................... 388
  10.8 A comment on methodology ............................................ 389
10.9 Limitations of the work ................................................................. 391

Chapter 11 Conclusion ........................................................................ 397
  11.1 Conclusions from the studies ...................................................... 398
  11.2 How the approaches informed one-another .............................. 402
  11.3 A note on integration ................................................................. 404
  11.4 A precautionary note about these results ................................. 406
  11.5 Future work ............................................................................. 407
  11.6 Preparing for change ................................................................. 409

References .......................................................................................... 411

Glossary ......................................................................................... 437

Volume 2

Appendix A......................................................................................... 449
Appendix B......................................................................................... 469
Appendix C......................................................................................... 505
Appendix D......................................................................................... 519
Appendix E......................................................................................... 531
Appendix F......................................................................................... 589
Appendix G......................................................................................... 615
Appendix H......................................................................................... 631
List of figures

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Figure 1-1</td>
<td>Simplified ‘steps’ in a scenario planning approach</td>
<td>7</td>
</tr>
<tr>
<td>Figure 1-2</td>
<td>Simplified ‘steps’ in a system dynamics approach</td>
<td>7</td>
</tr>
<tr>
<td>Figure 2-1</td>
<td>A reference diagram for scenario planning</td>
<td>10</td>
</tr>
<tr>
<td>Figure 2-2</td>
<td>Scenario planning as learning</td>
<td>18</td>
</tr>
<tr>
<td>Figure 2-3</td>
<td>Daft &amp; Weick’s (1984, p.286) learning process</td>
<td>31</td>
</tr>
<tr>
<td>Figure 3-1</td>
<td>A reference diagram for system dynamics</td>
<td>50</td>
</tr>
<tr>
<td>Figure 3-2</td>
<td>How Sterman (2000, p.88) depicts system dynamics in the decision making process</td>
<td>51</td>
</tr>
<tr>
<td>Figure 3-3</td>
<td>Hierarchy: Rules and relationships between constitutional order, institutions, organisations, and conventions (source: Boyer, 2001)</td>
<td>77</td>
</tr>
<tr>
<td>Figure 4-1</td>
<td>Simplified ‘steps’ in a scenario planning approach</td>
<td>94</td>
</tr>
<tr>
<td>Figure 4-2</td>
<td>Simplified ‘steps’ in a system dynamics approach</td>
<td>94</td>
</tr>
<tr>
<td>Figure 4-3</td>
<td>Simplified workshop activities of the 'benchmark' scenario planning approach</td>
<td>96</td>
</tr>
<tr>
<td>Figure 4-4</td>
<td>Identifying trends and drivers</td>
<td>100</td>
</tr>
<tr>
<td>Figure 4-5</td>
<td>Simplified activities of the 'benchmark' system dynamics approach</td>
<td>111</td>
</tr>
<tr>
<td>Figure 4-6</td>
<td>An influence diagram from the workshops</td>
<td>115</td>
</tr>
<tr>
<td>Figure 4-7</td>
<td>A stock and flow diagram from the workshops</td>
<td>116</td>
</tr>
<tr>
<td>Figure 4-8</td>
<td>The adapted system dynamics approach</td>
<td>120</td>
</tr>
<tr>
<td>Figure 4-9</td>
<td>Post-it protocol</td>
<td>125</td>
</tr>
<tr>
<td>Figure 5-1</td>
<td>An (over)simplified guide regarding which elements of the two approaches were adopted for this study and the order in which they were commenced</td>
<td>137</td>
</tr>
<tr>
<td>Figure 5-2</td>
<td>The basic approach adopted for the FDF study</td>
<td>142</td>
</tr>
<tr>
<td>Figure 5-3</td>
<td>The impact and uncertainty of the trends and drivers</td>
<td>149</td>
</tr>
<tr>
<td>Figure 5-4</td>
<td>Water stress</td>
<td>155</td>
</tr>
<tr>
<td>Figure 5-5</td>
<td>Social acceptability (of new technologies)</td>
<td>156</td>
</tr>
<tr>
<td>Figure 5-6</td>
<td>Level of adaptation to climate change</td>
<td>157</td>
</tr>
<tr>
<td>Figure 5-7</td>
<td>The Food and Drink Federation scenarios (Livesey et al., 2010)</td>
<td>160</td>
</tr>
<tr>
<td>Figure 5-8</td>
<td>The uncertainties in each scenario</td>
<td>162</td>
</tr>
<tr>
<td>Figure 5-9</td>
<td>The Food and Drink Federation scenarios (Livesey et al., 2010)</td>
<td>165</td>
</tr>
<tr>
<td>Figure 6-1</td>
<td>An (over)simplified guide regarding which elements of the two approaches were adopted for this study and the order in which they were commenced</td>
<td>179</td>
</tr>
<tr>
<td>Figure 6-2</td>
<td>The approach adopted for the HVM study</td>
<td>182</td>
</tr>
<tr>
<td>Figure 6-3</td>
<td>The HVM scenarios</td>
<td>188</td>
</tr>
<tr>
<td>Figure 6-4</td>
<td>The influences of using fewer materials</td>
<td>192</td>
</tr>
<tr>
<td>Figure 6-5</td>
<td>The influences of the manufacturing base of the UK</td>
<td>193</td>
</tr>
<tr>
<td>Figure 7-1</td>
<td>An (over)simplified guide regarding which elements of the two approaches were adopted for this study and the order in which they were commenced</td>
<td>207</td>
</tr>
<tr>
<td>Figure 7-2</td>
<td>The Four Futures for China Inc.</td>
<td>213</td>
</tr>
</tbody>
</table>
Figure 7-3: Emperor of Business ................................................................. 215
Figure 7-4: Emperor’s New Clothes .............................................................. 216
Figure 7-5: Emperor of Asia ................................................................. 217
Figure 7-6: Emperor of the World .............................................................. 219
Figure 8-1: An (over)simplified guide regarding which elements of the two approaches were adopted for this study and the order in which they were commenced .................. 231
Figure 8-2: The approach adopted for the Grass-Rabbits-Foxes study .............. 235
Figure 8-3: A causal loop diagram of the base Grass-Rabbit-Foxes model used in the study ......................................................... 238
Figure 8-4: The initial run of the Grass-Rabbits-Foxes base model .................. 240
Figure 8-5: The initial run of the Grass-Rabbits-Foxes base model (with the grass stock excluded from the graph only) .................................................................................................................. 240
Figure 8-6: The Grass-Rabbits-Foxes Scenarios ............................................. 246
Figure 8-7: The raw diagram drawn by the back-casters that depict the behaviour they observed occurring in Breeding like rabbits for the rabbit (top) and fox (bottom) populations .................................................................................................................. 248
Figure 8-8: The amount of grass and number of rabbits and foxes from the model-casters’ runs of Breeding like rabbits .............................................................................................................. 249
Figure 8-9: The number of rabbits and foxes from the model-casters’ runs of Breeding like rabbits .............................................................................................................. 249
Figure 8-10: Influence diagram for Breeding like rabbits .................................. 254
Figure 8-11: Influence diagram for Short and sour ......................................... 256
Figure 8-12: Integrated influence diagram of the Grass-rabbits-foxes scenarios .............................................................................................. 257
Figure 8-13: The additional structure to add to the base model from Breeding like rabbits ................................................................. 259
Figure 8-14: The additional structure to add to the base model from Short and sour .............................................................................................. 260
Figure 8-15: A causal loop diagram of the integrated dynamic model .............. 267
Figure 8-16: The amount of grass and the rabbit, fox, and bird populations ....... 268
Figure 8-17: The rabbit, fox, and bird populations .......................................... 268
Figure 8-18: Fractional death rate of foxes based on an infectious disease dynamic .............................................................................................. 269
Figure 8-19: Amount of grass and animal populations in Breeding like rabbits .............................................................................................. 270
Figure 8-20: Rabbit, fox, and bird populations in Breeding like rabbits ............ 270
Figure 8-21: Amount of grass and animal populations in a simulation of Short and sour ................................................................. 271
Figure 8-22: Rabbit, fox, and bird populations in a simulation of Short and sour .............................................................................................. 272
Figure 9-1: An (over)simplified guide regarding which elements of the two approaches were adopted for this study and the order in which they were commenced .................. 285
Figure 9-2: An overview of the method adopted for the L’Arche study .............. 291
Figure 9-3: L’Arche’s trends and drivers plotted on impact and uncertainty ........ 295
Figure 9-4: Participants discussing L’Arche’s trends and drivers ......................... 296
Figure 9-5: L’Arche’s scenarios ........................................................................ 299
Figure 9-6: Influence diagram from the scenario Creative sustainability ................ 306
Figure 9-7: Stock and flow diagram for the stock of L’Arche’s assistants ............ 313
<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>9-8</td>
<td>Stock and flow diagram for the stock of L'Arche's core members</td>
<td>314</td>
</tr>
<tr>
<td>9-9</td>
<td>Stock and flow diagram for the stock of L'Arche's funds</td>
<td>315</td>
</tr>
<tr>
<td>9-10</td>
<td>Shifts for the windtunnelling exercise</td>
<td>319</td>
</tr>
<tr>
<td>9-11</td>
<td>Participants in the windtunnelling exercise</td>
<td>320</td>
</tr>
<tr>
<td>9-12</td>
<td>The confidence model, a similar structure to the Bass model (Bass, 1969)</td>
<td>328</td>
</tr>
<tr>
<td>9-13</td>
<td>A diagram of how L'Arche builds and loses confidence in buying a new house</td>
<td>330</td>
</tr>
<tr>
<td>9-14</td>
<td>The model behaviour</td>
<td>333</td>
</tr>
<tr>
<td>10-1</td>
<td>The studies and the methods they followed as per the chapter guides</td>
<td>359</td>
</tr>
<tr>
<td>10-2</td>
<td>Base run of the Grass-Rabbits-Foxes model</td>
<td>368</td>
</tr>
<tr>
<td>10-3</td>
<td>The policy function, information filters and bounded rationality (Morecroft, 2007, p.210)</td>
<td>383</td>
</tr>
<tr>
<td>10-4</td>
<td>Daft &amp; Weick's (1984, p.286) learning process</td>
<td>385</td>
</tr>
</tbody>
</table>
Chapter 1  Introduction

‘There is nothing permanent except change’

Heraclitus

Informed policies and strategies are important to any government or organisation. The environments in which they operate are in constant flux. For them, change and reviewing their policies and strategies are a way of life. Their ability to adapt and change according to their environment often dictates whether they thrive, survive, or fail.

Turbulent environments make change and adaptation more necessary. Understanding the present environment can help inform policies and strategies. However, future events can render policies and strategies useless or even counterproductive.

In the past, major environmental perturbations have led the resurgence of work that explores the cause of these events. The oil crisis of the 1970’s and the credit crisis of 2008-2009 are examples of such events. They prepare the way for work that attempts to understand future trends that can create potential challenges and opportunities in the changing environment.

The desire for governments and organisations to understand the future has been consistently demonstrated. Governments continually try to identify the most appropriate ways to intervene and apply policy. The United Kingdom’s (UK’s) Technology Strategy Board (TSB, 2011), for example, focuses upon a policy and investment strategy that will make the UK more competitive in manufacturing in the future. Private firms also constantly explore strategic
options to gain a competitive advantage over other firms in their industry. Not-for-profit and non-government organisations also look for threats to achieving their goals and opportunities through which they might be achieved. Governments, private firms, and not-for-profit and non-government organisations (hereon collectively referred to as organisations, unless explicitly stated otherwise) all try to develop their understanding of the future in order to inform policies and strategies and prepare for change.

In response to the desire to understand the future, a number of techniques are used to explore and develop an understanding of what might occur. The drive for an understanding of the future underpins much research. Many texts have focused on ‘exploring the future’ in attempts to reveal the way the future may look. Improving these techniques can help organisations be more prepared for the future.

1.1 Context for the research

Policies and strategies (hereon policies) coordinate action and mobilise resources for common goals (Hanson et al., 2008). They assist organisations’ to realise their visions and goals. Without them, action can be aimless and resources can be mobilised with divergent, even counteracting, purposes and results.

Policies and strategies are developed in a context. While there may be no consensus about what policy and strategy actually are, there is little debate about the importance of considering the external environment in their generation (Porter, 1980; Porter, 1985; Mintzberg, 1994a; Grant 2002; Hanson et al., 2008; Hill, 2008). The external environment is the system in which an organisation operates. A system is a collection of things – people,
organisations, molecules, activities, concepts – that are interconnected in such a way to give rise to certain attributes and behaviours. A system can be influenced by external factors which may or may not influence the behaviour it exhibits. A car is a system; it is a set of interconnected mechanical, electrical and chemical components that gives rise to certain attributes and behaviours. In this case, the external environment is the system of economic, political, legal, socio-cultural, and technological conditions in which an organisation competes (Hanson et al., 2008). These factors must be considered when policies are developed.

However, policies that are developed are only sometimes realised. Some policies, or portions of them, are never implemented (Mintzberg, 1978; Mintzberg, 1987a; Mintzberg, 1994a). Furthermore, the changing external environment forces new policies to emerge; these are known as emergent policies (Mintzberg, 1978; Mintzberg, 1987a; Mintzberg, 1994a). The final realised policies can deviate considerably from the initial intention.

Complexity and randomness are two causes of the deviation between intended and emergent policies. Complexity impedes the ability to comprehend the system and understand it in its entirety. Randomness introduces new environmental and operational attributes that were not or could not have been considered, and is more prevalent than we think (Taleb, 2006). Policies and strategies could be improved if the future was known, but complexity and randomness mean that introduce elements that were not, or could not, be considered during their development.

Organisations, however, can be more informed about the future. Context, information of patterns and trends, and an understanding of decision making processes can all contribute to developing more effective policies. These elements constitute a greater understanding of the
current system in which the organisations exist. The current system has traits that partially
determine its future state. A greater understanding of the present system and how it might
change informs organisations about what might arise in the future. With this knowledge, more
informed policies can be developed and can give rise to smaller deviations between intended
and realised policies.

1.2 Understanding the future by understanding the present

Key to understanding the future is learning about present structures, what they are, and how
they might change. The process of learning can be encouraged by the adoption of approaches.
Forecasting, contingency planning and scenario planning are tools and approaches that are
used to explore the future. Forecasting focuses on extrapolating the current system to
understand what will occur in the future (Godet, 1987), but can be unreliable over medium
and long terms (Hogarth & Makridakis, 1981; Godet, 1987; Mintzberg, 1994a; 2000; van der
Heijden, 2005). Contingency planning ‘anticipates future events’ and generates ‘alternative
plans’ for them (Bloom & Menefee, 1994, p.227), but is often criticised for only working when
the instances calling for them arise often or consider events too specific to be useful in many
situations (Mintzberg, 2000). Scenario planning is a process of mapping and challenging mental
models through and for the purpose of exploring possible alternative futures (Wack, 1985a;
Schwartz, 1996; van der Heijden, 2005). Scenario planning is suited to the medium term
because of the way it considers uncertainty (van der Heijden, 2005). It also encourages
learning (van der Heijden, 2002; Burt & Chermack, 2008) and maps out a ‘space’ for the future,
rather than individual alternative futures. For these reasons scenario planning will be the focus
of this dissertation.
Scenario planning uses current trends and drivers to develop peoples’ understanding about what the future may hold. Linneman and Klein (1983) and Hodgkinson and his colleagues (1999) attest to the broad employment of scenario planning as an approach. This dissertation will focus on the particular form of scenario planning that is popular in the UK, the United States of America (USA), and Australia (an ‘Anglo-Saxon School’ if you will). This form of scenario planning uses people’s expertise, skill and understanding to develop coherent views of possible futures.

A scenario planning approach is founded on an understanding of today: their ‘world views’ or mental models. However, scenario planning is subjective and has no formal way of addressing people’s mental models. Without a formal method of mental model assessment, mental models could remain misinformed, decreasing the effectiveness of the process and hindering their ability to understand the future. System dynamics is an approach that is used to explore and inform people’s mental models. System dynamics is an approach that employs a set of techniques to surface, test and inform people’s mental models. System dynamics could be used to inform the scenario planning process by helping people to develop more informed views of today’s world.

The inverse however, can also be hypothesised: that scenario planning can inform system dynamics. Scenario planning assists to uncover new perspectives, which may provide new insight for a system dynamics approach. Furthermore, scenario planning considers a plurality of different views, which may also help system dynamics.
1.3 This work

Scenario planning and system dynamics both focus upon policy development. The aim of this work was to understand if system dynamics can inform scenario planning and if the reverse is also possible. This work explored the integration of these two approaches, its feasibility, mechanics, and benefits.

1.4 Structure of this dissertation

The dissertation begins with an exploration of the problems with scenario planning (Chapter 2) and system dynamics (Chapter 3), derived from the criticisms of the two approaches. To reduce the scale of the problem, standard benchmark approaches from the two fields’ literature were first established and the tools and methods adopted for their execution explored. These are discussed in Chapter 4. The dissertation then explores the testing of the benchmark scenario planning process in Chapter 5 and an alternative process in Chapter 6, both with small elements of system dynamics integrated into them. A novel integration of scenario planning and system dynamics is then discussed in Chapter 7 and more complete integrations of the approaches explored in Chapter 8 and Chapter 9. A number of possible variations of combining scenario planning and system dynamics based on the benchmark approaches were hypothesised and five of these were selected for further exploration (the description and reason for the selection of each study can be found at the beginning of each study’s chapter). Specifically, the project focused on the benefits of integration found in the applications of scenario planning and system dynamics and the different alternatives of their co-execution. These benefits are compared in Chapter 10 to the problems with the different approaches and the major conclusions and potential future work highlighted in Chapter 11.
To assist guidance through the thesis, a key will be used at the beginning of each of the study’s chapters (Chapter 5 to Chapter 9). The building blocks of the key are the simplified steps of a scenario planning (shown in Figure 1-1) and a system dynamics (shown in Figure 1-2) approach. The approach taken in each study is a different configuration of some or all of these steps. Blocks that are faded indicate steps that were intended, but not realised. A full set of the approaches taken is shown at the beginning of the discussion (Chapter 10).

Figure 1-1: Simplified ‘steps’ in a scenario planning approach

Figure 1-2: Simplified ‘steps’ in a system dynamics approach
Chapter 2  A critical review of scenario planning

2.1  Scenario planning

Scenario planning is an approach used widely in strategy and policy development (Linneman & Klein, 1983; Hodgkinson et al., 1999). Scenario planning is the process of gathering information about actors, events, trends and drivers, and synthesising this information to map out a series of feasible, possible futures at a particular point in the future (Schwartz, 1991; 1996; van der Heijden, 1997; 2005).

Often, one of the products of a scenario planning process is a set of scenarios, which are used to influence decision makers’ perceptions of the environment and how it might evolve (Wack, 1985b). Scenarios are 'coherent pictures of possible futures' (Mietzner & Reger, 2005). They describe the world, or a part of it, as a 'plausible story' (Raskin, 2005, p.134) of the future through a 'comprehensive, consistent narrative' (Cumming et al., 2005, p.144).

Scenario planning (and as will be discussed system dynamics) is an approach. It is a general perspective taken to deal with a situation or address a complex decision problem. It is a paradigm, which defines a set of concepts, beliefs, and language that are based on pre-established theories (Kuhn, 1996). Paradigms, different sets of concepts and theories, ‘cause their practitioners to define different problems, follow difference procedures, and use different criteria to evaluate their results’ (Meadows, 1980, p.24). Paradigms create the conceptual and theoretical backdrop for approaches. Processes or procedures are the sets of activities used to take and execute an approach. Processes or procedures, in the case of this
dissertation, are made up of activities that a person or people take to search for, extract, and collect information, motivate thinking and synthesis, and generate discussion.

Figure 2-1 shows a reference diagram for scenario planning. It outlines the inputs, common key activities, output and some of the desired impacts and consequences of engaging in scenario planning. It also shows the iterative, feedback nature of scenario planning. A more detailed description of a scenario planning process can be found in section 4.2. The rest of this chapter will focus on scenario planning as an approach, with some reference to specific procedures used in taking a scenario planning approach.

![Figure 2-1: A reference diagram for scenario planning](image-url)
2.1.1 The purpose and benefits of scenario planning

The cited benefits in literature and reasons for employment of scenario planning are numerous. From a strategic perspective it has been claimed that scenario planning fosters strategic thinking, learning, and the strategic conversation (Neilson & Wagner, 2000, p.10; van der Heijden, 1997; 2005), that it creates and accelerates organisational learning (de Geus, 1988; Postma & Liebl, 2005, p.165), and generates institutional knowledge (van der Heijden, 2005, p.135-6). It also assists strategy and policy development by providing a framework to comprehend, confront, and understand the implications of irreducible uncertainties (Wack, 1985a; 1985b; Schwartz, 1991; 1996; Schoemaker, 1995; van der Heijden, 1997; 2005; Cumming et al., 2005, p.144) and assists the process of strategy implementation (van der Heijden, 1997; 2005). Scenario planning also helps to assess the robustness of core competencies (Schoemaker, 1995, p.34) and helps to generate more robust strategic options (Schoemaker, 1995, p.34; Schoemaker & van der Heijden, 1992; van der Heijden, 1997; 2005). Finally it helps to evaluate options (in light of the scenarios generated) (Schoemaker, 1995, p.34) and reduce strategic paralysis by classifying predeterminants and uncertainties (Schoemaker, 1995, p.28).

From a leadership and change perspective, it has been expounded that scenario planning provides a guide for change and leadership for new initiatives (Bloom & Menefee, 1994, p.225; Neilson & Wagner, 2000, p.11). It also creates channels for communication and a rally point for discussion (Neilson & Wagner, 2000, p.11; Neilson & Wagner, 2000, p.11), frameworks to develop a shared vision, and influence behaviour (Neilson & Wagner, 2000, p.11) and builds consensus (Tenaglia & Noonan, 1992). It also creates a shared language for those involved (Schwartz, 1996, p.202-5).
Scenario planning has also been touted for its ability to assess assumptions and re-assess perceptions by providing understanding and clarifying perceptions and assumptions by making them explicit (surfacing), augmenting and simplifying understanding and information, and encouraging ‘reperception’ (Simpson, 1992, p.12; Schwartz, 1996, p.36-7; Fahey & Randell, 1998; Schoemaker, 1995, p.26; Senge, 1992). Scenario planning also helps people to understand how a variety of trends and drivers may integrate and combine to create a future setting (Bloom & Menefee, 1994, p.225) and understand what might happen (Phillips, 1996; Postma & Liebl, 2005, p.165). It challenges and dispels assumptions about the future by looking at both pessimistic and optimistic futures and maintaining an aggressive ‘can-do’ attitude while serving up unfavourable outlooks (Simpson, 1992, p.12; Neilson & Wagner, 2000, p.10). Finally, it helps to suspend disbelief about what might happen (Schwartz, 1996, p.193-7; Frittaion et al., 2010; 2011) and has been suggested as a way of overcoming overprediction and underprediction about what might occur in the future (Schwartz, 1996, p.193-7; Frittaion et al., 2010; 2011; Schoemaker, 1995, p.27).

These are not the only ways scenario planning can assist understanding. It has also been proposed as a ‘filter’ for relevant information to an organisation (van der Heijden, 2005, p.132-3) and as a way of simplifying huge amounts of data (Schoemaker, 1995, p.26). Postma and Liebl (2005, p.165) also point to its ability to integrate various types of future orientated data. The approach has been cited to integrate all this information and generate awareness (Bloom & Menefee, 1994, p.225) and augment understanding (Fahey & Randell, 1998). Schoemaker
A critical review of scenario planning

(1993) has also proposed that scenarios can help to overcome three biases: framing1, availability2, and anchoring3.

Scenario planning has also been advanced as a generator of new and unique ideas and fresh considerations and unique insights (Bloom & Menefee, 1994, p.225; Fahey & Randell, 1998; van der Heijden, 2005, p.147-9). It also helps to reframe existing decisions by broadening people’s perspectives and providing new perspectives and context (Fahey & Randell, 1998; van der Heijden, 2005, p.145-6; Schoemaker, 1995). It has also been suggested to increase the speed and rationality of decision making by anticipating future threats and facilitating the generation of options for decision making and contingencies (Simpson, 1992, p.12; Neilson & Wagner, 2000, p.10-1; Bloom & Menefee, 1994, p.225; Fahey & Randell, 1998).

Finally, as a foresight approach, scenario planning has been proposed as a method of creating ‘memories of the future’ (Schwartz, 1996, p.32-6; van der Heijden, 2005, p.149; Postma & Liebl, 2005) and training and assisting individuals and organisations to look for early warning signals about what might eventuate in the future (Schwartz, 1996, p.197-201; Schoemaker, 1995, p.34; van der Heijden, 2005, p.150).

2.1.2 Classifying scenarios and scenario planning

There are numerous classifications of scenarios and scenario planning. Schnaars (1987) broke scenarios into those that describe a possible future and those that describe the events that

1 Framing is the effect that the phrasing or conditions under which people are given some information influences the way they interpret it (Tversky & Kahneman, 1981; Schön & Rein, 1994; Bolman & Deal, 2003).
2 The availability heuristic is the tendency of people to judge the probability of an event by how readily memories come to mind (Tversky & Kahneman, 1973b).
3 Anchoring is the process of the result being defined by the starting point (see Tversky & Kahneman, 1974).
lead to a particular future. Scenarios have also been classified in other ways: Simpson (1992) and Neilson and Wagner (2000) define scenarios as optimistic and pessimistic, Inayatullah (1996) and Ratcliffe (2000a) believe that scenarios can follow a set of standard dimensions and Fahey and Randall (1998) categorise scenarios as global, industry, competitor, or technology orientated.

The numerous methods for generating scenarios (scenario planning) are also broken into several different categories (see for example Mietzner & Reger, 2005). Schnaars (1987) distinguishes between those that consider a number of key variables and uses intuition and synthesis to generate scenarios and those that consider vast number of factors and then use a number of different methods to constrain the number of scenarios generated. These groups are semi-analogous with the sometimes employed terms Anglo-Saxon School (pioneered by Herman Kahn while at the Research and Development – RAND – Corporation) and the French School of la prospective (pioneered by Gaston Berger and André Gros) respectively. Schnaars (1987) states that the problem with the first is that key factors may be missed and that the problem with the latter is that key combinations, and hence scenarios, may be missed. This chapter will focus on the first category of scenario planning.

There are several other classifications for scenario planning techniques (Bishop et al., 2007). Ratcliffe (2000), for example, offers two groups: future-forward planning and future-backward planning (also known as future mapping). Future-forward planning begins with a vision of the present and uses knowledge of the present to identify the evolution of events that might take place to define a particular future (Ratcliffe, 2000a). Future mapping is concerned with identifying a particular state in the future and then mapping the evolution of that future.

---

4 Chermack (2001) refrains from applying these names and breaks the first group into many different groups.
(Phillips, 1996; Ratcliffe, 2000a). Scenario planning, as it is generally accepted, is more recognisable with the first method: future-forward planning.

It is important that scenario planning, like any field of research, address its criticisms. Either by rebutting a criticism or redefining them in light of a well-founded criticism, theories become stronger, more robust and improve their chances of being accepted by a more general audience. Furthermore, its purpose and limitations can be made clearer to those who choose to use it. The rest of this chapter investigates the key criticisms that have been levelled at scenario planning. It explores how some of these criticisms are unfounded and looks at the work, if any, that has been done to deal with them. The chapter concludes by highlighting the key criticisms, and hence pertinent problems, with scenario planning and how they related to the dissertation.

2.2 Scenario planning, not strategic planning

A key criticism of scenario planning comes from its association with the troubled and mostly debunked field of strategic planning. Strategic planning is a set of planning tools that rose to prominence in firms in the 1970’s. Despite its prominence, troubles with the paradigm lead to a number of firms and academics abandoning it in the 1980’s and 1990’s (Wilson, 1994; Mintzberg, 2000). Studies reflected these troubles and one such study, carried out by Boyd (1991), had difficulty identifying a positive relationship between strategic planning and performance. Mintzberg (1990a; 1994a; 1994b; 2000) thoroughly outlines the failures of strategic planning and the reasons for its abandonment.
Scenario planning is commonly included as a tool of strategic planning (Mintzberg, 2000; Wilson, 1994). Wilson (1994) found that scenario planning was the second most used strategic planning technique in his survey of 50 firms, with 50% of firms using the approach and only 22% having little or no usage of the approach at all. Studies like these cause scenario planning to be grouped with strategic planning and thus that it carries similar issues. However, grouping scenario planning with strategic planning is not necessarily accurate. Wilson's (1994) assessment is that strategic planning evolved into strategic management and that during that evolution the approaches appropriate for strategic management, including scenario planning, were brought by firms through this transformation.

The movement away from strategic planning seems to have been a little more dislocated than Wilson (1994) proposes. Mintzberg (2000) outlines the changed role of planners and planning in a post-strategic planning firm to be somewhat different to their previous role. Furthermore, some of the techniques that Wilson (1994) identifies as transformational strategic planning, such as Porter's (1980; 1985) positioning work, are considered different schools of strategic thought all together (see Mintzberg, 1990a). This exemplifies the loose definition of what is considered strategic planning. Indeed in the literature, it appears that only Wilson (1994) considers it to be strategic planning. The only other reference to scenario planning found in strategic planning literature was Mintzberg (2000, p.250), who claims that in any case scenario planning is more about planners than planning.

How scenario planning differs from strategic planning depends on how one views its purpose. Strategic planning considers its external environment to be static and deterministic and therefore develops strategy and creates extensive plans and documentation detailing the action that should be taken in that environment. If scenario planning is used as a technique for
A critical review of scenario planning

prediction then it performs a similar function, creating the illusion of a static environment on the understanding of which strategy is developed. However, the aim of scenario planning is not to predict the future (Wack, 1985a; Morecroft & van der Heijden, 1992; Schoemaker, 1995; Morecroft, 2007). Rather, the aim of scenario planning is to ask questions about what is possible and to learn about the external environment (Othman, 2008; Schwartz, 1991; 1996; van der Heijden, 1997; 2005). These aims alter the perception of scenario planning, making it much more suitable to a non-deterministic environment. Where strategic planning, much like forecasting, gives answers, scenario planning is focused on asking questions and developing understanding (Othman, 2008; Schwartz, 1991; 1996; van der Heijden, 1997; 2005).

This link between strategic planning and forecasting is important when separating scenario planning from strategic planning. Forecasting and strategic planning are more about extrapolation than about detecting discontinuities (Mintzberg, 2000, p.237-8). In contrast, the emphasis in scenario planning is about suspending disbelief, gaining new perspectives on what is possible and attempting to detect discontinuities in the external environment to provide new insight into possible futures (Frittaion et al., 2010; 2011; Schwartz, 1991; 1996). Bean et al. (1992, p.73) emphasise this distinction by stating that scenarios are 'strategy tools, not forecasting tools'. These differences separate scenario planning from strategic planning and the general application of strategic planning criticisms to the approach. However, some individual criticisms can still be applied to strategic planning. They will be covered in various sections throughout this chapter.

Many of the criticisms of scenario planning can be understood using the conceptualisation of scenario planning and scenarios shown in Figure 2-2. The figure was built upon the idea of learning loops (Argyris & Schön, 1974; Argyris, 1976; Sterman, 2000, p.21; van der Heijden,
and demonstrates how information, perception, sensemaking and mental models are used to make decisions. The inner (solid) loop represents the present and short-term future. This loop shows how actions cause changes which affect information, which human perceive, make sense of retrospectively (retrospective sensemaking), and build into (or consolidate them in) their mental models, which are used to make decisions. The black arrows indicate the flow of the process and the dotted lines indicate the feedback, for example, revision in light of new information. This inner loop is a typical decision making cycle.

The blue arrows in Figure 2-2 initiate secondary loops and show the path that information selected for the development of scenarios follow. Scenarios can be focused on either the external environment or on the external environment and an ‘image’ of the organisation in the future (future self, the complete picture of which is not shown here). Abstractions – theories and concepts – that are used to develop scenarios may be consolidated in mental models or ‘loose’ abstract ideas not yet consolidated and coming directly from the ‘fuzzy’ sensemaking
phase. The ideas of future environment and future self (along with other organisational goals and strategies) are then compared for fit and a desirable future state selected. Decisions are then made to take action and create change to drive towards the desirable future.

The criticisms of scenario planning focus on two areas: scenario development (hereon scenario planning) and scenario interpretation. Scenario planning is the process of gathering and perceiving information, sensemaking, mental models and the ‘selection’ of information from mental models for the development of scenarios. Problems with information (for example Taleb, 2005; 2007) and perception (for example, Blake & Sekuler, 2006; Wack, 1985a) are well documented and apply to many different ‘foresight’ approaches, so they will be omitted here. The next sections describe and outline the criticisms involved in sensemaking, mental models, and information selection for scenario construction. Scenario interpretation is the engagement of decision makers with the scenarios produced. Dividing the two foci, scenario planning and scenario interpretation, is a brief review of involvement in the scenario planning process. The section after looks at the second focus: the interpretation of scenarios and how they are used. The final section explores the methodological techniques that are used to address the criticisms and implementation issues.

2.3 Scenario planning (as scenario development)

2.3.1 Sensemaking and mental models

Sensemaking is the process of interpreting ‘novel and ambiguous situations’ (Stigliani & Ravasi, 2012, p.1232; Weick, 1995). It is giving meaning to what is perceived and helps to define and group experiences (Weick, 1995). Sensemaking is more a process, like perception, rather than
Combining scenario planning and system dynamics

a form, like information or mental models. However, cognitive theory states that by sorting experiences based on similarities and differences, people form new mental models (Porac & Thomas, 1990). Sensemaking is the process of forming abstractions of the information gathered through perception and using these abstractions to construct mental models (for a pictorial representation see Figure 2-2).

Mental models and sensemaking are often discussed in parallel, with their issues strongly correlated, often due to a vague distinction between the two in literature. Mental models are abstract substitutions that people have for a real system (Forrester, 1961). Axelrod (1976) does not use the term, but implies that people mentally hold assertions about the world around them, a notion synonymous with mental models. Sterman (2000, p.16) stated that mental models ‘includes our beliefs about the networks of causes and effects that describe how a system operates’. Mental models are the consolidation of notions developed through sensemaking, structuring them into an often loose model of the perceived world.

However, mental models can often be misinformed, sometimes arising from incorrect inferences arising from the sensemaking process (Senge, 1992). These ‘problems’ make the use of mental models and sensemaking in developing scenarios questionable. One such problem with sensemaking is that it tends to be more about plausibility than accuracy; implying information (of events and structures) can be used to make a ‘plausible’ story rather than conceptualisations that are accurate (Weick, 1995). Taleb (2007) calls this the narrative fallacy – our ability to be seduced by stories that fit what we see, but may not necessarily be true. These ‘problems’ can lead to erroneous conclusions about current trends and drivers (a common starting point for scenario planning, see Chapter 4) and incorrect frameworks for scenarios. Furthermore, as discussed, one of the goals of scenario planning is to ‘push’ thinking
and make people consider options they had not considered previously (Bloom & Menefee, 1994; Fahey & Randell, 1998; van der Heijden, 2005). By looking for plausible ‘limits’ (or extremes, see Chapter 4) for the space scenarios map out, rather than accuracy, people could overlook significant possible future developments.

Dissidence with currently held mental models and a reluctance to assimilate new information (cognitive inertia) is another reason why they can be a faulty basis for the development of scenarios. People often resist new ideas and avoid assimilating them into their current mental models, this is known as cognitive inertia (Senge, 2006; Huff et al., 1992; Nickerson, 1998). This is the reason why many new ideas do not get implemented in firms (Senge, 2006).

Confirmation bias is a related problem. People tend to search for evidence that confirms their current thinking (Wason, 1960; Wason, 1966; Taleb, 2007). This tendency filters out information that can create robust mental models, making mental models less complete and informed.

Another issue with using mental models in scenario planning is their implicit and undefined nature (Senge, 1992; Meadows, 2008). Mental models are notoriously ‘slippery’, meaning the assumptions upon which they are based change constantly (Meadows, 2008, p.172). Without defining the models formally, these assumptions are free to change and move, which could be counter to the nature of the actual system they are supposed to represent. Senge (1992) believed that mental models are even more dangerous when we don’t know we have them. Furthermore, the vague nature of implicit mental models means that gaps could be difficult to identify.
Understanding of how sensemaking happens is limited (Stigliani & Ravasi, 2012), making it a problematic and questionable foundation for scenario planning. However, work is being done to understand sensemaking (for example see Stigliani & Ravasi, 2012). Given the group nature of scenario planning (for example as in Wack, 1985a; 1085b; Schwartz, 1991; 1996; van der Heijden, 1997; 2005), understanding group sensemaking and group mental models is also important. Stigliani and Ravasi (2012) studied how sensemaking occurred in groups and found that sensemaking is an individual cognitive exercise, in which people, who may be part of a group, individually make sense of experiences and then transfer that understanding to the group. Stigliani and Ravasi (2012) found that sensemaking is done individually and then transferred to the group. Although their work was in a design consulting firm, they believe that it applies to sensemaking more generally (Stigliani and Ravasi, 2012).

The dependence on sensegiving and mental models explains why the scenario planning process is vulnerable. The scenario planning process, as shown in Figure 2-2, depends heavily on sensemaking and mental models, despite these problems with them. People's knowledge, experience, inferences and mental models are mostly correct. Humans do this every day when using deduction to draw conclusions. However, as a system gets more complicated, people rely more on simplifications to understand the system because of cognitive limitations (Senge, 1992). They do not attend to all information available to them and incorporate it either because they cannot process it or they have not reduced it to a usable form (Braybrooke, 1964). The inability to process all the information is related to a series of issues, including cognitive inertia, but also cognitive limitations and time limitation (Simon, 1953). This is known in cognitive science as bounded rationality (Simon, 1953). It is scenario planning’s dependence on these faculties that threatens the validity of the scenarios it generates.
Scenario planning is an approach aimed at 'capturing decision-makers' mental models of how the future may unfold' (O'Brien, 2004, p.711). However, scenario planning alone offers no way to check if these mental models are correct. Scenarios may be and have been developed using knowledge and understanding that is scattered and anecdotal (Morecroft & van der Heijden, 1992, p.103). De Geus (1988) offers the opinion that scenario planning is about learning and using the learning process to audit the mental models. Schwartz (1991; 1996) and van der Heijden (1997; 2005) also support learning as a means of reviewing mental models. Schwartz (1991; 1996) outlined in detail where information can be acquired from to support this learning. However, there appears to be little that offers explicitly how this learning is to be achieved.

Senge (1992) offered some more explicit advice on how to inform mental models. Senge (1992) suggests surfacing and inquiry as means of testing mental models; notions that have been included in the activities in several scenario planning processes (see for example Wright & Cairns, 2011). Senge (1992) also advocated system thinking tools, such as system dynamics, but only discusses their feasibility in mental model development, rather than specifically in scenario planning.

The issues with sensemaking and mental models touch on several interrelated problems. Simon’s (1957; 1979) bounded rationality, Taleb’s (2005; 2007) black swan, Hume’s (T 1.3.4.1) problem of induction, and resistance to paradigm changes (Barber, 1961; Kuhn, 1996) all contribute to the discussion. Humans have limited information, cognitive capacity, and time (bounded rationality: Simon, 1957; 1979), fail to consider the exceptions or ‘wild’ events (Taleb, 2005; 2007), do not know when generalisations are appropriate or not (Hume, T 1.3.4.1; Taleb, 2007), and must always search to prove themselves wrong (Popper, 1966a;
1966b; 1974b). Given all this, how can they conceptualise understandings and give meaning and reasons to things? Popper (1966a; 1966b; 1974b) offers a solution: to conjecture and search for evidence proving the conjecture wrong, but always treating the conjectures as soft, malleable positions that are easy to reassess and discard. If the concepts and theories developed through sensemaking are treated in this way, then the caution required is in judgement, and the biases, effects, fallacies, and errors people are susceptible of when making them. These judgements form our assessments of information and the development from there of theories. This implies that sensemaking and mental models are only part of the issue.

### 2.3.2 Selection, decision making and judgement

Information needs to be selected for analysis both for sensemaking and from sensemaking and mental models for the scenarios themselves (see Figure 2-2). Braybrooke (1964) identifies that people only attend to some of the information available to them, possibly omitting vital information either because they cannot process it or they have not reduced it to a usable form. The issue of selection also arises because of people’s cognitive limitations. Only being able to process a certain amount of information (Simon, 1957; 1979) limits the amount of information that can go into developing scenarios, so the imperative exists that information must be selected to make sense of and to include in the scenarios. How do people know they have selected the ‘right’ information? Such an assessment is likely to only be made ex post.

With elements of sensemaking, mental models, and information selection, scenario planning is essentially a decision making exercise. Scenario planning is about problems that are ill defined, complex and have non-quantifiable factors, problems commonly known as wicked problems (Churchman, 1967). Essentially ‘what keeps... [people] up at night’ (Simpson, 1992, p.12). However, the scenario planning process itself is a series of smaller decisions that calls upon
A critical review of scenario planning

gathering information and making decisions about what to include and exclude from the process and the scenarios themselves.

As this step back is taken to view scenario planning as a series of decisions, some of the other problems with scenario planning become evident. In decisions making people make errors and succumb to fallacies, biases, and effects (for example see Tversky & Kahneman, 1974; Kahneman & Tversky, 1979; Tversky & Kahneman, 1983; Hogarth, 1987; Stanovich & West, 2000; Kahneman, 2011). However, once these flaws can be understood and their implications on scenario planning ascertained, some of them can be negated. In scenario planning, particularly the form focused on here, people who develop scenarios make a series of assessments, including what the trends and drivers are, their uncertainty, and which are important to focus on in the scenarios. These assessments require analysis, synthesis, learning, judgement, and intuition, which each have their own issues.

To understand the problems with scenario planning, a distinction will be used that is common in cognitive and behavioural science: Stanovich and West’s (2000) and Kahneman’s (2011) terminology of System 1 and System 2 cognitive processes. System 1 is a collection of automatic processes that operate immediately when a situation presents itself (see Kahneman, 2011). System 2 is the conscious thought stream that requires effort to mobilise (see Kahneman, 2011). A similar terminology warning to Kahneman’s (2011) must be made here. The use of the term system here does not allude to two different physiological systems within the brain or different hemispheres. Rather, they refer to two different processes of thinking. To consider them as different physiological systems is a ‘red herring that can only impede our understanding’ (Simon, 1987, p.89).
**Intuition**

Intuition is a set of skills that people have built up through exposure and experience that assists in recognising and reacting to a situation without conscious thought or reasoning (Khatri, 2000; Simon, 1987). Intuition is built up by experts in areas who have had training, exposure, or both to a particular field. These experts begin to develop the ability to recognise patterns and recommend responses without conscious thought. Intuition research has been conducted in cognitive and behavioural science, decision making, the realm of creative arts, and artificial intelligence (Simon, 1987). Intuition is part of what is known as System 1 – the automatic thinking that occurs in people when faces with new stimuli (Kahneman, 2011). It is important to note that this intuition is only part of the story (there is also system 2 – the deliberately engaged calculative and more effortful thinking that people engaging in), but it is the focus in this section.

When making decisions in the scenario planning process, people’s first inclination will be from System 1. They use System 1 to imply and infer what the important elements of the system of the problem they are focusing on are and how they behave. Intuition plays a valuable role in scenario planning, just as it does in Mintzberg’s (1994a; 2000) emergent school of strategy development. Analysing and modelling all aspects of an environment is impossible, so it is necessary to rely on the heuristics and cue-sensemaking that people have built up over years of experience. Furthermore, Frittaion et al. (2011, p.427) cite that people often focus on areas of their expertise – a sort of relevance or recency effect (see Steiner & Rain, 1989; Heneman & Wexley, 1983) – when developing scenarios, areas they are more likely to have develop intuition in. Input from intuition is not a completely flawed approach: indeed our intuition, a component of System 1 activities, is right most of the time (Kahneman, 2011).
However, reliance on intuition is problematic. Intuition can be incorrect; it can be ‘false’ intuition and it also prey to illusions. ‘False’ intuition is when people use intuition that is not properly informed or developed (Kahneman, 2011). Furthermore, people do not often realise that it is not properly informed or developed (Kahneman, 2011). Kahneman & Klein (2009) identify two requirements for the development of intuition: a stable environment and an opportunity to learn about the regularities of that stable environment. When these two conditions are met, people can, through feedback, develop the skills required to observe, recognise and react to a situation appropriately (Kahneman & Klein, 2009; Kahneman, 2011).

However, Hogarth’s (1987) term ‘wicked environments’ describes situations where the environment is irregular and people do not have simple means by which they can observe cause and effect and form structured theories of them. Instead people observe behaviour that results from of an amalgamation of many different causes, making resulting inferences tenuous. Such ‘wicked environments’ often accompany, and are causes of, wicked problems (Hogarth, 1987). Wicked environments make intuition difficult to develop. Furthermore, Kahneman and Klein (2009) hold one principle: ‘the confidence that people have in their intuitions is not a reliable guide to their validity’ (Kahneman, 2011, p.240). That is, that people do not know how developed their intuition is and how far it reaches. Overconfidence and ‘surprise’ when experts make up their minds before they realise it are evidence of this unawareness (Kahneman, 2011). It is important to know when intuition can be relied on and when it should not be trusted.

System 1 can also be ‘fooled’ by cognitive illusions, just as people’s eye (and brain) can be fooled by optical ones. A classic psychology example is the bat and ball problem, put simply as:

‘A bat and ball cost $1.10
The bat costs one dollar more than the ball.’
Combining scenario planning and system dynamics

How much does the ball cost?’

Kahneman, 2011, p. 44

The first number that typically comes to mind it 10 cents, but when this is reviewed it is realised that this is incorrect. The review process is the task of System 2; checking the responses of System 1 is done by engaging System 2 (Kahneman, 2011). Rationality has been termed as the tendency to engage System 2 to ‘check’ the responses of System 1. However, System 2 is effortful to deploy and is ‘lazy’, so people tend not to engage it (Kahneman, 2011). These illusions have the potential to be present in scenario planning. If people use intuition and do not use System 2 – some means of ‘calculating’ or reasoning for it, the incorrect conclusions drawn can be used in the scenario planning process.

Other cognitive influences: biases, effects, fallacies and errors
Cognition is also affected by many biases, effects, fallacies, and errors (for example see Tversky & Kahneman, 1974; Kahneman & Tversky, 1979; Tversky & Kahneman, 1983; Hogarth, 1987; Stanovich & West, 2000; Kahneman, 2011). An example of such a bias it the confirmation bias discussed earlier (see Wason, 1960; Wason, 1966; Wason & Shapiro, 1971; Huff et al., 1992; Nickerson, 1998), where people tend to search for evidence to support theories rather than to disprove them. By defining the group so broadly, cognitive illusions are closely linked to biases, effects, fallacies, and errors.

Overcoming cognitive flaws
Given the role of decision making and judgement in scenario planning, it is important that these cognitive flaws be overcome for effective scenarios to be developed. Understanding the limitations of one’s own intuition is an obvious conclusion, but how this can be achieved appears to be difficult. Perhaps encouraging more rationality and mobilising System 2 to check
the responses from System 1 is a more accessible solution. Some techniques of scenario planning aim to do this (see Section 2.6). Framing is another potential solution. Some modus ponens, such as those used in Wason’s selection task (see Wason, 1966), have been shown to be answered correctly more often when posed differently, for example cheating in social exchanges (Cosmides, 1989; Cosmides & Tooby, 1989; Cosmides & Tooby, 1992). In the same sense, perhaps Gigerenzer et al.’s (for example see Gigerenzer et al., 19995; Gigerenzer & Selten, 20016) approach to heuristics could help to develop techniques that frame the problems in a more ‘traditional’ sense so the responses they receive can be more accurate. However, the issue remains. Biases are difficult to overcome (Fischhoff, 1977) and methods of doing so are often unintuitive (Slovic & Fischhoff, 1977) and scenario planning, as a process, remains exposed to these flaws.

It has been demonstrated that scenario planning does assist overcoming some of these biases. For example, it has been shown that scenario planning can reduce the overconfidence bias (Schoemaker, 1993) and framing bias (Meissner & Wulf, 20137). However, neither study provided concrete ways to ensure this happens, only that it occurred. Furthermore, it does not address scenario planning’s exposure to these biases in the first place. Bradfield (2008) outlines several potentially flawed cognitive activities, including primacy, anchoring, and ignoring information that did not fit with participants’ current mental model of the world, that occurred during a (synthetic) scenario planning process.

---

5 This book is a compilation of papers written by Gigerenzer and his colleagues at the Center for Adaptive Behavior and Cognition
6 This book is a compilation book with various articles supporting this view.
7 This was published after the date of submission, but was pertinent enough that it was included while making the final changes to the dissertation.
2.3.3 Subjectivity

When distilled, the mode of the criticism is scenario planning’s subjective nature and its resulting susceptibility to the flaws of human cognition. A key characteristic of scenario planning is its heavy reliance upon people’s knowledge, experience, inferences, and mental models. If any of these are wrong then the scenarios generated will be fundamentally flawed. However, inversely, if they are all adequate in a group, then it is more likely that novel and informing scenarios will be created. In this instance and in this sense of the term subjectivity, scenario planning’s subjectivity could be a benefit. Such subjectivity allows the inclusion of other information in the process that may be overlooked by formal processes.

However, without a means of testing the knowledge, experience, inferences, and mental models people use to generate scenarios, the subjectivity of scenario planning becomes its key problem (Wulf et al., 2010). This is supported by the fact that scenarios can often be unrealistic and inaccurate (Bloom & Menefee, 1994, p.230). Some authors, such as Schnaars (1987), believe scenario planning has a more anecdotal rather than scientific nature. Subjectivity, used in this sense, refers also to its lack of formal testing or reviewing of the knowledge, experience, inferences, and mental models used to generate scenarios. Subjectivity and its exposure to cognitive flaws also feature in the way information is combined to formulate scenarios. These can be similarly offset by formally testing and reviewing the knowledge, experience, inferences, and mental models used to generate scenarios. Other methods, such as the more structured techniques employed by la prospective attempt to remove some of this subjectivity (see, for example, Godet, 2000a; 2000b), but many of these still appear unemployed in the Anglo-Saxon world.
2.3.4 Scenario planning as learning

Scenario planning is not just about scenarios; an important part, often cited as the most important element of scenario planning, is learning (Wack, 1985a; 1985b; Schwartz, 1992; 1996; Schoemaker, 1993; van der Heijden, 2005). Learning and sensemaking can be seen with respect to one another, through Daft and Weick’s (1984, p.286) learning model (Figure 2-3). In this figure, sensemaking can be seen as what Daft and Weick (1984, p.286) call interpretation. This interpretation gives rise to new understanding. Learning is then taking action that reflects this understanding (Argyris, 1976; Argyris & Schön, 1976). This fits with Argyris’ (1976, p.365) definition of learning: ‘the detection and correction of errors, and error as any feature of knowledge or of knowing that makes action ineffective’.

This makes the notion of ‘scenarios as learning’ a broad brushstroke. The essential element of scenario planning is about providing the ability to detect Argyris’ (1976, p.365) ‘errors’ and then take action, rather than just about learning. This definition of scenario planning places just as much emphasis on sensemaking (as a process) and mental models (as foundational structures) as it does on learning (as action).

2.3.5 Sensegiving

So far in the discussion, there has been a link in the chain observed in Figure 2-2 that has been overlooked: sensegiving, which is particularly pertinent if the scenario developers are not decision makers. Sensegiving is the process of giving someone else meaning that has been
formed through sensemaking. Sensegiving is an important step in team sensemaking and building team mental models: sensemaking occurs on the individual level and then conceptualisations are ‘given’ to others to begin the generation of common understandings (Stigliani & Ravasi, 2012).

Sensegiving is also the major role of scenarios. As Wack (1985a, p.84) said the goal is to:

‘design scenarios so that managers [or whoever the scenarios are for] would question their own model of reality [mental models] and change it when necessary, so as to come up with strategic insights beyond their minds’ previous reach’.

Wack, 1985a, p.84

The goal of scenarios is to deliver information and concepts to decision makers, who then process it using their own sensemaking and inform their mental models.

2.3.6 Theoretical foundations

A criticism of scenario planning is that it was born out of practice and as a consequence has little theoretical grounding (Chermack, 2004; Chermack, 2011). The application focus taken by many of the major sources of scenario planning, many citing Shell as a prime example, appear to support this view (see Wack, 1985a; 1985b; Schwartz, 1992; 1996; Morecroft & van der Heijden, 1992; van der Heijden, 2005; Schwarz, 2008). This focus does appear to emphasis the application of scenario planning rather than focusing on its theoretical development.

Chermack (2004, p.16) states that:
‘Many established authors in the scenario planning literature imply that theory is important in the application of scenario planning (Wack 1985c, Schwartz 1991, van der Heijden 1997, Ringland 1998; 2002) however, these claims are rarely clarified’

Chermack, 2004, p.16

However, the origins of scenario planning were in research orientated organisations. Those with an early role in the development of scenario planning include the Research and Development Corporation (RAND Corporation), the Hudson Institute, and the Stanford Research Institute (SRI) (Ringland; 2006). Herman Kahn, while working at RAND Corporation and then the Hudson Institute, published several seminal works using scenarios and was responsible for coining the term (Kahn, 1960; 1968; 1976; Kahn & Weiner, 1967). Many of these organisations were focusing on applied research, making the ‘line’ between research and practise somewhat unclear and the division between theory and application fruitless.

Theory, however, does appear to be lacking. Publications discussing the application of scenario planning are more prominent than those analysing theory. Chermack (2004) addresses this by exploring scenario planning through complex systems theory and Morgan and Hunt (2002) have drawn on cybernetics theory to place some theoretical foundations under scenario planning. These few examples offer only some framework to scenario planning. Chermack (2004, p.16) offers 'learning theory, cognitive development theory, decision theory, ... and performance improvement theory' as possible areas that could also be used, but work in these areas still needs to be done. Furthermore, a lack of an evaluation method makes comparable work exploring the impact of theoretical progress untenable.
Combining scenario planning and system dynamics

Suspending disbelief and the unlikely elements of scenarios

The suspension of disbelief is another area that demonstrates a shortage of theoretical understanding in scenario planning. The suspension of disbelief is important for developing scenarios (Schwartz, 1991; van der Heijden, 2005; Frittaion et al., 2011). Scenarios often contain surprises that people did not see coming, just like the future. People who build and people who are given scenarios both need to suspend disbelief as it helps them to accept the information offered and aids in influencing their perceptions of the future (Schwartz, 1991; van der Heijden, 2005; Frittaion et al., 2011).

Work into the suspension of disbelief and the requirements for it is being done, but the scenario planning shows little understanding of the conditions that assist participants to suspend disbelief, except for the quality of the scenarios themselves. Frittaion et al. (2011), for example, identify eight barriers to suspending disbelief⁸. However, more pertinent from Frittaion et al.’s (2011) study was their exploration of participants’ reactions to unlikely elements of scenarios. In this situation, Frittaion et al. (2011) were unable to explain why some participants tended to ignore unlikely elements of scenarios and others suspended disbelief and accepted them, demonstrating still further gaps in scenario planning research. The lack of understanding in this important aspect of scenario planning is problematic and exemplifies an area where theory is still needed in scenario planning.

---

⁸ Frittaion et al.’s (2011) eight barriers to suspending disbelief included: participants’ experience; the resulting scenarios’ contradiction to desired scenarios or scenarios participants are mentally prepared for; how likely individual participants perceived the attributes of each scenario; the level of preparation for working with the scenarios; the quality of the introduction to the workshops; the credibility and reputability of those who made the scenarios; the time with the scenarios; and the tendency of the groups participants are in to suspend disbelief.
2.3.7 Developing scenario planning: no single process and its inaccessibility

Arising from the application approach of scenario planning is the inclination of scenario planning researchers to go into ‘practise’, rather than to stay in research organisations and openly publishing findings. By going into ‘practise’, developments in scenario planning are only slowly released publicly, leading the field to grow more slowly and reducing the number of peer-reviewed publications than would otherwise be the case. Furthermore, with many different ‘scenario planning practises’ there is also no agreement in the field over the process (Chermack et al., 2001; Wulf et al., 2010, p.12), which leads to confusion about the field (Millett, 2003).

A key problem with scenario planning is that only a few people completely understand it (Chermack et al., 2001). Possibly caused by the slow flow of information from practise and low level of theoretical development, it creates a ‘club’ of people capable in scenario planning. This is compounded by the number of different scenario planning processes, making the field even more complex. The complexity of understanding scenario planning, perpetuated by the field’s ‘practise’ orientation is highlighted by van der Heijden’s (2005) name for one of his chapters, The Practitioner’s Art, which alludes to the difficulty of becoming adept in scenario planning.

2.4 Involvement

Using scenarios for sensegiving highlights the issues with involvement in scenario planning. If decision makers are not involved in the process, they will only have the scenarios from which to inform their mental models. Wack (1985b) saw this interface as the most neglected element of scenario planning. If decision makers are involved in the process then they are able to go through the team sensemaking and mental model building process as the scenarios are
developed, and have a richer context for the scenarios and exposure to the information that was used to form them. Greater involvement in the process also means decision makers have a greater role in the ‘strategic conversation’ (van der Heijden, 2005) and that their mental models are better understood, which helps the aim of trying to influence them (Wack, 1985a). Whether they should be involved is a question of resources: if the decision maker has time, whether the problem is significant enough and whether the scenarios are otherwise likely to be able to transfer the information effectively.

2.4.1 Resource intensity

A drawback of scenario planning can be resource intensity. The process of scenario planning can consume large amounts of time, money and other resources (Bloom & Menefee, 1994, p.229; Chermack et al., 2001; Millett, 2003; Wulf et al., 2010, p.5), which can affect its adoption rate in organisations. For example, it took a specialist team in Royal Dutch/ Shell several months to develop scenarios that were relevant, helpful, and accepted by managers (Wack, 1985a; 1985b). However, the approach’s resource intensity varies depending on the methods used to develop scenarios. A scenario planning approach can be designed with activities that utilise resources more efficiently, which reduces its resource intensity absolutely (rather than relatively to other planning and management processes and ‘tools’). For example, experts can be employed in activities that require information from their relevant area, rather than using them in areas unrelated to their expertise. Such developments would help increase its adoption in organisations. Furthermore, with a lower rate of investment, organisations would be more likely to reiterate through a scenario development process, which is important in scenario planning (Wack, 1985a; van der Heijden, 2005).
2.5  Scenario interpretation and use

2.5.1  Lack of evaluation method

Another problem with scenario planning is that it lacks a process of evaluation (Chermack et al., 2001). Chermack et al. (2001) identified this as the most critical aspect to the development of scenario planning as a field. Scenario planning is designed to inform decision making about possible future modes and help decision-makers deal with uncertainty (Wack, 1985a; 1985b; Schwartz, 1991; 1996; van der Heijden, 1997; 2005). However, without a method of evaluation, the impact that scenario planning has on decision-makers or decision making is unknown. Furthermore, without a method of evaluation, alternative methods and techniques cannot be tested for their impact on the scenario planning process. An extensive search of the literature has found that there are still no formal methods of establishing the impact scenario planning has on decision-makers or decision making.

Observation often forms the method by which scenario planning is assessed. Wack (1985a; 1985b), for example, made the observation that the scenarios developed by Shell had begun to shift the thinking of executives before the 1972 oil crisis hit. While these qualitative observations are valuable, a formal evaluation method defines common criteria to which scenario planning processes can be compared and assessed relative to one another, an element of scenario planning that still needs to be addressed.

Assessing scenarios

Despite there being no method of evaluation for scenario planning, the literature provides numerous ideas of what scenarios should be. Chermack et al. (2001, p. 27) compiled Schwartz’s (1991) and van der Heijden’s (1997) criteria for the properties a scenario should
exhibit and came up with five traits: scenarios should be simple, evocative, plausible, relevant, and have a short name. Miesing and Van Ness (2007, p.149) believe scenario should be internally consistent, relevant, recognisable, reasonable, and that they should be novel and challenge decision makers’ norms. Bloom and Menefee (1994) also state that scenarios should be credible, complete, realistic, probable, unique, and useful and productive. Finally, O’Brien (2004, p.720) suggested that scenarios should capture a number of different uncertainties, challenge assumptions, and influence a user’s understanding by capturing their imagination (for a more comprehensive list of scenario traits see Appendix A). Decision makers could be used to assess scenarios on these traits.

2.5.2 Implementation issues

Along with the theoretical issues with scenario planning, and sometimes inextricably intertwined with them, are a number of ‘implementation’ issues. This section will only focus on selection of those issues, namely: focusing on the scenarios rather than the process, the requirement of reputability, credibility and trust from scenario developers, and the understanding required to develop the scenario ‘narrative’.

*Emphasis on scenarios rather than the process*
An issue with the development of scenarios is the focus of decision-makers on the final product. One such problem with this focus is the inclination to choose a desired scenario. This often occurs because people chose a scenario that they think is most like a ‘business-as-usual’ future (van der Heijden, 2005). This can lead to developing strategies within just the one scenario, failing to consider the effect or consequences of those strategies in other scenarios, detracting from the strength of scenario planning over forecasting (a situation where the quantitative rigour of forecasting could make it a more appropriate option).
Another problem with a focus on the scenarios is that some of the benefits of the process, discussed earlier, can be lost. This point is heavily related to the involvement criticism previously discussed. If decision makers only focus on the scenarios then they miss the rich, contextual conversation that occurs in the scenario planning process and miss out on exploring the trends and drivers and surfacing novel views and perspectives. By focusing on the final scenarios, decision-makers not involved in the development process rely on all this information being captured in the final scenarios. Furthermore, these decision-makers miss out on the team-building and consensus-building that goes on in the development process.

This view, that scenario planning involves not only the final scenarios, but also the benefits of the development process is shared by other fields. In system dynamics, the process has been cited as more important than the static models that the methodology produces (Forrester, 1985).

Trust, Reputability, and Credibility

Trust is required in a scenario planning process (Selin, 2006; Frittaion et al., 2011, p.429). Scenarios are not always generated by those who use them and in many scenario exercises a 'core' group generates the scenarios for a larger or different group to analyse them (for example Wack, 1985a; 1985b; Frittaion et al., 2011). It is important that these 'users' of the scenarios see this core group as reputable and credible. If the core team is not reputable or credible to the 'users' then trust is not generated. Without trust, participants find it more difficult to suspend disbelief, which is an important component of a scenario planning process (Frittaion et al., 2011).
The notion of trust, reputability, and credibility can also be extended to the deliverers of scenarios, not just their developers. It is important that receivers of scenarios believe those delivering them are also reputable, credible, and trustworthy for the scenarios to be accepted (Frittaion et al., 2011).

Scenario planning literature however, has little to say about reputability, credibility, and trust in scenario planning. The reasons for and implications of little or no trust between scenario developers and decision-makers is anecdotal rather than grounded in academia. Furthermore, the literature has little to say about how to develop these important traits in a scenario planning exercise. Authors have proposed a range of techniques to try to build reputability, credibility, and trust into their processes, such as involving people with relevant domain experience in scenario development. However, because of the shortage of evaluation processes, the effectiveness of these techniques can only be given anecdotally.

*The (Illusive) Narrative*

Narratives or plots are often used in scenario planning to convey the future situations outlined by each scenario (Schwartz, 1991; Frittaion et al., 2010). These narratives help to encourage the inclusion of topics or elements of the future not usually present in the strategic or policy discussions, they help to reflect the complex dimensions future scenarios have and create images which help scenario users to visualise future alternatives and assist participants to suspend disbelief (Frittaion et al., 2010, p.1159). The way in which these narratives are written can have a role in determining how effective scenarios can be.

However, little research appears to have been done into what is required in these narratives to help them achieve their desired aims. There are many accounts of what a scenario narrative
A critical review of scenario planning

should include (see Schwartz, 1991; Merwe, 2008; Allan, 2001; Denning, 2006; Mietzner & Reger, 2005), but little on how and why these particular aspects have an impact.

What a narrative requires is one such area where work is needed. Denning (2006) outlines many of the pitfalls of narratives, but there is little evidence in literature of how to avoid these. A quote from a participant in Frittaion et al.’s (2010, p.1160) study believes that they were not telling them the whole story of the future so that the participants would piece it together. The question of how much detail is required in the narratives for optimal results appears to have thus far not been researched.

2.6 Methodological techniques used to address the criticisms and implementation issues

2.6.1 Teams, team composition and the role of facilitators

Team composition and facilitators are two methods used to navigate the threats of political interests and agenda control in the scenario planning process. By selecting a cross-section of people, political interests can be off-set and facilitators can act to reduce political activity and agenda control in teams.

The use of facilitators has its own issues. While facilitators in theory act as objective parties in the process, they can drive scenario development in a particular direction. This can be unbeknown to the facilitator themselves and could be driven by an interest to see results from the exercise. Either way, driving the process can detract from the conversation that occurs during the development of scenarios.
2.6.2 Appropriate skills, experience and knowledge

Commonly cited solutions for the subjectivity issue in scenario planning is to choose people for scenario development exercises that have the appropriate knowledge and experience and assume that these experts have appropriately developed inferences and mental models of their area of expertise (Schwartz, 1996; van der Heijden, 2005). However, it has been shown in many situations that even experts can have misinformed mental models (see, for example, Schwartz, 1996, who discusses his experience with an expert panel on drugs in the USA). There have been numerous examples of misinformed mental models, as has been shown many times in the field of system dynamics (see for example Sosna et al., 2010).

The scope of scenario planning exercises can be very broad; demanding knowledge of areas such as macro-economic, political and scientific developments. As people’s experiences are limited to the situations to which they have been exposed, bounded rationality says that the shortage of information can impact on people’s optimal decision making capacities (see Simon, 1953; 1957). To cover the broad range of issues, a number of people can be involved in the exercise. This has interesting consequences which are discussed in the next section.

2.6.3 Varied expertise & perspectives

Another technique employed to abate some of the above criticisms is to use a group of people with varied expertise in the relevant space in which the desired scenarios are to be developed. Indeed, part of the scenario planning process is for individuals to bring together and share ‘data and beliefs about the environmental assumptions’ (Miesing & Van Ness, 2007, p.149). Groups have been used in many instances, including in Royal Dutch/Shell’s scenario planning work (Wack, 1985a; 1985b; de Geus, 1988), in the development of scenarios for the Forest Sector in Canada (Frittaion et al., 2010; 2011), and with several of GBNs scenario planning
projects (Schwartz, 1996; van der Heijden, 2005). Using a group in the scenario planning process assists scenario development in a variety of ways. It encourages discussion so people air their assumptions and they can be sense-checked by others, important contributions to sensemaking (Stigliani & Ravasi, 2012), and informing mental models (Senge, 2012). Secondly, it increases the experience and information that will be drawn on to develop the scenarios (Schwartz, 1996), helping to somewhat overcome individual bounded rationality. Frittaion et al. (2011, p.426) provides an example where this was the case:

"For example, many Aboriginal participants focused on scenario aspects directly relating to Aboriginal people, whereas many participants from the forestry industry focused on aspects relating to the industry. Bringing these perspectives together led to some participants being able to see the bigger picture"

Frittaion et al., 2011, p.426

However, an unusual dynamic arises between these two benefits. Firstly, to ‘test’ and sense-check people’s assumptions and understanding of a situation, people need to have experience in similar areas, albeit from different perspectives. However, the more people you have experienced in similar areas, the more limited the breadth of areas will be covered by the group, limiting the second benefit. Therefore, a scenario planning team will have to settle with one of the following:

1. Lack of breadth of experience – perhaps fine in scenarios with a limited scope, but limiting the scope too much can be problematic;
2. Lack of diverse perspectives – the group has little way to check individual experts’ views and assumptions; and
3. Some compromise between these two
In these group situations trust is very important for the group solution to be effective. Trust in a group gives rise to open communication and a cooperative environment (Vennix, 1996). However, issues of group dynamics, such as politics and fear of reprisal, work against the benefits of using groups (Vennix, 1996).

To take full advantage of the range of expertise and perspectives in a group, facilitators and group members have to be aware of the pitfalls of working in groups. Group members can be intimidated (Frittaion et al., 2011, p.426). Furthermore, Frittaion et al. (2011, p.426) states that '[t]he discussion among participants with a range of perspectives, experience, and expertise in the groups both encouraged and discouraged broadened thinking and suspension of disbelief.' Understanding what can be used to avoid the pitfalls and capitalise on the diversity of these groups is subject to much literature (for example, see Steiner, 1972; Kanter, 1988; Karau & Williams, 1993; Watson et al., 1993; Cronin & Weingart, 2007). This literature needs to be drawn out in scenario planning literature in order to assist scenario planning facilitators and participants of scenario planning activities to capitalise on the diversity present in the activities. While the information may be out there, facilitators and participants alike do not have the time to research at length into this topic, and can conceivably go into a scenario planning process with little idea of how to capitalise on group diversity in scenario planning activities.

2.6.4 Accuracy and internal consistency

Another solution offered by scenario developers is to use various techniques throughout the scenario development process to ensure the scenarios developed are accurate. An example of such a test is Cumming et al.’s (2005, p.150) internal consistency checking of scenarios - that it should be 'ensure[d] that the details of each scenario are consistent with reality'. However,
these techniques do not comprehensively check the decisions made during the development process and the assumptions made in the scenarios developed. Furthermore, these techniques can be poorly executed or infrequently used. Finally, there is little work on how internal consistency can be checked, despite many expounding its importance, and as such offer limited help dealing with the subjectivity of scenario development.

2.6.5 Using actors and stakeholders to assess scenarios

There is a possibility in scenario planning to use stakeholders and those involved in the scenario planning process to assess the scenarios. Frittaion et al. (2011) for example, use participants to evaluate the plausibility of scenarios. However, as discussed, there appears to be little work in scenario planning on its evaluation (Chermack et al., 2001).

At the simplest level, as discussed in Chapter 4, scenarios themselves can be assessed. The scenario planning literature suggests many traits that scenarios themselves should have (see Appendix A). Scenarios can be assessed based on their degree of attainment of these traits. However, this only tests the product of scenario planning and risks placing too much emphasis on it, rather than the process.

Drawing on other literature can assist with assessing the process. Platts (1993) draws on action science and the collection of direct and participant observations to assess a process. By iterating through process and measurement more appropriate approaches in content, method, and process can be designed. Furthermore, the area of complex decision problems and problem structuring methods offer many traits that a process addressing problems should have (see Appendix A). Since scenario planning focuses on issues that ‘keep up at night’, some
of the problems it addresses can be similar to those addressed in this literature. The assessment of scenario planning against some of these traits is also a method of quasi-assessment. This will be discussed further in Chapter 4.

2.7 Key conclusions

There are many problematic areas of scenario planning. First among all of these is its subjectivity. The role people play in scenario planning by using sensemaking, their mental models, and judgement can lead to a flawed process and misleading scenarios. Many other criticisms have also been made of scenario planning, including its resource intensity, lack of evaluation procedure, lack of theoretical continuity, and the field’s ‘club’ like nature, partly caused by much of its research occurring in private enterprises.

Many methodological issues have been suggested by literature to attempt to remedy some of these criticisms. Groups have been used to gather appropriate information and moderate each other’s perceptions and mental models (Schwartz, 1996; McShane & Travaglione, 2005), but groupthink can still prevail (Senge, 1992). Internal consistency is touted as a way of ‘checking’ scenarios, but few practical methods of achieving this have been adduced.

To address these criticisms more work is needed to theoretically ground scenario planning and provide practical approaches for its application (Chermack, 2004; Chermack, 2011). If scenario planning is indeed as widely employed in organisations as scholars propose, then Schnaars’ (1987, p.107) claims that ‘the applications of scenario analysis far outnumber the investigations of the approach itself’ is still pertinent. When combined with the extent of its use, the urgency in which this shortcoming must be addressed becomes apparent.
2.8 This work

This work aims to explore whether system dynamics can be used to address these criticisms. This chapter has helped to develop an understanding of scenario planning, its limitations and its pitfalls. This work will employ system dynamics to understand if and how it can be used to address these criticisms. Before this can be done a similar investigation of system dynamics, its limitations, and its criticisms must also be done. This will be addressed in the next chapter.
Chapter 3  A critical review of system dynamics

There are many approaches, tools, and techniques that could be used to help improve scenario planning and avoid some of its pitfalls. System dynamics is one such tool. System dynamics aims to formally identify the structure of a system and the internal reasons for its behaviour. In doing so system dynamics tests and informs people’s mental models of the system, which could possibly assist scenario planning.

This chapter will begin by defining what system dynamics is and what it aims to achieve. In the six sections after it will review some major criticisms of the paradigm and cover some of the work that has been done to address these (Section 3.2 to Section 3.7). These will then be brought out in a discussion (Section 3.8) and related to this work (Section 3.9). The chapter will then outline work that has previously been done in areas shared by the approaches or previous preliminary work done combining them (Section 3.10). The chapter will conclude by covering the aim of this work (Section 3.11).

3.1 System dynamics

System dynamics is a 'means of inquiring into the behaviour of part of the world in order to understand it and hence indicate ways of improving its performance' (Keys, 1990, p.480). The paradigm is one of many fields that can be used to try to understand the complex nature of the systems in which we work. System dynamics has roots and relationships with a number of diverse fields, including: systems thinking, servo-mechanism theory, dynamical systems theory, cognitive science, and history (Richardson, 1991; Sterman, 2000; Meadows, 2008; Newell, 2012).
Combining scenario planning and system dynamics

Figure 3-1 shows a reference diagram for system dynamics. It outlines the inputs, common activities that are executed during a system dynamics intervention, possible outputs and some of the desired impacts and consequences of engaging in a system dynamics approach. It also shows the iteration involved and the feedback of information that occurs in the approach. A more detailed description of a system dynamics process can be found in section 4.3. The rest of this chapter will focus on system dynamics as an approach.

A central focus of system dynamics is to inform decision making processes and mental models (Sterman, 2000; Meadows, 2008). Figure 3-2 shows Sterman’s (2000, p.88) interpretation of how system dynamics fits into the decision making process. System dynamics uses information
from the real world, mental models, and information about current strategies, structures, and decision rules to inform mental models and decisions. Some of the similarities between system dynamics and scenario planning are evident when Figure 3-2 is compared with Figure 2-2 from the previous chapter.

![Diagram](image)

**Figure 3-2:** How Sterman (2000, p.88) depicts system dynamics in the decision making process

System dynamics was chosen because one of its goals is to explore a system and test people’s mental models of that system (Sterman, 2000; Meadows, 2008). The dependence of scenario planning on mental models means that these mental models must be properly informed; a goal system dynamics endeavours to achieve. There are also several other areas where system dynamics could assist scenario planning, including reducing some of its subjectivity (by reducing its reliance on intuition, overcoming cognitive flaws, and its exposure to biases, effects, fallacies, and errors) and by providing possible grounds for testing scenarios developed in a rigorous manner.

---

9 Sterman (2000, p.88) gives more detail (a process) for the central element, *System dynamics*. For more on this see Chapter 4.
3.2 Critiquing system dynamics

Before an exploration of the integration of the two approaches can be conducted, a critique of system dynamics will be conducted. As with scenario planning, it is important that the field of system dynamics address its criticisms to understand, and help others to understand, its limitations, to strengthen the field, and improve its general acceptance. This chapter’s main contribution to the dissertation, and to the field of system dynamics, is to bring many of these criticisms together and use the literature and an understanding of the paradigm to address them, identify which are valid, and identify those that remain unaddressed. By understanding the possible problems with system dynamics, the approach can be applied appropriately with an understanding of its aims, limitations, and areas where it could possibly be ineffective.

Of particular interest in this chapter are criticisms of the fundamentals of the system dynamics paradigm and not specific criticisms of technique, specific content theories of system dynamics, or how these criticisms apply to other approaches often used instead of system dynamics. For example, Rouwette et al. (2011, p.1) claim there is 'no clear evidence for the effectiveness of group model building, and a conceptual model linking elements of the modeling process to goals is missing'. This is a flaw in a technique used in system dynamics, not of the whole paradigm itself and as such possible 'gaps' like this will not be included in the analysis. The latter exclusion, that of other approaches, could prove a valuable extension to the body of systems research, but is omitted from this chapter.

The next five sections of this chapter will review five ‘groups’ of criticisms that have been levelled at the field of system dynamics and explore the field with respect to these criticisms. It will evaluate their validity and the measures that have been taken by academics and
practitioners within the field to address the criticisms (as did Featherston & Doolan, 2012). These five ‘groups’ are listed below.

1. Applications of system dynamics
2. Mimicry of historical data and validation
3. Complexity
4. Determinism
5. Hierarchy

3.3 Applications of system dynamics

One of the more prolific categories of criticisms of system dynamics is how the approach is applied, rather than of the paradigm itself. These criticisms of the application of system dynamics come from people from within as well as outside the field. These criticisms range from system dynamics being applied to the wrong situation to criticisms of particular models’ complexity, layout and size (Forrester, 2007; Barlas, 2007).

It can be difficult to find published examples of poor applications of system dynamics. This is generally for two reasons. Firstly, many are not published. With the peer review process in many journals, poor applications of system dynamics, like poor journal articles, are rejected. The second reason is that for a model to be bad, someone analysing the model must know the system well and either analyse the proposed model to find its flaws or be able to prove how the assumptions or relationships within the model are fallacious.
3.3.1 Reasons for drawing criticisms

There are four main reasons for these modellers drawing criticisms, many of which are covered by Forrester (2007) and Barlas (2007). Firstly, many of the examples of system dynamics that generate criticism are because system dynamics was applied to the wrong 'type' of problem (Forrester, 2007; Barlas, 2007). System dynamics is designed to explore 'problematic behaviour patterns caused primarily by the feedback structure of the setting' (Barlas, 2007, p.470). Often however, system dynamics is applied to problems where exogenous influences drive the system. In the words of Barlas (2007, p.470) 'many so-called SD [system dynamics] modeling projects are about problems that simply do not have SD [system dynamics] characteristics.'

Secondly, some modellers just apply system dynamics incorrectly. System dynamics provides a set of tools and techniques to apply to the appropriate problems (as outlined above). However, some modellers misuse and mismanage the tools of system dynamics. Forrester (2007) and Barlas (2007) cite the cause of this being the inherent difficulty of learning and applying the concepts of system dynamics. A claim supported by Cronin et al. (2009) and Sterman (2010) and their work with the understanding of the fundamental system dynamics concept of accumulation. Forrester (2007) and Barlas (2007, p.469) also cite 'no formal/clear accountability for poor modeling' as a possible cause of inexperienced modellers publishing models that apply system dynamics incorrectly and flout many of the paradigm’s rules and limitations.

Some people also have a different concept of what system dynamics is. As a group of theories and techniques, system dynamics can be seen as just a name applied to techniques and a process used to produce models. As a consequence, a modeller can call a process system
dynamics in a situation where others would not agree. Equally, someone observing a model can call the process used to get there system dynamics, even if it was not employed by the modeller. An example of this is Hayden's (2006) criticism of a model by Boyer (2001) that purports to define system dynamics' views on constitutional order, institutions, organisations and conventions. Radzicki & Tauheed (2007), question whether Boyer even proposed the model reflected the view system dynamics took to these facets of a system or even if it reflected anything of system dynamics at all.

Finally, the tendency to build unnecessarily large models to address 'big' problems is another aspect of modelling that draws criticism (Forrester, 2007; Barlas, 2007). Barlas (2007, p.470) explores several reasons why large models is an issue, stating that large models 'are not only difficult to build, they are also nearly impossible to understand, test, and evaluate critically'.

Both inexperienced and experienced modellers draw criticisms for their applications of system dynamics. Many instances where system dynamics has been applied poorly are done by practitioners with little system dynamics experience or those that are learning; we, for instance, have several examples that belong to that group. These tend to be of poor quality and Barlas (2007, p.469) notes that there are 'too many system dynamics models - published or applied - that do not meet our minimum standards of quality'.

However, some more experienced modellers also draw criticisms for their applications. Solow (1972), Marxsen (2003) and Simon (1981), for example, criticise Meadows et al.'s (1972) results published in the book Limits To Growth (also see Schmandt, 2010). Many of the criticisms of Meadows et al. (1972) were aimed at the different assumptions about the real world, some of which were clarified in the subsequent updates of the study (Meadows et al.,
2004; Meadows et al., 1992). Others, such as Simon (1981), had fundamental differences in assumptions, which lead to the study drawing his criticism.

Other criticisms, founded as they may be, do not apply to system dynamics because they miss some of the basic theories and limitations of the methodology. For example, criticisms of models’ inability to perfectly simulate reality miss the point that models are often simplifications of reality used to understand behaviour modes. As Meadows et al. (1972, p.21) wrote “The model we have constructed is, like every other model, imperfect, oversimplified, and unfinished.” These simplified and often unfinished works are therefore difficult to compare to historical data, a point discussed at greater length in the next group of criticisms.

### 3.3.2 Regressing the problem and its implications

To regress the problem of why there are poor applications of system dynamics only brings us to some well understood ideas within the field. The reasons for system dynamics being applied poorly and for people to fall victim to the reasons mentioned above are few, succinct, and commonly known: the phenomena that system dynamics tries to explain are counterintuitive and training is needed for people to master the field (Forrester, 1961; 1971b; Cornin & Gonzalez, 2007; Cronin et al., 2009; Sterman, 2010). However, there is one more aspect that this research does not appear to cover: they demonstrate a poor understanding of the field of system dynamics.

This analysis draws us to two points. Firstly, that there are examples of and many reasons for poor applications of system dynamics, some of which quite rightly draw criticisms and some that should. As will be discussed, these reasons are mostly about misunderstanding the
A critical review of system dynamics

purpose or system dynamics and how it is applied. Secondly, that there are misplaced criticisms on models that meet high quality standards in the field of system dynamics. These problems were the cause for Forrester's (2007) call for greater (more & better) systems education in schools and universities and for greater promotion of system dynamics in the public sphere.

Note will also be made here of a criticism put forward by Hayden (2006, p.534) that to my understanding has not been addressed in other literature. Hayden criticises the generality and unclear terminology used in system dynamics and its models. Further education of people outside of the field of system dynamics in the terms used in the paradigm could help to address this. Criticisms in this area help to illustrate how important further promotion and education in system dynamics is for the paradigm.

3.4 Mimicry, validity, comparison & prediction

The inabilities of models to mimic reality and predict the future are common criticisms levelled at system dynamics (Solow, 1972; Simon, 1981; Keys, 1990; Hayden, 2006). Meadows et al.'s (1972) Limits to Growth provides an example of this. Many critics, such as Simon (1981) and Solow (1972), picked up on attributes of the model that lead them to believe the model did not reflect reality, disenchanting them towards the entire model and the conclusions that were drawn from it. What was lost, however, was that the basic dynamics of the model still appear correct today, regardless of its inability to reflect exact points in historical time or to reflect the material wealth of the world today (Meadows et al., 2004). Furthermore, if reflecting history is not necessarily a requirement of the field, then how do people know if the model is an accurate explanation for the underlying behaviour? This reflects a group of damaging criticisms that have been levelled at the system dynamics paradigm: models not mimicking reality,
comparisons of models and reality, model verification, and the dependence of the paradigm on data.

3.4.1 Mimicry

Many criticisms of system dynamics are aimed at the inability of the paradigm's models to mimic reality (Solow, 1972; Simon, 1981; Keys, 1990; Hayden, 2006). However, it is relatively widely accepted within the field of system dynamics that models are not designed to and cannot perfectly imitate the real world (Sterman, 2000; Forrester, 2003; Lane, 2000). As such, to get a model that reflects the actual system perfectly is not the goal of system dynamics.

Instead, the goal of modelling in system dynamics is to assist people to understand the internal systemic structure of a system that drives behaviour (Forrester, 1961; Senge, 1990; Sterman, 2000). Forrester (1985) and Radzicki and Tauheed (2007) even propose that the process of generating the model and learning about the system could even be of more benefit than the model itself. Their justification is that the process of modelling promotes greater learning about the internal causes and effects of systemic structure than the model on its own would.

Criticisms of system dynamics’ tendency not to mimic reality appear to come from one of two areas. Firstly, from the point of view that system dynamics is a 'hard' systems thinking perspective (Keys, 1990). Hard systems thinking approaches, such as systems engineering and systems analysis, tend to operate in environments of low complexity and high problem visibility. As a consequence they are designed to mimic historical data very closely. System dynamics, however, is applied in situations of high complexity (with varying degrees of problem visibility), making it stand out as a field that 'doesn't work' because models are often
unable to mimic historical data. Another possible reason for its apparent separation from other 'hard' systems methodologies is that because of its endogenous focus it often does not exhibit the behaviour caused by external shocks without the cause for the shock being explicitly included in the system.

The second reason arises from poor understandings of the goal of system dynamics: not to mimic or mirror the real world but to use models to understand why certain behaviour is occurring (Forrester, 2007; Radzicki & Tauheed, 2007). This again arises from system dynamics not being understood more widely. System dynamics is one of many fields that attempts to make sense of a complex environment. It does not propose to uncover all there is to know about a system and like the other techniques it has its own goals, limitations, and expected outcomes.

3.4.2 Model verification and confidence building

Despite much of the learning coming from the modelling process rather than 'the' model, models are still an important part of communicating conclusions and testing their 'validity'. A model itself however, cannot be tested for validity. In fact, the idea of verifying a model is fallacious (Sterman, 2000). As Sterman (2000) points out, 'no model can be verified. Why? Because all models are wrong... all models, mental or formal, are limited, simplified representations of the real world'.

Many researchers believe that building confidence in models is the central method of verifying a model (Radzicki & Tauheed, 2007; Sterman, 2000; Forrester & Senge, 1980). Confidence building in system dynamics is a method of verifying a model 'along multiple dimensions'
(Radzicki & Tauheed, 2007). Sterman (2000) points out that Popperian philosophy tells us while we can’t establish if a model is correct, we can establish that a model is false. We can then alter the model to form a modelling version of an auxiliary hypothesis which we can then test. By subjecting models to a series of tests we can slowly build confidence in it: the more tests it passes the more confidence we have that the model reflects the correct behaviour. Peterson (1975, Appendix B) provides thirty-five informal tests that models can be subjected to build confidence. Similarly, Sterman (2000) provides ten such tests. However, testing a model against historical data is still important for some modellers. For some, consultants in particular, comparing a model to historical data is the most important test of the model (Homer, 1997). For others, comparing the model to historical data is still considered (just) one of the tests for building confidence (Sharp & Price, 1984; Sterman, 2000). One of Sterman’s (2000) ten tests is the Behaviour Reproduction Test, which compares the model's numerical behaviour to past data (while at one point qualitative behavioural testing is proposed, Sterman does not discuss this point any further). However, Sterman (2000) does state that fitting the data does not mean validation and that the Behaviour Reproduction Test’s purpose is to uncover flaws and structural issues with the model.

Sterman’s (2000) focus on historical data (a decent portion of the section dedicated to model testing) seems to differ somewhat with some other system dynamicists. Forrester (2003, p.5) claims that ‘the dynamical character of past behaviour is very important, but the specific values at exact points in historical time are not’. Barlas (2007) supports this by purporting that ‘proper measures of historical fit would stress fitting past dynamical patterns, such as periods, amplitudes and trends’ (p.471). Keys (1990, p.488), after some discussion concludes that, ‘model validity should be assessed relative to the purpose and not to a universal measure of
A critical review of system dynamics

correctness'. All of these appear to contrast with Sterman's (2000) *Behaviour Reproduction Test*, which mostly espouses 'fit'. Even when there is only a variation in the bias equation ($U^M$) of Theil's Inequality Statistic Sterman (2000, p.876) still claims a systematic error should be 'corrected by parameter adjustment'.

The disagreement over the role of historical data in model validation makes Forrester's (2001) claim that more work needs to be done in the field to establish methods of model validity still pertinent. Ultimately, Keys’ (1990, p.488) claim that models 'should be assessed relative to the purpose' is appropriate. It also seems generally accepted in the field that comparing a model to historical data is one of the least powerful methods for building confidence in the model (Forrester & Senge, 1980; Saeed, 1992; Radzicki, 2004; Radzicki & Tauheed, 2007). However, there must be a use for historical data in building confidence in a model that is supposed to emulate it.

Perhaps one of the more significant and overlooked tests is the qualitative assessment and comparison of a model’s behaviour with historical data. As stated earlier, Sterman (2000) recommends qualitative comparison, but does not draw out the point any further. Peterson (1975, Appendix B) offers several tests that use historical data, but only qualitatively compares the relevant behaviours (although some could progress towards quantitative measures, Peterson does not explicitly include this extension in his test). Qualitative tests such as these could be used to address Forrester's (2001) and Barlas' (2007) assessments of model data with general patterns of behaviour.

Some of the criticisms, mostly originating from the 'hard' systems thinking approaches, claim that system dynamics generates models that have trouble matching historical data (Keys,
As has been shown, researchers in the field still disagree about the role of historical data in building confidence in a model. Many researchers appear to agree that matching historical data exactly is not the aim of system dynamics, but this seems to be a source of much criticism. It seems researchers in the field need to ensure their critics are better informed about the theories they espouse.

3.4.3 Prediction and prophecy: Determinism

When grouping system dynamics with other 'hard' systems thinking techniques, a common accusation of the field is its determinism and the accompanying tenet that it can predict or prophesise the future (Ansoff & Slevin, 1968; Sharp & Price, 1984; Jackson, 1991; Lane, 2000; Forrester, 2001). Many people disagree with this proposed capability; indeed it makes many others feel uncomfortable (Lane, 2000).

The complexity in the argument comes from the partial adherence of system dynamics to 'hard' system methodologies. Determinism is often considered a characteristic of 'hard' systems thinking approaches (Checkland, 1978; Lane, 2000). For situations with low uncertainty and relatively low complexity, hard methodologies, such as cybernetics, have been employed to mathematically model the system to predict behaviour. As system dynamics adopts some of the characteristics of 'hard' systems thinking, many see this as also taking a deterministic view of the world. Many however, believe that system dynamics cannot be as deterministic as other 'hard' approaches because of the complexity of the systems it attempts to deal with. As Hayden (2006, p.539) states, 'Social systems are much too open, irregular, and dynamic for a mechanistic theory to apply' (this statement contains a variety of criticisms which will be decomposed gradually throughout the chapter).
Forrester (1968) and Coyle (1986) counter determinism by arguing that system dynamics is concerned with the structure of the system under examination and the structural reasons for the broad behaviour of the system. These observations in isolation exclude the use of system dynamics models to observe the implications of actions on systems, for example, in the Beer Game. This would encourage only setting a model in action and seeing where it tended to find equilibrium and not using it to test pulses or shocks to the system.

Perhaps Lane's (2000) invocation of Popper's (1957; 1966a; 1966b) view of determinism is more appropriate: 'prophecy is sharply distinct from that of 'technological/scientific prediction'' (p.7). Popper (1957; 1966a; 1966b) defines technological/scientific (here on technological) prediction as being conditionally dependent on the assumptions; if one of the assumptions changes then the prediction becomes invalid. From a system dynamics perspective, models and any of their predications have similar limitations. Lane (2000) even draws attention to early writing in system dynamics, (such as Forrester, 1961) to demonstrate that a deterministic view was never really espoused by the field. Perhaps such a description may not even apply to many of the so-called 'hard' systems thinking approaches.

Forrester's (1968) and Coyle's (1986) views are not necessarily divergent to Popper’s (1957; 1966a; 1966b) and Lane's (2000). Understanding the system is one of the main goals of system dynamics, key to Forrester’s (1968) and Coyle’s (1986) counterarguments. It is beyond understanding the current structure and cause of behaviour and into technological prediction, where the dynamic aspect of assumptions and conclusions are more uncertain, when Popper’s (1966a; 1966b; 1957) and Lane's (2000) counterarguments becomes important.

---

10 The Beer Game was developed at MIT as a supply chain game that exemplified the effect that delays can have on a supply system, also known as the ‘bullwhip effect’ (see Christopher, 2005; Senge, 2006).
### 3.4.4 Tipping points

A note can be made here about the idea of tipping points. Both Sterman (2000) in his explanation of the Susceptible-Infectious-Recovery (SIR) model and Morecroft (2007) in his explanation of models of fisheries, use the term tipping point. Tipping point in these instances refers to the shift from one feedback loop being dominant to another and a shift in the behaviour of the overall system. Sterman’s (2000) and Morecroft’s (2007) examples demonstrate that the techniques used in system dynamics are capable of simulating these shifts.

However, there are other shifts that system dynamics may not be able to simulate as well. As shown above, system dynamics is only a methodology of technological prediction, limited by the assumptions made in 'foreseeing' the implications of action taken on the system. Sometimes an event or change may occur in the system that results in new feedback loops forming and becoming dominant; a shift in the structure of the entire system. Often, revisiting a model, like one does with their mental models, is the only way to understand a change in system structure, though this often occurs in retrospect of the structural change.

Perhaps scenarios could be helpful to simulate these structural shifts. 'Scenarios' have been used to simulate shifts in parameters and observe their effect on the resulting systemic behaviour (Zagonel *et al.*, 2011). These can simulate possible shifts in feedback loop dominance within a system before the event occurs (Morecroft, 2007; Sterman, 2000). However, the situation is different when addressing a shift in the structure of the system. Maybe scenario planning, that envisions entirely different system structures and not just scenarios in the form of parameter variations, could be used to build a methodology that
A critical review of system dynamics

considers these potential structural shifts and uses system dynamics to help understand potential systemic behaviour.

### 3.4.5 Implications

These criticisms are damaging for system dynamics as they negatively affect general opinion of the field and its validity. By demonstrating that the model upon which conclusions are drawn does not reflect historical data, people who aren't versed in the particular theories and limitations of system dynamics begin to believe that the field offers little value. That is, if people believe that system dynamics tries to mimic and even predict the real world, and are shown models that are proposed as system dynamics models do not do this, then they may tend to believe it is the paradigm at fault and not the criticism of prediction itself.

### 3.5 Complexity: Richness, reductionism, pluralism, and social systems

From a 'soft' systems perspective, it is argued that the dependence of system dynamics on quantitative data and explicit relationships does not allow system dynamics to deal with the complexity of the real world and reduces the richness of analysis it can conduct (Keys, 1990). 'Soft' systems thinking and approaches often deal with more complex environments than 'hard' systems thinking (Checkland, 1978; Jackson & Keys, 1984). To deal with this complexity 'soft' systems thinking relies on qualitative information and linguistic terms to describe complexity (Checkland, 1978; Keys, 1990). Many believe that this level of detail cannot be caught by the hard data and mathematical models that are used in system dynamics.

In reply to this criticism, Keys (1990, p.489) argues that 'the use of causal loop models is a movement towards the soft systems type of model but the reliance upon a single model
remains a basic difference between [system dynamics] and soft systems methodologies'. This counterargument only goes some of the way to answering the criticism.

Perhaps a better approach to addressing this criticism is by emphasising that the model itself is only a portion of what the system dynamics proposes it can do. As stated earlier, system dynamics is essentially a learning tool and the 'process' of modelling is often seen as more important than the model itself (Forrester, 1985). The process of modelling involves information transfer of a rich linguistic and qualitative nature that 'soft' systems proponents believe system dynamics lacks. Moreover, it assists the field to deal with increasingly complex situations, similar to those addressed by 'soft' systems thinking.

3.5.1 Reductionism

System dynamics has often been accused of being reductionist (Keys, 1990). Reductionism - the act of describing a system through only discussing the interactions of its parts - has generally been deemed inappropriate for social messes (Ackoff, 1974). 'Hard' systems theories use reductionism to create laws and rules that define how the system operates (Keys, 1990). 'Soft' systems methodologies however, which are designed to deal with social messes, do not take a reductionist perspective (Jackson, 1982). As system dynamics appears to break down the system to understand how its components interact - essentially using reductionism - many perceive system dynamics as unable to deal with social messes (Keys, 1990).

Rather than these criticisms taking issue with the reductionist nature of system dynamics - the breaking down of the system into nodes in a model - the issue seems to be with using these nodes to construct the system that simulates the behaviour under examination. However, the
'reductionist' criticism assumes that a reductionist hypothesis implies a constructionist hypothesis, an assumption disproved by Anderson (1972).

The constructionist criticism is, however, harder to disprove. Anderson (1972, p.393), states that the 'constructionist hypothesis breaks down when confronted with the twin difficulties of scale and complexity'. However, it is sensible to conclude that in many situations a limited increase in the scale and complexity can allow one to construct the system out of the basic theories, just as Newton's theories of mechanics can be used to construct Kepler's laws of motion. As Anderson (1972) points out, to do this, one must have an understanding of the functionality, structure and goals of the 'higher hierarchical' system (or theory, as is the case in the above example).

System dynamics essentially does just this. It uses complex basic principles to describe complex systems. However, constructing the system, or rather a model of the system, from these principles requires an understanding of the structure of the system in question, precisely where the paradigm proposes to start. Furthermore, as outlined above, the techniques involved in system dynamics can only be applied to the 'right' type of problem. While it seems clear that more work needs to be done on the theoretical foundations of system dynamics in this area, it is apparent that part of the notion of 'the' right problem is one that can be analysed using the right amount or types of reduction.

### 3.5.2 Pluralism

The notion of pluralism affects two distinct acts in system dynamics. Firstly, pluralism affects it in the form of multiple perspectives of the complex decision problem, the goals of system
intervention, and different perspectives of the system itself. Secondly, pluralism affects it in the way individuals behave differently within a system.

System dynamics, as Forrester (1961; 1969; 1971a) defined it and its approaches (otherwise known as Forresterian system dynamics - the system dynamics of the Massachusetts Institute of Technology in the 1960's and 1970s), is accused of not dealing with pluralism (Keys, 1990). What 'type' of pluralism Keys (1990) is referring to is not immediately evident. However, when referring to 'hard' systems thinking, Jackson and Keys (1984, p.476) state that '[a] set of decision makers is pluralist if they cannot agree on a common set of goals and make decisions which are in accordance with differing objectives.' That is, 'Hard' systems methodologies do not consider a range of perspectives on goals, 'the' problem, or 'the' system offered by the relevant people. The idea that multiple perspectives should be considered is known as weltanschauung, a term used frequently by Checkland (1981; 1987).

If this is the 'type' of pluralism Keys (1990, p.485) is referring to then it seems he believes that Forresterian system dynamics makes no greater attempt to deal with plurality of perspectives as any other 'hard' systems thinking approach. However, Keys (1990) sees the introduction of influence diagrams into system diagrams in the 1980's, by a group at Bradford University, as a significant step towards dealing with pluralism (see Wolstenholme, 1982; 1983; Coyle, 1983; Coyle & Wolstenholme, 1983 for a brief history of causal mapping see Sharp & Price; 1984). Keys (1990) believes these diagrams allow system dynamics to accommodate many perspectives on 'the' goals of intervention, the problem, and the system in question.

More recently techniques such as Collaborative Conceptual Modelling (CCM), developed by Newell et al. (2008), Newell & Proust (2009) and Newell et al. (2011), further allows system
dynamics to accommodate pluralism. CCM uses a collaborative approach whereby people map out their own perspectives of the systems and then slowly build on this with other stakeholders or 'relevant' people to come to a broad agreement on the structure of the system. Processes such as these can however, be politically charged and it is the responsibility of the system dynamicist to negate any of the possible negative consequences that such processes can entail.

The system dynamics paradigm appears to be gradually addressing pluralism. However, it seems that more work needs to be done to ensure plurality is considered. In situations where problems and system structures are hard to define (wicked problems, Churchman, 1967), it is important that people do not become subject to group think or narrow avenues of thought in order to properly identify the goals and system structures and assist the adoption of any recommendations offered (Größler, 2007).

From the perspective of a plurality of actors within the system, system dynamics has the ability to model at an aggregated level right down to the individual level. Osgood (2009) states that while many studies are aggregated (and provides many supporting examples), some dynamics models need to model individual behaviour. The level of detail depends on the purpose of the model and the implications of individual behaviour. Osgood (2009) proposes a model to assist with modelling individuals' behaviour in a more effective way, bridging the gap between aggregation and individual modelling and assisting system dynamics to consider plurality. However, as simpler models are easier to understand it is important that the correct level of aggregation is selected.
3.5.3 Social systems: 'Open, irregular, and dynamic'

One of Hayden's (2006) central claims against system dynamics is that the social systems that system dynamics attempts to explore are 'much too open, irregular, and dynamic' and states that cybernetics - a very mechanistic approach of analysing systems - is far too structured to deal with such complexities (p.530). To explore this criticism, it will be broken down into its components, beginning with the proposed link between system dynamics and cybernetics.

Cybernetics
In their critique of Hayden's criticisms, Radzicki and Tauheed (2007) refer Hayden to the work of Richardson (1991). Richardson (1991) takes an in-depth look into the history of feedback thought in both the social sciences and systems thinking. He identifies 'two main lines of development of the feedback idea... the servomechanisms thread and the cybernetics thread' (Richardson, 1991, p.1). Richardson (1991) explicitly places the system dynamics 'tradition' in the servomechanism thread (see Richardson 1991 for more on the servomechanism theory and system dynamics).

Open
Many social systems are open and subject to outside influences. Hayden (2006) claims that system dynamics cannot model this apparent openness in these systems and on this point it appears theory in the field supports this claim. System dynamics does not attempt to model the effect of external behaviour on a system, instead it addresses the behaviour generated internally by a system; that is, it takes an endogenous view of behaviour. It is the internal behaviour of a system that often drives the system (Forrester, 1961; Senge, 1990). Richardson (2011) believes that it is this endogenous perspective that is the field's greatest contribution to the study of systems. This endogenous view was behind one of the first applications of servomechanism theory to economics, conducted by Goodwin (1951).
The endogenous perspective may be confused somewhat by comments such as 'in reality flows are determined by so many external things' (Hayden, 2006, p.534). Sterman (2000, p.95) argues that system dynamics addresses this, claiming that 'the focus in system dynamics on endogenous explanations does not mean you should never include any exogenous variables'. However, Sterman (2000, p.95-6) clarifies by saying, 'the number of exogenous inputs should be small, and..... carefully scrutinized to consider whether there are in fact any important feedbacks [involving the exogenous input]'. This is how Sterman (2000) justifies the ability to use historical data in some sense to test a model: without any external inputs, the model's behaviour may be completely different to the behaviour of the actual system.

Irregular
Social systems appear irregular. However, driving humans’ behaviour is a system of rules, obligations, controls, regulations, and limitations that is defined by them. This appears to be a deterministic view, but as outlined earlier and by Lane (2000), this view is not deterministic as it integrates the 'agency and structure' that is common in many contemporary social theories.

When taking this view it seems many of the irregularities are removed. However, external factors still play a large role in determining the behaviour of the system. Take, for example, the Beer Game (see Senge, 1990). The Beer Game begins with a shock to the system, without which the behaviour commonly observed in the game would never take place. This is where the internal focus of system dynamics is important. Once the internal system architecture is understood and the shock that caused the real behaviour is understood, in an appropriate application of system dynamics, the behaviour of the system is dictated internally after the shock.
This perspective is supported by much of the thinking on mental models - the mental constructions we have of the real world. Real systems can be very complex and humans often have difficulty accurately identifying the causes of certain systemic behaviours due to factors such as time and spatial separation of cause and effect and incorrect or limited information (Piaget, 1928; 1930; Sterman, 2000; Sosna et al., 2010). Consequently, what may appear irregular is actually not, it is just the inability of humans to properly attribute cause or recognise patterns or cycles of apparent inconsistencies.

Dynamic
Hayden (2006) also believes that system dynamics cannot deal with the dynamic nature of social systems, but does not elaborate further on this point. Much of a social system’s dynamics stem from the irregularities and openness of the system. Both of these characteristics can cause a system to fluctuate so much that it would be difficult to understand the underlying causes and patterns in the behaviour. However, as has been shown, system dynamics uses limited openness to understand the exogenous influences on the system. By limiting its scope, it is providing a perspective that could help explain the dynamic characteristics of the system. Furthermore, irregularities in the system are often only apparent irregularities with many suggesting that there is an underlying order, as has been shown in the Beer Game (Senge, 1990).

A different perspective on the criticism is that Hayden (2006) believes that system dynamics cannot handle dynamics or explore dynamic behaviour. As the goal of the paradigm is to understand dynamic behaviour and as dynamicists have provided many examples that the tools of the field do handle and explore system dynamics, this seems unlikely (Forrester, 1961; for examples of system dynamics see references). However, without any further clarification of Hayden’s (2006) criticism, further discussion on this point is likely to yield little.
3.6 Determinism: Dehumanising, 'grand' theory, and austere

Somewhat linked to the previous discussion of determinism from the point of view of prediction and prophesy, system dynamics has also been accused of being deterministic in the sense of dehumanising, aspiring to be some 'grand' theory of systems, and operationally austere (Jackson, 1991; Lane, 2000). These differ from determinism as it was previously discussed as the criticisms relate to an accused imposition of system dynamics on humans and theories. These are still considered as deterministic attributes however, because these criticisms still imply the human aspect of systems research be somewhat removed. Grand theory is placed here because of its apparent disregard for the variation between systems, particularly from the human perspective.

3.6.1 Dehumanising

Jackson (1991) believes system dynamics is deterministic and that it relegates people to 'cogs in a system' and disregards free will. Many instances of such criticisms view system dynamics making the assumption that laws operate outside of human subjectivity and of dehumanising its topic (Lane, 2000). Lane (2000) cites Forrester (1961) and Bowen (1994) to demonstrate that system dynamics is not as deterministic as Jackson (1991) believes. As a detailed analysis is given by Lane, only a brief account of the counterargument will be given.

Forrester's view is that system dynamics takes the perspective that 'decisions are not entirely "free will" but are strongly conditioned by the environment' (Forrester, 1961, p.17). Furthermore, system dynamics is designed to allow people to recraft a system advantageously and promote different behaviour, thereby acknowledging the actual environment that 'conditions' people's behaviour (Lane, 2000). Bowen's (1994) take on the topic is somewhat similar, believing the ability to change the system structure and the conditions of decisions
places system dynamics on a middle point of human determinism. This is somewhat supported by Bloomfield (1982), who demonstrated that system dynamics is described by neither complete determinism or complete free will.

However, Lane (2000) believes that this ‘mid-point’ between deterministic and complete ‘free will’ is an unsatisfactory conclusion. Lane (2000, p.10) recommends that more contemporary ‘social theories which integrate agency and structure by giving an account of the process that mutually shape them both’ is a more appropriate lens through which to observe the paradigm's treatment of human action.

### 3.6.2 System dynamics as a 'grand' theory

A second aspect to the determinism criticism of system dynamics is that it is proposing a form of a ‘grand’ theory. The idea of a ‘grand’ theory is not unknown in science, for example Von Bertalanffy's (1968) General Systems Theory (GST). These ‘grand’ theories proposed to bring together ‘models, principles, and laws that apply to generalized systems... It seems legitimate to ask for a theory, not of systems of a more or less special kind, but of universal principles applying to systems in general' (Von Bertalanffy, 1968, p.32).

However, system dynamics is only a methodology applied to different situations and does not promote a single ‘grand’ theory of systems (Lane, 2000). While this does fit, for example, within one of Von Bertalanffy's (1968) domains, it still removes the notion of universally applied concepts and principles of General Systems Theory and other 'grand' theories.
3.6.3 Austere

Another perspective on the deterministic nature of system dynamics is given by Jackson (1991), when he groups the paradigm with that of systems engineering and systems analysis. Jackson’s (1991, p.80) criticism of the group is that 'people are treated as components to be engineered just like other mechanical parts of the system. The fact that human beings possess understanding and are only motivated to support change and perform well if they attach favourable meaning to the situation in which they find themselves is ignored'.

To address this criticism, Lane (2000) explores the idea that 'system dynamics has an austere view of what should be in a model and a coercive view of how users should respond to such a model' (Lane, 2000, p.15). He explores many of the soft aspects of system dynamics, including the multitude of views considered by system dynamics, the multiple possible objectives of system dynamics, relationship between modeller and problem owner, and the fallacious idea of using system dynamics to search for an 'optimal solution' (Lane, 2000).

The idea that Jackson (1991) is referring to the operational austerity of the process seems only part of the criticism made by Jackson. Lane (2000) demonstrates that in the execution of the techniques of system dynamics, understanding and motivation are considered. It seems just as likely though, that the criticism is aimed at the understanding and motivation of people within the system being explored. These notions are addressed by system dynamics in such elements as the 'modes of behaviour' the paradigm wishes to explore and goal seeking activity (Forrester; 1961; 1969).
3.7 Hierarchy

Hayden (2006) makes three direct criticisms of system dynamics all with regards to a figure purported by Boyer (2001) (see Figure 3-3). One of the criticisms was in relation to system dynamics and its consideration of hierarchy. Radzicki and Tauheed (2007, p.1) address this criticism by demonstrating that Boyer's figure is not intended to describe how system dynamics considers hierarchy. Radzicki and Tauheed (2007, p.1) go further by explaining that the non-linear nature of system dynamics puts limitations on the systems that the methodology deals with and that these limitations describe the system's hierarchy. This explanation appears to be only part of how system dynamics considers hierarchy, but before we go further, a brief exposition of hierarchy is needed.

Checkland (1981) sees 'emergence and hierarchy, communication, and control' as 'basic' systems ideas and central to understanding a system's behaviour. Hierarchy, in Checkland's sense, is the relationship sub-systems have to each other (Checkland, 1987). The hierarchy that forms in a system defines a set of rules, obligations, controls, regulations, and limitations that exist within the system (Hayden, 2006). To address these criticisms, system dynamics should have a clear picture of how its techniques consider and inform users of these features of hierarchy.

Techniques in system dynamics, such as influence diagrams and causal loop diagrams address the rules, obligations, controls, regulations, and limitations to a certain degree by outlining the structure of the system and linking relationships between elements of the system. However, they do not describe much about the relationship between the elements of the system as, because these are simplified reflections of peoples' mental models, they are not designed to do so.
A critical review of system dynamics

It is not until a system dynamics model is built that the rules, obligations, controls, regulations, and limitations are formalised and crystallised to reflect the system. These models define the rules, obligations, controls, regulations, and limitations within the model by mathematically defining the relationships between elements.

These arguments only scratch the surface of the question of hierarchy in system dynamics. Radzicki and Tauheed’s (2007) contribution is that the nonlinear nature of system dynamics places some of the limiting factors on systems explored by system dynamics. Here it is argued that the modelling of systems and the relationships outlined in those models contain many more of the 'rules, obligations, controls, regulations and limitations' in the system and that modelling plays a greater role in addressing hierarchy. Perhaps hierarchy, and maybe Checkland’s (1981) other 'basic' system ideas, need to be discussed application by application to ensure their consideration in modelling. However, it is evident that system dynamics does need to crystallise its thinking and construct formal theories around system hierarchy.

![Figure 3-3 Hierarchy: Rules and relationships between constitutional order, institutions, organisations, and conventions (source: Boyer, 2001)](image_url)
3.8 Discussion

3.8.1 Communication

As was shown in the above review, while many of the criticisms that have been aimed at system dynamics are theoretically founded, many are invalid in the context of system dynamics. These demonstrate more a poor understanding of system dynamics rather than failures of system dynamics.

However, the concepts behind and encapsulated in system dynamics can be difficult to understand and learn (Forrester, 1961; 1971b; Cornin & Gonzalez, 2007; Cronin et al., 2009; Sterman, 2010). Furthermore, the conclusions reached through a system dynamics process and its models are often difficult to communicate to people not directly involved in their generation (Größler, 2007; Barlas, 2007). These pose great challenges for the field of system dynamics.

These errable criticisms exemplify the problem for system dynamics. It demonstrates that many people, including those willing to criticise it, have a poor understanding of the underlying theories of system dynamics; in particular its aims, techniques, and limitations. Overcoming this through communication and developing a greater understanding of system dynamics in a general audience is important for the field (Forrester, 2007).

Despite this level of aptitude in communication, some believe that system dynamics does have some intuitiveness in its communication. Sharp and Price (1984, p.5) believe that 'it would seem unlikely that policy prescriptions generated via SD [system dynamics] models would
enjoy even their present success, if the reason for them working could not be appreciated by the decision maker in a straightforward way. However, this view is concerned with the communication of results, rather than communication of the theories underpinning system dynamics, a different discussion that itself needs development (see for example Größler, 2007).

### 3.8.2 Adoption

Forrester (2007, p.361) stated that the ‘failure of system dynamics to penetrate lies directly with the system dynamics profession and not with those in government’. System dynamics has been developed over fifty years and has been applied successfully to many situations: one must question why is it not widely used. Forrester (2007) later describes some of the exigent needs for the field, including education, increasing public awareness, and promoting system dynamics as a tool that can be used to help solve some of their problems. The above review demonstrates that this call is still pertinent. Perhaps Ulli-Beer et al.’s (2010) model of acceptance (adoption) and rejection (abandonment) dynamics could provide more insight into how this could be achieved.

### 3.8.3 Critical review

The review has uncovered some exigent theories in system dynamics that need to be developed and consolidated. How to build confidence in models is one such area that was identified. There are several different theories in the field regarding confidence building that appear to conflict with each other. Reconciling contrasting theories that allow people to build confidence in different ways would be beneficial for system dynamics. However, the different perspectives on confidence building, in particular the importance of historical data and how it
can be used, can be damaging for the field as it gives external observers the impression that the paradigm is in its adolescence, with major theories still in contention. This could be a partial explanation for the low adoption rate of system dynamics.

System dynamics also has some criticisms that remain unaddressed. While individually system dynamicists can somewhat deal with the endogenous nature of system dynamics and the as yet unsettled debate on the use of historical data in confidence building, together they create some unease and do not appear to coexist. If historical data is important then the study of purely endogenous behaviour is diluted as external noise and pulses are required to mould the model to simulate historical data. If endogenous behaviour is the central aim of any application of system dynamics, as has been shown by Richardson (2011) and above, then comparison to historical data is likely to be one of the less useful tests for a system dynamics model. A clearer understanding of this apparent inability to coexist or proof that it is not a dichotomy at all would be a valuable contribution to the field.

Hierarchy is another area that seems to have received little attention in the system dynamics literature. The argument above is that system dynamics builds into its models the rules, obligations, controls, regulations, and limitations to which the term hierarchy refers. However, if hierarchy is one of the four 'ideas' central to understanding a system's behaviour as Checkland (1981) purports, then perhaps more developed and detailed work in this area is required. By establishing and addressing these more commonly accepted 'systems ideas' perhaps greater dialogue and exchange can begin to occur between the field of system dynamics and the larger field of systems research, something that others have observed have been lacking in the field (see Forrester, 2007).
The review has also uncovered theories that have been somewhat addressed, but a shortage of literature and research in the area suggests more work needs to be done to establish a strong theoretical position. For example, work is being done on pluralism from the perspective of differing points of views on the problem at hand, goals of intervention, and the structure of the system itself (for example Newell et al., 2008; Newell & Proust, 2009; Newell et al., 2011). However, system dynamics could draw on other pluralistic activities, such as those suggested by Sibbet (2010; 2011) or those used in Technology Roadmapping (Phaal et al., 2010), to improve its ability to build consensus and consider multiple perspectives. Bounded rationality limits one's decision making abilities (Simon, 1953). By including more perspectives in the process and increasing the 'bounds' that limit the problem and potential adaptations (actions & reactions to the problem), the rationale used to make decisions - and in the case of system dynamics learn about systems and test and develop mental models - can be improved and perceived limitations can be removed.

Another example of partially addressed theories is that of pluralism from the perspective of aggregation within the system. This tends to be addressed on a contingent, application-by-application basis. It can be difficult for people learning system dynamics to achieve an appropriate level of aggregation and often trial and error is required to do so. It appears the field could benefit from work being done to generate more formal and teachable rules for aggregation in system dynamics models.

One obvious conclusion that became clear in our search and review of the criticisms of system dynamics is that there are few criticisms aimed at the mathematics behind system dynamics. It is likely that this is because of the field's strong mathematical foundation in Dynamical Systems Theory, a branch of mathematics that has been around for hundreds of years and has its
Combining scenario planning and system dynamics

82

origins in the work of Isaac Newton (Beltrami, 1987). This strength of the field is important and should not be lost in the process of addressing and developing the more qualitative and philosophical issues raised in this review.

3.8.4 Overcoming the criticisms

Calls for education (Forrester, 2007; Barlas, 2007) and calls for more theoretical work (Forrester, 2007; Lane, 2000) are two often cited areas that the field of system dynamics could develop to help overcome its criticisms. Developing the theories underpinning the field and informing people of its goals, techniques, and limitations would help reduce invalid criticisms of system dynamics and build its theoretical resilience.

In addition to education and theoretical work, the review has identified an image issue for system dynamics. Bourne from poor education in the field, partially explained by its complexity, many seem to believe the field unready or unable to assist in dealing with the complex world for which it was designed. Whether it is because of its seeming unsettled validation techniques, its implicit handling of hierarchy, unconventional take on determinism and free will, its adaptable take on pluralism, or some other yet unidentified issue, applications of system dynamics seems to incur scepticism among many individuals. Despite positive reviews in many fields of the benefits of applying system dynamics and optimism of its potential, it is important system dynamics works to address the scepticism that it imbues.

3.9 This work and system dynamics

This chapter has covered several criticisms that have been levelled against system dynamics. Two central problems highlighted by the criticisms are that it is often misapplied (Richardson,
2011) and that people are often misinformed as to its goals, expected outcomes, and limitations. Many other criticisms of system dynamics, such as its determinism and human austerity have been addressed. However, theoretical work still needs to be done on some of the other criticisms, including the role of historical data in building confidence in models, the field’s reductionist perspective, and how system dynamics addresses plurality and hierarchy.

This work aims to explore if scenario planning can be used to address any of these criticisms. The group learning orientation of scenario planning could help system dynamics capture a plurality of perspectives. Furthermore, the qualitative aspects of the approach could help capture and depict the hierarchical structures of the system in which scenarios are set. Finally, scenarios, among other things, could be used to build confidence in system dynamics models generated by system dynamics. Before an explicit statement of this work can be made, previous work combining scenario planning and system dynamics will be discussed.

3.10 Previous work with scenario planning and system dynamics

There are a number of examples in the literature of scenario planning and system dynamics being used somewhat in concert, but many of these are partial integration of some of the techniques used in the approaches or a matter of definition.

3.10.1 System dynamics in scenario planning

One of the more significant examples of system dynamics being used in a scenario planning approach is by van der Heijden (2005). Van der Heijden (2005) uses influence diagrams and causal loop diagrams to establish causality and check inferences during a scenario planning process. Van der Heijden’s (2005) causal loop diagrams does engage some of the benefits of
systems thinking, including how agents interact, recognising the boundaries of mental models, and feedback (for the benefits of system thinking see, for example, Booth Sweeny & Sterman, 2000). As well as exploring several other elements of system thinking, van der Heijden (2005) uses the influence diagrams and causal loop diagrams to explore feedback that is ‘not explored or tested in detail in most existing global scenarios’ (Cumming et al., 2005, p. 144).

However, there are many other benefits of systems thinking that stem from system dynamics that are not captured in causal loop diagrams, which also do not appear in van der Heijden’s (2005) employment of the techniques, including: how systemic structure drives the behaviour of the system, stock and flow relationships (accumulation), delays, and nonlinearities. Furthermore, just as with scenario planning, influence diagrams and causal loop diagrams have no formal method for assessing the validity of mental models. While van der Heijden (2005) employs some of the techniques from system dynamics, his approach stops short of using the full potential of system dynamics to inform people’s mental models and assist scenario planning.

Schoemaker (1995, p.29) also suggests using elements that are part of, but not exclusive to, system dynamics when developing scenarios. Schoemaker (1995, p.29) recommends that quantitative models should be developed during the scenario planning process. The development of these models is part of a research phase, but there is little indication about what type of models should be developed, with only a brief example of Royal Dutch/Shell using economic models (Schoemaker, 1995). Such models could be used to inform mental models, but again do not reap the benefits of a more complete system dynamics approach (see, for example, Sterman, 2000; Booth Sweeney & Sterman, 2000).
3.10.2 Scenario planning in system dynamics

Many references to scenarios in the system dynamics literature are referring to the generation of scenarios by changing variables and calling the set of variables and the resulting model behaviour ‘scenarios’. Such ‘scenarios’ are similar to a use of system dynamics models as a means of policy design and evaluation; analogues to Forrester’s (1961, p.43) ‘management laboratory’ where factors are varied to simulate the impact of a policy or strategy (for examples of policy experimentation also see Forrester, 1961, p. 276-308). The focus in this type of activity is on using the model, rather than the learning from the modelling process, to generate scenarios. It has been argued that the system dynamics ‘process’ is more important than the model (Forrester, 1985). When scenarios are generated from the model in this way, the learning from the process is not taken into the scenario planning process.

Examples of the generation of scenarios from varying runs of a model are plentiful. In Limits to Growth Meadows and her colleagues (1972; 1974) develop scenarios in their World Model based on variations in population growth rates (for example, see the stabilised population scenario in 1974, p.160). Morecroft (2007, p.110-111) also suggests a ‘scenarios and what-ifs’ activity in a system dynamics process as a method of learning from the model in a similar way. Morecroft (2007, p.182-7) also introduces the Fliers Simulator – a simulator of the number of passengers taking to the air – which is used to create scenarios by varying variables. Other examples include Randers (2012) and Zagonel and others (2011) to name just a few.

3.10.3 Common themes

There are many studies that discuss the common themes in scenario planning and system dynamics. Senge (1992), for example, involves both scenario planning and system dynamics in his discussion of mental models. Senge identifies system dynamics as a way of checking
people’s mental models and lists scenario planning as a tool that can be used to ‘unfreeze’ mental models and convey a new way of perceiving the world. However, Senge (1992) does not discuss or espouse the view of using the two techniques together.

There are also a number of similar themes between the approaches that suggest that scenario planning and system dynamics might be conducive to informing each other. Both approaches attempt to explore the underlying nature of events, as described by the use of the iceberg metaphor (see Maani & Cavana, 2007; van der Heijden, 2005). Both also focus on learning and overcoming barriers to those (see, for example, van der Heijden, 2005; Sterman, 2000; de Geus, 1988). Other potential benefits include assisting reperception, potentially reducing uncertainty, combining the scenarios and the model into Forrester’s (1961, p.43) ‘management laboratory’, co-validation, and different perspectives of the future (for discussions on some of these topics please see Meadows, 2008; Maani & Cavana, 2007; van der Heijden, 2005; Chermack, 2005; Chermack et al., 2001; Geus, 1988).

### 3.10.4 Greater integration of scenario planning and system dynamics

Maani and Cavana (2007) suggest the use of scenarios in system dynamics in their book *Systems Thinking, System Dynamics*. In the book, the authors recommend developing dynamic models to inform scenario development, just as Schoemaker’s (1995) did (discussed above). However, Maani and Cavana (2007, p.92) go one step further and suggest using a dynamic simulation ‘to design and analyse the implications of policies and strategies against the backdrop of the scenarios’. This implies the process generates scenarios and uses them to input different values into a dynamic model to see their consequences on the system; a greater integration of the techniques than previously discussed. However, in the case study
used to exemplify the process, scenarios are only sets of values for variables which are placed into the model and their impact observed and not generated using scenario planning. This is more a scenario generation exercise by variable modification like Meadows’ and her colleagues (1972; 1974) and Morecroft’s (2007). Despite this Maani and Cavana (2007) still propose a process that further integrates scenario planning and system dynamics that needs to be examined.

Morecroft both with van der Heijden (Morecroft & van der Heijden, 1992) and on his own (Morecroft, 2007) has also explored using scenarios and system dynamics in close concert. Morecroft and van der Heijden (1992) and Morecroft (2007) propose using system dynamics ‘in global scenarios’ of the oil industry (Morecroft and van der Heijden, 1992, p.102). Again, while appearing to be a more comprehensive integration of the approach, the developed model is only used to create scenarios based on the variation of variables and the focus of the literature is on the model, with little on the process.

The major processual contribution of Morecroft and van der Heijden (1992) and Morecroft (2007) is the involvement of the planners (those who develop the scenarios) in the modelling process. By involving the planners Morecroft and van der Heijden (1992) and Morecroft (2007) open up the possibility of learning from the modelling process and taking this into scenario planning. However, the exploration stops short. The authors suggest that the process redefined classifications that could be used in scenario planning, saying, ‘the model’s characterization of OPEC in terms of three behavioural decision-making components…. made possible a wider range of industry scenarios than the conventional models’ (Morecroft & van der Heijden, 1992, p.118), but there is little further exploration into the impacts and consequences of involvement in the modelling process. Furthermore, the focus on the model,
Combining scenario planning and system dynamics

as already outlined, detracts from the learning potential of the process – which is more valuable than the model itself (Forrester, 1985).

Finally, Genta and his colleagues (1994) discuss the use of system dynamics and scenario planning in the world oil exploration industry. Genta and his colleagues (1994, p.53) state:

'...the scenario managers used a systems thinking approach to brainstorm the factors influencing the dynamics of the world oil and gas industry. From this process the group was able to develop a set of five distinctly different plausible futures that might develop.'

Genta et al., 1994, p.53

The systems thinking approach was a brainstorming session that incorporates Hodgson’s (1992) hexagon technique in a group workshop to generate ideas around what participants’ “concerns, fears and hopes” (Genta et al., 1994, p.54) were regarding the world oil exploration industry. They cluster these ideas to generate scenarios. Genta and his colleagues (1994) then develop causal loop diagrams to ‘uncover and change any flaws in ... [their] thinking’ (p.56). The developed causal loop diagrams, however, suffer from the same shortcomings as those of van der Heijden’s (2005). In this application, the causal loop diagrams do not help to consider how systemic structure drives the behaviour of the system, stock and flow relationships (accumulation), delays, and nonlinearities, despite claiming many participants in the workshop were previously involved in systems thinking workshops (Genta et al., 1994). Furthermore, the causal loops are combined into a diagram that has 39 elements and 23 feedback loops, which describe a system that, without modelling, has delays, stocks, and nonlinearities that are difficult to comprehend.
3.11 This work

This work aims to integrate scenario planning and system dynamics to understand how the approaches could be used to inform each other. It will understand if integration is at all possible and what the benefits and pitfalls of such integration are. More specifically it will aim to understand if integrating the two techniques can help overcome any of the criticisms covered in the last two chapters.

Both scenario planning and system dynamics are learning tools and as such when used together it may seem like a foregone conclusion that they will be able to be used together. This work aims to explore how integrating the approaches in a comprehensive way can help overcome the obstacles to and improve the results of the steps in the other. This is much more than simply using the two techniques in parallel.

As detailed in the previous section some authors have already written about using scenario planning and system dynamics together. However, many of these authors only discuss the use of the two approaches in parallel and only hypothesise about the benefits. Furthermore, the few authors that do attempt to integrate the approaches only use minor elements of one to inform the other. This work will attempt more comprehensive integrations of the two techniques and explore if and how they were able to inform each other.

More broadly, this work aims to explore the integration of the two paradigms – the concepts and frameworks behind the approaches. Integration of different paradigms is difficult and the assumptions and preconceptions that come with the different paradigms can be challenging (Meadows, 1980). However, if achieved, the two paradigms together could have much to offer decision makers and help build more robust strategies and policies.
There are many potential benefits of integrating the two approaches. Specifically, this work is investigating if system dynamics’ formal approach to informing peoples’ mental models assists in developing scenarios. However, it will also try to understand if there are any other benefits of integration. The next chapter will describe the technical applications of the approaches adopted for the study and outline how case studies were conducted to test for these potential benefits.
Five studies were run to explore if scenario planning and system dynamics can be integrated and that they inform each other. Each of these studies was a combination of the various steps involved in executing the two approaches. Basic steps were taken from benchmark approaches outlined in the literature and altered and arranged for each study. Each study was designed for its particular application to help achieve its aims. For example, one of the studies, the Food and Drink Federation study, was predominantly a scenario planning exercise, with only one ‘step’ (non-exclusive) from system dynamics inserted. The processes executed in each study then allowed the benefits of that particular combination of ‘steps’ to be interpreted.

Given the tenants of post-positivism, particularly falsification as outlined by Popper (1934: 1959), it cannot be proved that scenario planning can inform system dynamics or that the reverse is true. Instead it can only be demonstrated how the two approaches may have helped each other in these five case studies. From the observations in these studies, falsifiable generalisations can then be drawn.

Benchmarks of scenario planning and system dynamics had to be established from whence combinations of ‘steps’ could be generated. As stated earlier, the scenario planning approach that will be the focus is the form stemming from Royal Dutch Shell’s Planning Group. This approach is articulated by, in particular, Wack (1985a; 1985b), Schwartz (1991; 1992; 1996), and van der Heijden (1997; 2005). This form of scenario planning appears to be the dominant form in the United States of America (USA), the UK and Australia (generally dominant in the Anglo-Saxon world) and underpins the approaches adopted by the Global Business Network.
Combining scenario planning and system dynamics

(GBN)¹¹ (see Schwartz, 1996) and other consultancies such as Chermack Scenarios¹² (see Chermack, 2011).

The system dynamics approach adopted is the one underpinned by Forrester (1961), Sterman (2000), Meadows (2008), and Morecroft (2007). Forrester (1958a; 1958b; 1961; 1964; 1968a; 1968b; 1969; 1971; 1973a) is generally attributed with the foundation of this field and its approaches along with Meadow’s and her colleagues’ work (Meadows et al., 1972) and other researchers and students at MIT (Massachusetts Institute of Technology).

Generally, the integration of these approaches was applied to complex decision problems. A complex decision problem is a difficult and complex problem that deals with open societal systems (Radford, 1977, p.xiii). These problems are usually related to what Ackoff (1974) called social messes: situations that involve complex social or political relationships. They are also often synonymous with Churchman’s (1967) wicked problems, which have social elements, are ill-formulated, have confusing information, involve many different stakeholders, and have unclear ramifications throughout the system in which they rest. They will here on be referred to as decision problems.

4.1 Method of evaluation for thesis

The method of evaluation for the thesis of this work was essentially an action research approach. Action research is the process of deliberately altering a process or system and observing its consequences (Platts, 1993). In action research the researcher is directly involved

¹¹ www.gbn.com
¹² http://www.thomaschermack.com
in the observation of the implications of process alteration and is less interested in ‘understanding the current approaches to tasks’ (Platts, 1993, p.6).

The altering that occurred in the studies was the five different structures for the five different studies. Various techniques were then used to evaluate the processes adopted. Observation, being the main method behind action research (Platts, 1993), was used in the first three studies. Also used in these studies was participant observation via direct feedback, where it could be recorded. In the fourth and fifth studies these techniques were complimented with surveys – which aimed to supplement direct feedback and directly capture participant observations.

A note of caution must be made about the application of action research in this instance. An element of action research is to vary a small, limited number of elements between applications so that the differences in results can be compared. This project, however, was about the exploration of whether system dynamics could inform scenario planning and if the opposite was also true. It looked for specific incidences of where this could be found. As a consequence it did not aim to compare between the results from different studies, but rather use them as exemplars of the approaches co0informing each other, compare them back to them to benchmark processes typical in the approaches, and attempt to find the underlying reasons for their occurrence.

A consolidated description of the benchmark ‘steps’ of the approaches used in the studies is presented in the next two sections (Section 4.2 and Section 4.3). The next sections describe some of the techniques and activities used to execute those steps (Section 4.4 and Section 4.5). The final section is a brief explanation of the methods of evaluation employed for the
Combining scenario planning and system dynamics

studies (Section 4.6). Specifically, these discuss the observational process and surveys that assisted in the evaluation of integrating scenario planning and system dynamics.

To help structure the following section and chapters color-coded ‘blocks’ are used to represent the general workshop activities involved in the approaches. Figure 4-1 shows simplified steps of the scenario planning approach adopted and Figure 4-2 shows simplified steps of the scenario planning approach adopted. These will help guide the reader through the remainder of this dissertation, but should be noted as over-simplifications and not descriptions of the approaches; they should be used for guidance purposes only (for detail about the approaches see their descriptions see the detail provided in this chapter, Chapter 2, and Chapter 3).

![Figure 4-1: Simplified ‘steps’ in a scenario planning approach](image1)

![Figure 4-2: Simplified ‘steps’ in a system dynamics approach](image2)

4.2 Scenario planning process

The purpose of the first study, the Future Scenarios for the Food and Drink Federation Study (the FDF study), was to establish an appropriate and functioning process for developing scenarios. Establishing a benchmark process was needed because only partial or vague methods of applying scenario planning could be found in the literature, despite the number of publications on scenario planning. Partial reasons for this are the strategic benefits for those
who can develop scenarios effectively and the organisation intellectual property and consulting benefits for those who have developed a process\textsuperscript{13}. The vague or partial accounts of applying scenario planning available in the literature make them amenable to interpretation, adaptation, and application. This study was mostly based upon Wack’s (1985a; 1985b), Schwartz’s (1991; 1996), and van der Heijden’s (1997; 2005) explanations of and approaches to scenario planning. The steps used in the FDF study became the standard for the subsequent studies as it had been successfully trialled and was known to facilitators and study managers. It should be noted that many other scenario planning approaches exist: some are similar to the one used here and others vary considerably.

The development of this process began at a high level. Schwartz’s (1991; 1996) discussed the theory behind scenario planning, and did not offer as defined steps towards scenario development as other authors. This was used to loosely structure the process. Then the more applied steps discussed by Wack (1985a; 1985b) and van der Heijden (1997; 2005) were introduced. The reason for starting at such a high level was because this work aimed to develop methodologies that applied both scenario planning and system dynamics. Beginning at such a high level allowed a process to be designed and built, deconstructed and reconstructed, which allowed the testing of different means of integration. The description here is specific, but flexible to pave the way for the descriptions in the different studies about how it was integrated with system dynamics. When it was applied in a particular study, it was ridged and defined, which assists people ‘to deal with the complexities, ambiguities and uncertainties of the content’ (Wright & Cairns, 2011, p.18).

\textsuperscript{13} One notable exception to this is Wright and Cairns’ (2011) process, but this was published after this process was established.
There was a nuance in timeframe and method that must be noted between the approach to scenario planning described here and the one discussed by, in particular, Wack (1985a; 1985b) and van der Heijden (1997; 2005). The processes suggested by Wack (1985a; 1985b) and van der Heijden (1997; 2005) describe a long period of learning that takes place to understand the operating environment, collect data, and synthesise it to develop new perspectives which are then communicated using scenarios. The approach established here was based around workshops (discussed later) which used multiple perspectives to consolidate mental models and generate learning. The findings in the workshops were then captured through the generation of scenarios. The reason for the use of workshops is discussed at length in Section 4.4, but quickly here, it was to ensure the knowledge required was captured, to generate learning, to increase the likelihood of the learning being adopted more broadly, and because of its low resource requirements to achieve all this (as is necessary for doctoral theses).

Figure 4-3: Simplified workshop activities of the ‘benchmark’ scenario planning approach

4.2.1 Identify the client

The first step in the adapted scenario planning approach was to identify the client or people for which the scenarios were being developed. Despite Wack (1985a; 1985b) focusing on the manager (internal) and van der Heijden (1997; 2005) focusing on a client being consulted (external) they are, in effect, the same. The person or people for whom the scenarios were being developed could also be from any facet of society, including public, private, or not for profit organisations, collectives of organisations, or countries (such a broad collective has similarly broad terms, but as it is mostly applied at the organisational level, organisations will
be used from hereon). However, they must be identified early as they dictate the goals and aims of the approach (Eden & Simpson, 1989). Each organisation has individuals and groups who have their own agendas and whose focus would generate different result and the client must be identified to understand ‘whose aim... will [be sought] to attain’ (Eden & Simpson, 1989, p.65). Identifying the client is important in any form of intervention - the engagement in an approach to help address a problem.

4.2.2 Identify the purpose

The purpose of the scenarios was the next stage. Simpson (1992, p.12) believes this phase is focused on answering two questions: ‘what keeps the operating managers [or client] up at night’ and ‘what really makes a difference’. Answering these questions gave a general idea as to the issues facing the organisation and the possible specific foci of the scenario development exercise.

4.2.3 Articulate mindsets/ mental models

The next phase of the adapted process was to articulate the mindsets, or mental models, of the client. Involving preliminary cognitive mapping and interviews, this stage involved people who had direct contact with the areas of concern that ‘kept people up at night’ and that ‘mattered’. Cognitive mapping, such as that adopted by Eden and Simpson (1989) in Strategic Options Development and Analysis (SODA), was employed at this stage. These rough maps help to define the issues, decision structures, and responsibilities in the organisation. They encourage the client and related people to clarify their own mental models of the organisation and began to help pinpoint the specific underlying problem.
4.2.4 Refine the focus and set horizon year

Through the answering of Simpson’s (1992) two questions and the articulation of general mental models, the focus of the exercise was refined. There could have been a range of aims for the scenarios, including a policy decision in which stakeholder involvement is important, a crisis that needs to be addressed, or something that needs to be communicated (van der Heijden, 2005, p. 158-9). The aim could have also been a focus on “the big unarticulated” problem – a problem in the form of a threat or opportunity that is either not tractable or yet to be comprehended by the organisation, but whose presences is known (Martin, 1977). Radford (1977) defines such issues as decision problems. For the purpose of the process, the scenarios had an aim that was the focus of the study. This aim was slightly more general and was more congruent with Wack’s (1985a; 1985b), Schwartz’s (1991; 1996), and van der Heijden’s (1997; 2005) definition of the aim of a scenario development exercise.

Refining the aim also led to the identification of the future date, or target date, for the scenarios. This data is the date that the scenarios will describe in the future. Van der Heijden (2005) explains that if this date is too soon, forecasting would be a more appropriate exercise and if it is too long then there is little help scenarios can be. Bloom & Menefee (1994) believe the time frame should be between five to fifteen years. However, scenarios vary as to what that ‘middle’ timeframe is. Randall and Goldhammer’s (2006) scenarios of China have no particular target date, the Global Business Network’s (1998) scenarios of Colombia aim their scenarios for sixteen years into the future, The Mont Fleur Scenarios (le Roux & Maphai, 1992) were based ten years into the future, and Raskin (2005), while looking specifically at ecosystem scenarios, believe they should be generated over a ‘long’ time horizon, at least several decades. Part of the refining process was to decide the optimum date for the target date for the scenarios.
Once the aim was identified, the people to involve in the study, specifically the workshops, were selected. It was desirable to have people with a broad range of perspectives involved in the scenario development exercise in order to provide new, unique, and unconventional views and insights (Bloom & Menefee, 1994). To assist in the attainment of novelty, Schwartz (1991; 1996) and van der Heijden (2005) recommend the use of remarkable people - these are people with unique and unconventional views of the world. They could have been senior managers or people working in unique fringe areas related to the organisation or its environment.

4.2.5 Identify driving forces: trends and drivers

Identifying the trends and drivers was generally the first activity executed in workshops. These were identified through a group brainstorming activity. Participants were given Post-it notes and five posters, one for each of the categories: political, economic, social and consumers, technology, and the food industry (in general). For each trend and driver identified, participants wrote it on a Post-it note and placed it on the poster whose category they thought corresponded best with their trend or driver. An example of the poster and the use of Post-its can be seen in Figure 4-4.
Participants began in small groups of five or six people from a cross-section of stakeholder groups and focused on one category (poster), noting as many trends and drivers as they could. Multi-stakeholder groups were used so that a variety of perspectives was drawn on for the groups’ discussion. The number of perspectives were maximised by ensuring there was one person from each major stakeholder group in each workshop group.

Once the groups had exhausted their input to the first poster, they moved in their groups around all the posters (an activity called ‘carrouselling’). At each poster the group reviewed the trends and drivers already identified and added their own.

During this activity anyone could proffer a trend or driver and it could not be slandered, altered, or removed. Participants were however encouraged to question trends and drivers. This was to encourage open and frank discussion and assisted to capture the entire groups' thinking. Facilitators at times also had to propose trends and drivers that certain participants
may be intimidated to provide publicly (i.e. play the supporting role). Participants were
encouraged to roughly group the trends and drivers they identified on the posters as they
went. When everyone had been around to all of the posters, a representative was then
selected from each of the groups to present their initial poster to all workshop participants.

After this activity the individual data points (Post-its) were ‘bucketed’ (Stigliani & Ravasi, 2012)
or clustered to form more general groups of trends and drivers for the participants to focus on.
Van der Heijden (2005) recommends some limited causal mapping here to understand the
major influencing factors. This work endeavoured to go further, by mapping the causal
structure more stringently and more completely, through the use of mapping tools and more
comprehensive diagrams (those offered by van der Heijden, 2005 have no more than seven
variables). The work also endeavoured to make system dynamics models to inform peoples’
mental models.

4.2.6 Identify predeterminants and uncertainties

The clustered trends and drivers were then separated into those considered predetermined
and those considered uncertain. This was done by participants voting on the trends and
drivers’ uncertainty and impact. This allowed them to be mapped out on a space with
uncertainty on one axis and impact on the other. The eight to twelve with the highest
uncertainty and impact were taken as the key uncertainties. O’Brien (2004, p.711) suggests
twelve to be a practical number that allowed a certain level of complexity without flooding the
participants with variables to consider – where it was feasible, twelve were selected.
More information on the key uncertainties was then collected. The key uncertainties were clearly and explicitly defined and their feasible range was selected by choosing two extreme endstates. The term extreme endstates were used to convey to the participants that they had to stretch their thinking and assign endstates that were at the limits of what they considered possible, hopefully even a bit further. Participants were asked to suspend disbelief and to think of limits that really were at the edge of their thinking. Pushing their thinking of what is possible, partially by considering the uncertainties in isolation and partially through the consideration of ‘extremes’, were two of the key goals that dictated the exercise’s structure.

Participants discussed the multiple dimensions on which these endstates could be measured and how they were related. They provided two very different ‘extreme’ endstates for each key uncertainty. The dimensions that endstates can be measured on vary, from a continuous spectrum to a discrete option. Exact figures for the ‘extremes’ were not required as this is too difficult to obtain with any accuracy. However, descriptions of the ‘extreme’ endstates were required to ensure other participants, particularly those in the other groups, knew exactly the situation each endstate described.

The purpose of identifying the ‘extremes’ is to ‘push’ what participants perceive to be possible. This is one of the main purposes of scenario planning: to make people consider new possibilities and reperceive the world (Wack, 1985a; 1985b; Schwartz, 1996; van der Heijden, 2005, p.225). Wack (1985b) called this ‘the gentle art of reperceiving’ (p.147). By considering the key uncertainties in isolation, people can focus on pushing their thinking and try to understand, without distraction, what might be possible. However, considering things in isolation may mean that when recombined they are improbable and unlikely, even to the point
where they are unbelievable. The next step in the process tests that the recombination of these uncertainties and their extremes is feasible.

### 4.2.7 Develop initial scenarios

Participants then selected amongst the key uncertainties the dimensions on which the scenarios would be drawn. Using the information gathered on the uncertainties to clarify their role, participants chose those that would most affect or ‘what would really make a big difference (van der Heijden, 2005, p.92), and deviate from their ‘business as usual’ position the most. Participants often found it useful to merge two closely related uncertainties in this stage. Many also found it useful to view the scenarios emerging in a table or matrix. Sibbet (2010) supports the notion of using tables to create combinations in this manner. Some viewed the tables or matrices as three by two, but the most common representation was in a two by two matrix as is often observable in literature (see for example Randall & Goldhammer, 2006).

In the literature this step is often unclear and is probably one of the areas where van der Heijden’s (2005, p.155) ‘practitioner’s art’ is most significant. The leap between the uncertainties and scenarios is discussed in some books and papers. Van der Heijden (2005, p.155) seems to discuss this more than other authors, using the uncertainties to explore different interpretations of what is happening. Van der Heijden (2005, p.236-253) then discusses inductive, deductive, and incremental methods of scenario generation. The inductive method uses the different interpretations of what is happening to allow the general scenarios to emerge from specific information (van der Heijden, 1997; 2005). Van der Heijden’s (1997; 2005) deductive method follows a series of premises to allow the specifics to emerge from the general premises. The incremental method is a method of building scenarios around specific issues (sometimes called the “threat” approach) when the client may not necessarily
acknowledge the benefit of a scenario planning approach (van der Heijden, 1997; 2005).

However, van der Heijden (1997; 2005) is particularly unclear when he uses *The Mont Fleur Scenarios* (see le Roux & Malphai, 1992) as examples of inductive and deductive scenario development, describing a similar approach in both.

A more suitable description of scenario development that helps to describe the way they were developed here is the distinction between future-backward and future-forward scenario development (Ratcliffe, 2000; Othman, 2008). Future-backward development is where the futures are defined by the end-states of the uncertainties and attempts are made to discover the path to them (see Backcasting later in this section). Future-forward builds on ‘present forces and their likely evolution’ (Ratcliffe, 2000, p.131) and appears to be similar to both inductive and deductive methods as described by van der Heijden (1997; 2005).

It was chosen here not to use pre-defined themes or dimensions. Schnaars (1987) suggests themes for the scenarios should be identified before they are developed. Inayatullah (1996) also notes that pre-defined ‘dimensions’, such as Status quo, Collapse, Steady State, and Transformation are often used in scenario planning exercises. These were deemed to restrict flexibility during scenario development and difficult to enforce during the workshops and were not adopted.

As well as theme, there is also some debate about how many scenarios a scenario planning process should yield. Mercer (1995) argues that because of managers’ limited ability to consider multiple scenarios, only two scenarios should be generated. Schnaars’ (1987) early survey of scenarios suggested that three scenarios were most common (see for example Schwartz, 1996; Bloom & Menefee, 1994). Genta *et al.* (1994) chose to use five scenarios to
keep buy-in high and not exclude ideas. However, it is common to see four scenarios being generated (see Global Business Network, 1998; le Roux & Maphai, 1992; Randall & Goldhammer, 2006). Furthermore, van der Heijden (2005) and Schwartz (1996) both argue for the number of scenarios to reflect a particular application, but that the number of scenarios generated should be between three and five. This process will try to abide by van der Heijden (2005) and Schwartz (1996) and build between three and five scenarios, contingent upon each application.

4.2.8 Add detail to the scenarios and name them

Detail was then added to the scenarios and they were given a name. Detail is added to scenarios to ‘flesh’ them out and create congruent stories. The process developed for doing this in the first study was uncertainty assignment.

Uncertainty assignment was a method of assigning ‘values’ to the key uncertainties for each of the scenarios. The assignment of values was on a Likert scale of one to seven, where one represented one ‘extreme’ endstate previously identified and seven represented the other. Some uncertainties were pre-defined, either having the scenarios built off them or being closely related to it. Some uncertainties were identified as being in a range on this scale. Many were independent of the axes and gave an opportunity to vary them between scenarios to ensure they were sufficiently differentiated. This exercise gave an opportunity to back-fill information for the scenarios, as is done in future-backward scenario development. The benefit of providing information in this way is that it forces information inconsistent with individual scenarios out of consideration.
The purpose of this exercise was to add more content to the scenarios and check they were internally consistent. Scenarios are stories of the future ‘constructed for the purpose of focusing attention of causal processes and decision points’ (Kahn & Weiner, 1967, p.6). So far the scenarios were only defined by the two axes upon which they were plotted. By assigning ‘levels’ of the other key uncertainties to each scenario, a more detailed picture of that scenario could be defined. This also acted as a check on the internal consistency of the scenarios. By running through this activity, participants may have picked up if there were any contradictions or incompatibilities in the scenarios. This is not a definitive way to check the internal consistency of scenarios, but some of the more obvious inconsistencies would have been detected. Furthermore, by assigning the ‘levels’ of the key uncertainties, internal consistencies would have been picked up before they were even inserted into the scenarios.

A name was also given to the scenarios. The participants chose the names to be a suitable summary of the scenarios that would inspire imagery that captured some of the key attributes of the scenarios. These names were often revised.

### 4.2.9 Draft plots (stories)

The facilitators then gathered the information together and drafted the scenario plots – stories that describe the scenarios. Developing the plots required the facilitators to draw on the information captured and describe the situation. This is where van der Heijden’s (2005, p.155) ‘practitioner’s art’ is pertinent. They are often written in the past tense (see Hawken et al., 1982) 'to enhance [their] the psychological impact (Schoemaker, 1993, p.201). The plots were then provided to the participants to review and provide feedback.
4.2.10  Iteration and reassessment of the scenarios

The scenario development process is ultimately an iterative process (Wack, 1985a; van der Heijden, 2005). At this point in the workshops the scenarios were reviewed and many of the previous activities were reiterated. In one of the studies, for example, the process of adding detail and reviewing the name of the scenarios, causing a reiteration of the plot drafting, occurred multiple times until the scenarios had suitable depth and detail.

4.2.11  Backcasting

Backcasting, Impacts and Implications, and Windtunnelling were three exercises that were contingent to the situation and were offered to the client as the first step towards using the scenarios and demonstrations of what the scenarios could be used for. They were unprecedented exercises, but their tenants came from the literature.

Backcasting was an exercise where participants outlined the events, turning-points, and decisions that lead from today to their scenario in the target year. The purpose of this exercise was to understand how the environment could change from the present to the target year, and understand how the scenarios might eventuate. This would create ‘signposts’ that decision-makers can use to identify changes in the environment, known in scenario planning as ‘memories’ of the future (Postma & Liebl, 2005; van der Heijden, 2005; Schwartz, 1996).

Participants broke into smaller groups, each based around one scenario. They began by listing the state of the environment in the present and in the target year if their scenario eventuated in six areas: political and legal, economic, social and consumer, technological, environmental, and the food industry. This was again done with Post-its and was collated on a poster with the
six sections down the side and a timeline along the top. Present day attributes were placed at the far left of the poster and the target year attributes at the far right, using the space between to indicate the time between the present and the scenarios. Participants then outlined the events, turning points, and decisions that occurred and transformed the environment into the scenario observed. Arrows were then drawn to show causality and consequences of the events, turning points, and decisions in the diagram.

This activity had three intentions. First, it aimed to add detail to the scenarios and their plots. Second, it aimed to provide another means of testing for internal consistency, by explore whether the present environment could indeed feasibly evolve into one outlined by a scenario. Finally, it aimed to produce memories of the future by identifying indicators that could be used by participants to monitor the external environment and help them to understand the causes and consequences of its changes.

4.2.12 Impacts and implications

The Impacts and implications exercise focused on the impact of each of the scenarios on various stakeholder groups and their consequences. Participants were given key metrics for the organisation on a chart and used a five point Likert scale, to assess how these metrics would change between the present and their scenario. The Likert scale was:

- a large increase was denoted by two 'up' arrows;
- a moderate increase was denoted by one 'up' arrow;
- no change was denoted by a horizontal arrow;
- a moderate decrease was denoted by one 'down' arrow; and
- a large decrease was denoted by two 'down' arrows.
The purpose of this exercise was to provoke participants thinking about how the scenarios could be used to help develop policy and strategy by developing an understanding of the impact and implications of the scenarios. Thinking about the impact and implications of the scenarios was the first step to developing ideas about how they could be enhanced or mitigated. This shift in thinking was a step towards being able to use the scenarios.

4.2.13 Windtunnelling

Windtunnelling was an activity employed in the workshops to take the scenarios further than just their development and to feed into the decision-making structures of the organisation. In the windtunnelling activity, participants were given a scenario and tasked with identifying strategies to move from one to the other. Realising they could only influence their contextual environment (Emery & Trist, 1965) participants might have found it impossible to completely shift from one scenario to the other, particularly if the scenarios deviated heavily in their general environment. This was the first time actionable strategies based on the scenarios were developed and was used as an example for the organisation to see how it might use the scenarios.

4.2.14 Implicitly included activities

The approach outlined here also aims to include some implicit benefits, which can be seen as its implicit activities. The central implicit activity was the creation of common language, which is an important benefit of scenario planning (Schwartz, 1991; 1996). The use of common terms, for example, for trends and drivers and for the scenarios was designed to help develop common language among workshop participants and the client group.
4.2.15 Information collection

Throughout the adapted process, information was collected, collated, and organised. Wack (1985a; 1985b), Schwartz (1991; 1996), and van der Heijden (1997; 2005) outline the importance of information gathering in a scenario planning process. From the workshop exercises to interviews and meetings, information about the organisations, their environment, how they work, and their particular problems, threats, and opportunities was collected. Much of the information was gathered during the activities executed in workshops. The information was often used in the following activity, driving the process forward during the workshops.

The literature on scenario planning provides numerous sources of information for the process. Van der Heijden (1997; 2005) supplies a list of techniques used for gathering information including a Strengths-weaknesses-opportunities-threats (SWOT) analysis, a competitive positioning analysis (essentially an analysis like Porter’s, 1980; 1985), and interviews. Van der Heijden’s (1997; 2005) particular emphasis is on understanding the business idea – understanding what environmental conditions and internal capabilities the organisation relies on for success. Schwartz (1991; 1996) provides a list of areas where information can be found including science and technology, music, and people and encourages seeking information from the ‘fringe’ of commonplace thinking. Schwartz (1991; 1996) also recommends the use of other people who can filter and supply you with relevant information from magazine editors to people within your own network. Many of these methods and sources were employed in the studies.

The reason for gathering this information was to provide an informed view of the organisation. The people involved in the process brought as many different, but relevant, sources of information together as possible. The diversity of information is what provides these unique
views and helps the conversation that occurs during scenario development to look into blind-spots – areas traditionally overlooked by the organisation. Van der Heijden (2005, p.222) emphasises the importance and the opportunity of introducing novelty during information gathering. Sources of this novelty could be what van der Heijden (1997; 2005) calls remarkable people or information from the ‘fringe’ of standard sources of information (Schwartz, 1991; 1996).

4.2.16 Develop mental models

Throughout this process the aim was to articulate, capture, and challenge mental models and to attempt to form common group level mental models. The early capturing of the clients’ mental models was used as a starting point (as suggested by Wack, 1985a; 1985b; van der Heijden, 1997; 2005), but were very ‘slippery’ and ill formed as many mental models are (Meadows, 2008). The group exercises were aimed at capturing elements of individuals’ mental models and developing a common group one, but the vague clustering and voting provided only elements of a solid model. This was where system dynamics was often used to inform the process.

4.3 System dynamics approach

Figure 4-5: Simplified activities of the ‘benchmark’ system dynamics approach
4.3.1 Problem identification

As with scenario planning, the first step in the adapted system dynamics approach was to ‘establish the problem to be explored and the questions to be answered’ (Forrester, 1961, p.21). This is always the first step in any decision making or intervention exercise (Drucker, 1985; Eden & Simpson, 1989). Again it was important to identify who the problem was being explored for and whose questions were being answered; in essence, the client (Eden & Simpson, 1989).

4.3.2 Develop understanding and collect information

The next step was to understand the system of the problem. The system of the problem is the causal relationships, including decision structures and information flows, the rules that define these relationships, and the boundaries of relevant information. Forrester (1961) and Meadows (2008) emphasise the need here to gather information to inform understanding about the system. Meadows (2008, p. 170) discusses the need to ‘get the beat of the system’ and understand what is occurring in it and why. Forrester (1961, p.13) applies a similar information gathering mode, but also outlines the need to ‘isolate the key factors that appear to interact to create the observed symptoms’ of the problem. Sterman (2000) is yet more explicit, stating that key variables and the time horizon are what need to be identified.

A number of sources of information can also be used to acquire information and understanding about a system. Forrester (1961, p.57-9) discusses many such sources. In this approach many sources including reports, communicating with personnel, observation of operations, and general observation were used to gain a general understanding of how the system worked and its natural behaviour. From this understanding the key variables were then identified.
4.3.3 Collect reference modes

The importance of a standard against which models can be compared is highlighted by Forrester (1961) and Sterman (2000). Reference modes are the information against which any model will be compared. Sterman (2000, p.90) describes a reference mode as, ‘a set of graphs and other descriptive data showing the development of the problem over time’. The only differences between Sterman’s (2000) and Forrester’s (1961) notions of reference modes is that Forrester (1961, p.13) uses a roughly equivalent definition, ‘all pertinent available knowledge’ and introduces it after a system dynamics model has been developed.

As will be seen, much of the information gathered about the system and the mapping in this approach was done in group workshops. As a consequence much of the reference mode was difficult to identify before model development, particularly when the activities in the workshops somewhat blurred the lines between mapping and modelling. Despite this, the approach aimed to identify the reference modes before lengthy dynamic modelling was undertaken. This helped to remove the traps of confirmation bias and using selective data to build confidence in the model (Wason, 1960; Taleb, 2005).

4.3.4 Develop a dynamic hypothesis

The final step to execute before the workshops is to develop a dynamic hypothesis. Sterman (2000, p.95) states that ‘a dynamic hypothesis is a working theory of how the problem arose’. Specifically outlining a dynamic hypothesis reduces confounding the problem and theories of its causes (Sterman, 2000). Having a dynamic hypothesis to test means that the system can be clarified more clearly and probing questions can be asked, finding more specific information about the system for mapping and modelling. Forrester (1961, p.13) does not discuss the development of a dynamic hypothesis.
Sterman (2000) then expounds the need to develop a dynamic, endogenous hypothesis. The hypothesis needs to be dynamic because the feedback effects of the decisions can only be observed over time. Endogeneity is also a focus because system dynamics is an approach focused on behaviour arising from the structure of the system (Forrester, 1961; 1987; 2001). The endogenous aspect of system dynamics has been argued as one of the greatest contributions of system dynamics (Richardson, 2011).

Again, as much of the information is gathered in the workshops, this stage generally occurs in and between the workshops. It emerges through discussion and is made explicit by the facilitators.

### 4.3.5 Map the system: Influence diagrams, causal loop diagrams, and stock and flow diagrams

Mapping of the system was conducted mostly in workshops. Forrester (1961, p.13) believes that an essential part of understanding the system is to understand how decisions are made and to trace the ‘cause-and-effect information-feedback loops that link decisions to action to resulting information changes and new decisions’. Axelrod (1976) believes that cognitive maps, very similar to the maps used in the workshops, capture the causal elements of the assertions in mental models and other non-consolidated abstractions (hereon referred to as mental models). These maps captured the way people saw the system and were used as part of the process of testing their mental models.

There are three main tools used to do this: influence diagrams, causal loop diagrams, and stock and flow diagrams. Forrester (1961; 1969) used stock and flow diagrams (Forrester, 1961; 1969) and something similar to influence diagrams (Forrester, 1961) to depict the structure of
his systems. Influence diagrams, as they are used today, were established by Wolstenholme (1982; 1983) and Coyle (1983a; 1983b, also see Coyle & Wolstenholme, 1983). They loosely link elements in a system through cause and effect. A picture of an influence diagram from the workshops can be seen in Figure 4-6. Causal loop diagrams are covered in detail by Sterman (2000) and focus on consolidating the links between elements, giving them a ‘direction’ of influence (or causation), and focuses specifically on feedback loops. Stock and flow diagrams explore the influencing factors, and in particular feedback, around a particular stock and its flows in and out. A stock and flow diagram from the workshops can be seen in Figure 4-7.

Figure 4-6: An influence diagram from the workshops

In the adapted approach most of the mapping of the system occurred in workshops. Participants were instructed in how to develop influence diagrams, causal loop diagrams and stock and flow diagrams (hereon called system diagrams) and developed them. Often this was done individually and then in groups, but there were instances where only a group approach
was used (see individual applications). As feedback can be difficult for people to observe and document (Axelrod, 1976), special attention and emphasis was given to it.

The main aim of this exercise was to externalise mental models. Externalising mental models is one way of evaluating their validity and a step towards developing more informed mental models (Senge, 1992). As people externalise their mental models, they test them both as they articulate them and as they review them (see Section 2.3). These externalised models can then be reviewed by the group. Individuals can then keep, alter, or renounce their mental models based on the feedback they receive from themselves and others. Meadows (2008, p.172) calls this step, ‘expos[ing]… mental models to the light of day’.

4.3.6 Develop dynamic model

A system dynamic model was then developed from the information gathered in the workshops, in particular the system diagrams. Forrester (1961), Sterman (2000) and Meadows
(2008) all emphasise the importance of modelling to understand system behaviour. Developing a model helps to understand if the suspected structure of the system is correct and what gives rise to the systemic behaviour observed. It is a way of disproving, informing, and confirming various aspects of the system diagrams and their affiliated abstract mental models.

System dynamic models are often complex and involve nonlinear differential equations. To handle the complexity, system dynamics modelling utilises computer software, which is often specially designed for system dynamics modelling. The software used in this dissertation’s studies were STELLA™ (Stella) and ExtendSim AT™. Vensim™ was also used for generating the causal loop and influence diagrams.

The dynamic model was developed by the author outside of the workshops, but using the information gathered inside the workshops and all other modes of information collection and using workshop participants and other stakeholders as guides. The workshop participants did not develop the models as they did not have the appropriate skills to develop dynamic models (indeed to start with neither did the author, but these were developed over time). However, the information they provided was invaluable. Workshop participants and other stakeholders of the problem were consulted throughout the development phase and were taken through the model being developed several times during development. They clarified points, provided information, and gave feedback about the model and how it reflected reality. This information was taken forward into the development of the model.

---

14 Stella™ is produced by isee systems, inc. www.iseesystems.com
15 ExtendSim AT™ is produced by Imagine That! www.extendsim.com
16 Vensim® is produced by Ventana Systems, Inc. www.wentantsystems.com
4.3.7 Comparison to reference mode

Once the model was developed, the behaviour it exhibited was compared to the reference mode. Comparing results against information obtained from the actual system is a step in the modelling process advocated by Forrester (1961, p. 13), Sterman (2000), and Meadows (2008). Following on from the discussion of confidence building in Chapter 3 and, in particular, the comparison of models to historical data (Section 3.4), the comparison followed Forrester’s (2003, p.5) perspective and that ‘the dynamical character of past behaviour is very important, but the specific values at exact points in historical time are not’. As a consequence, the comparison of the model to the reference mode looked only at comparing the general behaviour of the model to the reference mode and its ‘direction’, for example up, down, oscillating, overshoot, and collapse (see Sterman, 2000 for other general systems observed behaviours).

4.3.8 Revisions and calibration

Revision and calibration were used to alter the model until it represented the system. As discussed in Chapter 3, it is generally accepted that models are not designed to and cannot perfectly imitate the real world (Sterman, 2000; Forrester, 2003; Lane, 2000). However, many modellers still dedicate much time to produce results that imitate data collected from the real world in their models (see Chapter 3). Despite this, some calibration was still needed. In some instances there were variables that could not be known and only vague indications of their values could be obtained. In this case they were estimated and then varied to understand their impact on the behaviour the model exhibited. This is more closely aligned with Forrester’s (1961, p.13) general statement to ‘revise the model until it is acceptable as a representation of the actual system’.
Following rough calibration, the approach then went through a stage of revision, data checking, and readjustment. This stage called on feedback from many individuals about the model and involved several meetings with more superior personnel within the organisations. During the revisions, confidence in the model improved, until it was seen as a satisfactory description of the observed behaviour.

### 4.3.9 Robustness and sensitivity

When confidence in the model was satisfactory, the model went through a stage of robustness and sensitivity testing. This is where model variables, particularly those that had been ‘calibrated’, were varied and their impact on the resulting behaviour exhibited by the model observed. This is a step advocated by Forrester (1961, p.172), Sterman (2000), Meadows et al. (1972), and Osgood (2009). If the model was amply robust and variables’ sensitivity was within reason, further confidence was placed in the model (Osgood, 2009).

### 4.3.10 Policy design and implementation

The final stage of a system dynamics approach is to use the understanding developed during the process and from the model to design policies, possibly simulate their effects in the model, and implement them (Forrester, 1961; Sterman, 2000). This was the longest stage of the work and continued well after the writing of this dissertation.

### 4.3.11 Iteration

Iteration through a system dynamics approach improves the model as new information and understanding are assimilated (Sterman, 2000). Figure 4-8 demonstrates how the adapted
approach was manipulated to incorporate iteration in a workshop style application. It should be noted that problem identification and understanding the system and dynamic hypothesis all started before the workshops, but all were completed either during or after them. The system mapping, dynamic model development, and reference mode identification all began during the workshops. The adapted approach gathered vital information during the workshops, but saw a substantial amount of its work conducted outside of them.

![Image of adapted system dynamics approach](image)

**Figure 4-8: The adapted system dynamics approach**

### 4.4 Workshops: Data capture

Both the scenario planning and system dynamics approaches emphasise the need for data capture, much of which was done during the (group) workshops. Workshops provided the opportunity to engage many different stakeholders and gather their perspectives, expertise, and opinions in many different fields relating to the purpose of the workshops. Furthermore, workshops are an important means for developing strategy (Hodgkinson et al., 2006). The workshops were generally held with between six and thirty participants who were from a diversity of backgrounds and were often cross-functional, cross-organisational, or even cross-industry. They focused on engagement, discussion, and the generation of physical artefacts, aiming to capture the multiple perspectives present to ensure the data collected was considered and comprehensive.
During the workshops a series of activities were used to capture information, including brainstorming, discussions, the mapping and recording of ideas, voting, clustering, and categorising information through ordering or grouping. Facilitators guided the activities during the workshops and were present to answer participants’ questions and clarify activities. Workshop agendas kept the structured activities to a schedule to assist their completion in the given time.

There were two mains reasons for using workshops. First, the workshops allowed groups to be involved in the studies. Second, the workshops assisted the integration of physical, visual tools into the studies, which facilitated sensemaking and mental model development. These two reasons are discussed at greater length in the next two sections.

4.4.1 Groups and collaboration

The reason for using workshops was predominantly to engage groups in the process. There are several benefits of using groups to assist in system dynamics and scenario planning. First, they ensure that the required knowledge is captured (Forrester 1961; 1987; Vennix, 1999). The number of different perspectives helps people to ‘learn and discover new knowledge’ (Zand, 1997, p.74) and provide more information and more insights to a problem (Kanter, 1988). For example, when the rules of engagement are defined appropriately a group of experts can be more adept at addressing a problem than individuals by focusing on their areas of expertise (Steiner, 1972). Different perspectives can also be captured from these experts in the workshops, as they tend to provide different knowledge in a group setting than they do individually (McGraw & Harbison-Briggs, 1989). Together, these perspectives can converge to contribute to a consolidated, sizable, well informed body of knowledge (Phaal et al., 2010, p.100).
Second, and related to the first, groups can enhance learning. By incorporating a number of perspectives more information is supplied for the sensemaking and mental model development. Involving the people for whom the study was conducted (clients, who are usually groups) also enhances the learning that takes place (de Geus, 1988; Morecroft, 1992; Vennix, 1999). Furthermore, the use of groups encourages buy-in and ownership of the results, which increases the likelihood of the implementation of any learning that occurs (Weil, 1980; de Geus, 1988; Morecroft & Sterman, 1994; Vennix, 1999).

There are a number of other benefits of using groups. Groups have the ability to recognise and reject unfeasible or incorrect suggestions or solutions (sense-check) (Shaw, 1932). Groups also help to regulate individuals’ perspectives (McShane & Travaglione, 2005). Furthermore, using groups in the workshops helps to develop group mental models and language; dialogue within a team helps to build common models for thinking (Senge, 1990). Groups can also be self-directing, reducing the need for supervision, while still allowing inputs to be captured from a large number of people (McShane & Travaglione, 2005). Finally, while the cognition and sensemaking still happen on the individual level first, Stigliani and Ravasi (2012) observed that group work is an important part to giving rise to group sensemaking, and hence mental model development.

However, there are also several drawbacks to the use of groups. Teams aren’t always needed for every activity (Sinclair, 1992), this is why some activities were individually orientated and others occurred outside the workshops. Second, teams take time to develop (Steiner, 1972) and in the workshops teams had little time before they had to begin to produce results together. Third, teams always have the issue of social loafing, where people reduce their work intensity and productivity when working in teams (Karau & Williams, 1993). This can be a
particular problem with workshops because they are an unusual activity that participants could have seen as a ‘break’ from their usually daily work. Finally, teams also need a constructive environment that provides them the time and opportunity to develop (McShane & Travaglione, 2005).

The workshops tried to circumnavigate these issues in several ways. First, they used facilitators to guide the work and encourage discussion. They acted as an early intermediary to encourage discussion and draw those not participating into the discussion. Second, hastening through team development (see the team development model in Tuckman & Jensen, 1977) to a point where they could be productive was also another method employed to avoid some of the costs (time) and delays in creating a productive team. The facilitators assisted this process too by focusing the team and urging for constructive input to the activities early. Icebreaker activities also help to hasten the team development stage of the workshops. In the studies team development did not prove much of an obstacle during the workshops because many of the participants were at least familiar with each other and their fields before they began, which was a partially anticipated bonus. Finally, the activities themselves were designed to encourage team work, input, and critical, unaggressive discussion. The culture in the workshops, the task meaningfulness and expectations of performance were also used to reduce social loafing (Karau & Williams, 1993).

Another problem with using groups is the notion of groupthink (Whyte, 1952; Janis, 1971; Janis, 1972; ’t Hart, 1990). Despite the fact that groups can increase the perspectives drawn on, there is still the possibility that there is excessive concurrent thinking among a group (Janis, 1972). However, groupthink mainly occurs when small groups are the main locus of decision making (’t Hart, 1990), expanding the group by introducing a number of stakeholders,
specifically those that might not otherwise have been included, the opportunity for groupthink to occur is reduced.

Groups as a source of knowledge have been used widely in system dynamics. Randers (1977) suggested using reference groups to support dynamic model development. Richardson et al. (1989) looked at small groups and how they could help develop models, particularly given the computer software available. Vennix (1990) has also worked on using groups to develop models, but with larger groups in workshop like situations (for other examples see Morecroft, 1992; Lane, 1992; Morecroft & Sterman, 1994; Vennix, 1996; Phaal et al., 2010; Wright & Cairns, 2011).

4.4.2 Materials and physical visual tools: Posters, markers, Post-its, and sticky-dots

Another reason for using workshops was that it allowed visual, physical tools to be employed. Visual tools assist individual sensemaking to rise up through a group (Stigliani & Ravasi, 2012). However, not only did the use of workshops allow the use of physical materials, but the use of physical materials helped the workshops to operate. To assist with data capture many tools commonly used in visual meetings were employed (see Sibbet, 2010; 2011; Stigliani & Ravasi, 2012). These tools have been used extensively in other workshop driven approaches, including Technology Roadmapping (Phaal et al., 2010) and used extensively by many organisations and institutions, including the Institute for Manufacturing Education and Consultancy Services (IfM ECS), University of Cambridge.

The physical visual tools were designed around the activities in the workshops. Almost all the activities used posters, Post-its, sticky-dots, specifically designed worksheets, or a combination
of these. In many of the activities participants offered ideas and suggestions (hereon information) they thought needed to be captured for the activity. The information was put on Post-its and placed on posters. There was a ‘Post-it protocol’ which outlined the desired structure of information on the Post-it (see Figure 4-9). Participants included their initials on the Post-its so that the ideas could be traced if clarification was needed. The posters were structured to provide clear guidance on the aim of the activity, often with categories to help stimulate ideas and assist clustering Post-its. Sticky-dots were used for voting to rank the Post-its or to assess the information on the Post-its. For example, in the scenario planning exercises people had to vote on the uncertainty of trends and drivers. Finally, in a few activities, worksheets were used to capture the information. These were particularly useful for individual exercises, in the blending exercises (discussed in Section 4.5.1), and where mobility was important.

![Figure 4-9: Post-it protocol](image)

There are three groups of benefits which were the reasons for using the visual tools in the workshops. The first group of benefits focused on gathering the raw information needed for the activities. The second group developed the information further and creating new concepts and encouraging the synthesis of the information present. The final group of benefits were ‘post benefits’, the benefits of having used the visual aids during the workshop for probing and verifying ideas.
Capturing information

- The ‘physical handle’ - The visual aids provided a ‘physical handle’ on abstract concepts for both profferer of the concept and other participants (Stigliani & Ravasi, 2012). Doing this helped to capture ideas and assists to consolidate ill formed concepts (Stigliani & Ravasi, 2012). Furthermore, it clarified the ideas for other participants, making them more accessible (Stigliani & Ravasi, 2012). Post-its were particularly useful here for their ability to be removed and clarified or discarded if the information was not relevant.

- Externalisation – the visual tools encourage the externalisation and articulation of concepts. Making them explicit means they are open to debate, even for sceptical review by the individual who proposed the concept. Senge (1992), calling it externalisation, and Meadows’ (2008, p.172), calling it ‘exposing…. to the light of day’, believe that this is key to assessing one’s mental models.

- Focus – visual aids help to focus the participants (Sibbet, 2010, p.34). The posters were used to gather the participants around, to keep the aim of the activity clear, and to keep them on task.

- Framing – the posters and other participants’ concepts helped to frame the activity for participants, assisting them to understand what was needed and how this information was being communicated.

- Capturing a number of perspectives – the flexibility of physical tools enable a number of different perspectives to be captured without being restricted by the constructs of other perspectives (Sibbet, 2011, p.17).

- Stimulation of information to include – By creating categories for ideas on the posters, context was created for the data required for the activities. Furthermore, physical aids meant that participants could easily read the materialisation of other participants’ ideas, possibly prompting them to include information they had not previously selected for inclusion.

- Energising – the use of physical materials got participants up and moving around, removing the doldrums of presentations.

- Retrospective reassessment of ideas and concepts to establish if current beliefs hold (Stigliani & Ravasi, 2012, p. 1248)

Developing concepts further

that such ‘bucketing’ is the sorting of experiences that Porac and Thomas (1990) argue
gives rise to new mental models. Furthermore, the ability of Post-its to stick to a poster
and then be moved provided flexibility to cluster and re-cluster concepts.

- Filtering – physical tools allow easy and direct comparison between information, allowing
it to be filtered for significance and relevance (Sibbet, 2011, p.16).
- Extending the mind – as ‘cognitive artefacts’ (Norman, 1991, p.17), the visual tools extend
the capacity of the brain (Stigliani & Ravasi, 2012; Clark & Chalmers, 1998; Clark, 2008). By
storing the information physically in artefacts they act as additions to memory and assist in
processing (Clark & Chalmers, 1998). In short they can help to overcome many of the
cognitive limitations of the mind.
- Production of new abstract concepts – visual tools also assist the development of new
abstract concepts (Stigliani & Ravasi, 2012). By developing new links and seeing what
information might be relevant, the physical materials assisted the development of new
concepts. Furthermore, Stigliani and Ravasi (2012) found that purposeless manipulation of
the artefacts can lead to an idea emerging accidentally, which was not ruled out in the
design of the workshops and the inclusion of physical tools.
- Blend perspectives - Experiencing concepts physically has also been demonstrated to assist
finding the relationships between different viewpoints (Cronin & Weingart, 2007; Bürgi &
Roos, 2003).
- Physical representation of gaps leading to identification – Visual tool assists the physical
representation of gaps that may be obscure when abstract. Cronin and Weingart (2007)
found that physical tools assist with the identification of gaps between different sets of
conceptual understandings. By the same method, the physical artefacts helped to define
general conceptual gaps, leading to the identification of their presence abstractly.
- Encourage comparison – Visual aids also encourage the comparison of concepts (Sibbet,
2010, p.112). By materialising the concepts and making them readily communicable,
participants readily made comparisons between concepts or clusters of concepts.
- Encouraging communication and discussion – the use of physical materials creates a
common metaphor which assists communication and discussion (Lakoff & Johnson, 1980).
The visual materials also got participants up and moving around physically facilitating
communication and discussion (Sibbet, 2010).

‘Post benefits’ – Probing and recording
• Audit trail/ referencing system – having the information captured in a physical form meant that the information was easier to trace (Stigliani & Ravasi, 2012). Furthermore, practices like the Post-it protocol ensured concepts could be traced to their origin.

• Retrospective confirmation – visual aids allowed participants to analyse the route through which concepts were developed (Stigliani & Ravasi, 2012). This retrospective confirmation allowed participants to follow thought pathways and check for their feasibility.

• Transport – capturing the ideas on Post-its and posters made them easy to transport and store.

Perhaps the best way to conclude this section is to examine the role of physical materials in sensemaking, rather than just their benefits. Stigliani and Ravasi (2012) provide four macrophases of sensemaking: noticing and bracketing, articulating, elaborating, and influencing. Through sensemaking participants are examining stimuli and their mental models and comparing their disparities. Through these four phases sense is made out of stimuli, and along the way, people are scrutinising their mental models. Table 4-1 (opposite) shows how some of the benefits of visual tools assist the process of sensemaking. The other benefits discussed above not included in Table 4-1 are either procedural or have other non-sensemaking benefits for the process.
### Table 4-1: The four macrophases of sensemaking the benefits physical aids have in those phases

<table>
<thead>
<tr>
<th>Macrophase of sensemaking (Stigliani &amp; Ravasi, 2012)</th>
<th>Benefit (and reason for the employment) of physical aids</th>
</tr>
</thead>
<tbody>
<tr>
<td>Noticing and bracketing</td>
<td>'Noticing’ and including information individuals already have</td>
</tr>
<tr>
<td>Articulating</td>
<td>Gather relevant information</td>
</tr>
<tr>
<td></td>
<td>Individuals 'checking' tentative concepts by articulating them</td>
</tr>
<tr>
<td></td>
<td>Make concepts (and hence mental models) 'explicit and subject to public examination’ (Senge, 1992, p.9)</td>
</tr>
<tr>
<td></td>
<td>Providing a 'physical handle' on abstract concepts (Stigliani &amp; Ravasi, 2012)</td>
</tr>
<tr>
<td>Organising</td>
<td>Organising - classifying and clustering ideas, based either on their similarity, causal relationship, chronology, or some other method of categorisation (Stigliani &amp; Ravasi, 2012)</td>
</tr>
<tr>
<td>Elaborating</td>
<td>Common metaphor for communication and discussion (Lakoff &amp; Johnson, 1980).</td>
</tr>
<tr>
<td></td>
<td>Making the connections between concepts stronger (Stigliani &amp; Ravasi, 2012)</td>
</tr>
<tr>
<td></td>
<td>Production of new abstract concepts</td>
</tr>
<tr>
<td></td>
<td>Blend different perspectives (for example see Bürgi &amp; Roos, 2003)</td>
</tr>
<tr>
<td></td>
<td>Finding gaps in conceptual understandings</td>
</tr>
<tr>
<td></td>
<td>Encouraging comparisons (Sibbet, 2010)</td>
</tr>
<tr>
<td>Influencing</td>
<td>Strengthen concepts by using the materials for retrospective ‘checking’ and consolidation (Stigliani &amp; Ravasi, 2012)</td>
</tr>
<tr>
<td></td>
<td>Demonstrating the links between concepts and the flows and causes of events (Stigliani &amp; Ravasi, 2012)</td>
</tr>
<tr>
<td></td>
<td>Support the development of a group level mental model</td>
</tr>
</tbody>
</table>

## 4.5 Techniques

### 4.5.1 Pair-blending

Pair-blending is a technique that uses the different experiences and opinions of people to create a single understanding of the world. People are placed in pairs (although three can be used, pairs are best as it means one person cannot be excluded from the discussion) and asked to compare and merge their perceptions of reality or an idea and use discussion to come up with one single representation.
The origins of pair-blending are unclear. It appears to be a tool frequently used in education as one of many collaborative learning exercises (Macpherson, 2000). The author’s first exposure to it during this work was at the University of Cambridge, whose industry fellows used the technique in many different guises in their workshops. It was later discovered that pair-blending was also used in Collaborative Conceptual Modelling (CCM), a technique pioneered by Barry Newell and Katrina Proust at the Australian National University (see Newell et al., 2008; Newell & Proust, 2009; Newell et al., 2011).

4.5.2 Data capture: System dynamics

Data and understanding the state of the system is a pivotal part of a system dynamics approach (Sterman, 2000; Meadows, 2008). Data helps develop an understanding of the system and how it is behaving. In terms of modelling, data provides the inputs and defines the reference mode for the system – the behaviour against which simulations are compared (Sterman, 2000).

The data for the system dynamics approaches taken in this work was collected in a variety of ways. Data was gathered during the workshops, where individuals and groups mapped out the system: its boundaries, stocks, variables, and inferences and highlight their feedback loops. Data was also gathered outside of the workshops, through financial records, individual interviews and meetings, group meetings, and board meetings. Data captured through these methods was also used to define the relationships between variables, particularly for those that could not be directly observed, and was used to develop the dynamic models and assess confidence in them.
4.5.3 Hexagons

The 'Hexagon' method outlined by Hodgson (1992) and Lane (1992) was used to develop preliminary influence diagrams. Participants, again in their small groups of five or six, placed one of the assigned key uncertainties on a hexagonal Post-it note in the middle of a poster. They were asked to place factors that influenced or were influenced by the central factor, one per hexagonal Post-it note, adjacent to the key uncertainty. Factors that influenced the key uncertainty through another factor were placed adjacent to the first order factor and so on, expanding the influence diagram and building a visual connection between the influencing factors.

4.6 Method of process evaluation

To establish if scenario planning can inform system dynamics and if the reverse is also possible, a method of evaluation was developed. The evaluation of the case studies was essential for understanding the combined approaches and ameliorating them. Without a method of evaluation, the effectiveness of the case studies could not be assessed and possible methods of improvement could not be established.

The techniques employed in gathering information for the evaluation were: surveys, in-workshop observation, recorded results, ongoing feedback through meetings, and public documents. Platts (1993) identified three methods of research evaluation for process development: action research, direct observation, and participant observation. Action research was the approach taken for the overall development of the process, as outlined earlier. Direct observation was elicited through workshop notes of observations and analysis of results from the workshops. Participant observation was achieved through surveys, informal feedback (also captured in workshop notes), meetings, and public documents.
4.6.1 Direct observation

The final method of evaluation, and the most subjective, was observation, non-surveyed questions, and feedback. Observations were made during the workshops and notes were made. These were about the general behaviour of participants, how they reacted in particular situations, and general information that would not have been captured in the workshops. Informal feedback was also gathered during the workshops, mostly where participants made verbal comments about the process or about the results. Finally, some of this feedback was in response to general comments or questions made by the facilitators ‘in the moment’. Some of the responses to these comments and questions were noted down. It is important to note that as the workshop requirement from facilitators were high, sometimes notes were not made. However, where possible they were recorded.

4.6.2 Participant observation

Participant observation was predominantly gathered through surveys, but also involved informal feedback, meetings, and public documents. The informal feedback, meeting notes, and public documents were collated for the assessment throughout the studies. This feedback was potent when it came from a number of people involved in the process. Peterson et al. (2003), for example, believe that a way to assess scenarios’ plausibility is by finding if a number of actors and stakeholders also find the scenarios plausible. However, in many cases the meeting notes and public documents were brief, contained little information, or both. The most employed and valuable source of participant observations were the surveys.
4.6.3 Surveys

To capture much of the information for evaluation, surveys were adopted in two of the case studies. These surveys were constructed using literature (see Appendix A). They were also constructed for five central purposes, to evaluate: the scenarios, the system dynamics elements of the process, the ability of the process to address decision problems, how the understanding of participants changed during the process, and whether the mechanics of the process involved worked.

**Scenario planning traits**
The evaluation of scenarios focussed on the traits that scenario planning researcher, and practitioners have advocated scenarios should have. Scenarios themselves ‘cannot be proved or disproved’ (van der Heijden, 2005, p.110). However, there is ample advice from van der Heijden (2005) and others (including Wack; 1985a; 1985b; Schoemaker, 1995; Schwartz, 1996; Miesing & Van Ness, 2007) as to what scenarios should be. A consolidated list of these traits and the questions that attempt to extract that information from workshop participants and clients can be seen in Appendix A. The authors suggest that these are traits that will help scenarios be more effective and change the mind-sets of decision makers (for example, Wack, 1985a; Schwartz, 1996; van der Heijden, 2005; Chermack et al., 2001). A similar approach to the ‘products’ of system dynamics was not taken as authors in the field do not expound the desired traits of a dynamic model. For a description of these traits please see Appendix A.

**System dynamics**
The system dynamics literature identifies little in the way of what the final ‘product’ of system dynamics should be (more what it should do). As a consequence the evaluation of system dynamics is more in the process, with only two ‘product’ traits. Such process factors include improving participant’s understanding of key variables (Sterman, 2010; Meadows, 2008),
accumulation (Booth Sweeney & Sterman, 2000; Meadows, 2008; Sterman, 2010), and feedback (Booth Sweeney & Sterman, 2000; Meadows, 2008; Sterman, 2010). A full list of the system dynamics process and product traits and their corresponding questions can be found in Appendix A.

Process traits
The criteria for evaluating the process was also drawn from the literature on problems, decision making, problem structuring methods, system dynamics, and scenario planning literature. Measuring only the outcomes of a process does not give a complete evaluation of it (Holton, 1996), so this process approach was adopted to accompany the assessment of workshop outcomes. Advocated traits of processes that address decision problems (remembering that this includes decision problems, ‘wicked’ problems, and the related ‘social messes’) was collated and compared and used to structure the surveys. The process traits included its ability to Surface an individual's views (Shaw, 2006; Senge, 1992), Use the knowledge acquired to expand understanding of the situation, Uncover new perspectives (Radford, 1977; van der Heijden, 2005), and generate ownership (Rosenhead, 1996). A full list of the process traits and its corresponding questions can be seen in Appendix A.

Understanding
Many of the questions in the questionnaires were aimed at understanding if the client group’s understanding changed over the process and how. This was done in two ways, firstly by assessing understanding before and after the workshops and assessing if their understanding had changed. The dimensions on which understanding was measured included the participants’ change in perceptions of the problem (Schoemaker, 1993) and the participants’ change in perceptions due to the scenarios (Wack, 1985a; Schwartz, 1996; van der Heijden, 2005) and to the system dynamics model (Forrester, 1961; Sterman, 2000; Senge, 2006). A full
list of the dimensions and their corresponding survey questions can be found in Appendix A. These were perhaps more important than assessing the nature of the scenarios or system dynamics model (van der Heijden, 2005, p.159), but are difficult to assess with accuracy.

4.7 Summary

As stated, to understand if and how system dynamics can inform scenario planning, and the reciprocal, five studies were run that integrated the two approaches in different ways. The next five chapters outline each of the five studies and their different approaches to integrating scenario planning and system dynamics. The studies discuss the application of the elements of the approaches discussed in this chapter and identify those that worked and those that did not. An understanding of the practical elements of system dynamics and scenario planning and how they interacted was required to develop effective integrated approaches.

The studies also exemplify alternative methods of integrating the approaches. It is essentially a process of trial and iteration to devise approaches that integrate scenario planning and system dynamics usefully and effectively.
Chapter 5   Future Scenarios for the Food and Drink Industry

![Diagram](image_url)

Figure 5-1: An (over)simplified guide regarding which elements of the two approaches were adopted for this study and the order in which they were commenced.

5.1 Key structure elements

The Future Scenarios of the Food and Drink Industry was the first study conducted. This study adopted an approach very similar to that of the benchmark scenario planning approach, with only a minor inclusion of system dynamics. Little of the literature actually describes a scenario planning process (an obvious exception, which was published after this study was conducted, is Wright and Cairns, 2011). The benchmark approach was developed based on the vague approaches described in the various sources cited in the previous chapter. This study was used to establish if the benchmark scenario planning approach could generate useful, realistic, believable, relevant, and complete scenarios, all of which are important traits of scenario planning (Wack, 1985a; Schwartz, 1991; Bloom & Menefee, 1994; Schoemaker, 1995, p.30; van der Heijden’s 1997; Wilson, 1998; Chermack et al., 2001, p.27; van der Heijden, 2005, p.225; Miesing & Van Ness, 2007, p.149). The results from the case study make important contributions to assessing the method (as well as being valid conclusions in their own right). The methodological conclusions from this study were then be used to assist the development of the scenario planning approaches used in all the following studies.
This study had one difference to the scenario planning benchmark process: the inclusion of a systems mapping exercise, specifically solely the development of influence diagrams, into a scenario planning process (as shown in Figure 5-1). In this study, this activity was done after the key uncertainties had been identified, but before the scenarios were developed. This timing of this activity was chosen because a discussion of the drivers of a system flowed on from the discussion of trends and drivers and the uncertainties in that system. This activity was included because this study was to set help establish the benchmark approach, and it was a low impact inclusion into the scenario planning process. Furthermore, the low impact inclusion was also desirable as it was applied to a real world study, which used the resources of private and public organisations, who were interested in developing scenarios, and not in the integration of system dynamics.

5.2 Context

The study was part of a scenario planning project for the Food and Drink Federation of the United Kingdom (FDF)\textsuperscript{17}. The FDF Future Scenarios Study (here on the FDF study) was a group based method, designed to gather information through workshops and develop group based scenarios. The study was run by the Institute for Manufacturing Education Consulting Services (IfM ECS)\textsuperscript{18} at the University of Cambridge, with assistance from the author. Many of results from the study were published in Livesey et al. (2010).

This study provided a real world application of scenarios planning, using experts from diverse stakeholder groups. This formed a benchmark study to understand the scenario planning process and representative insights.

\textsuperscript{17} http://www.fdf.org.uk/
\textsuperscript{18} http://www.ifm.eng.cam.ac.uk/services/overview/
The FDF study aimed to bring together a multitude of stakeholder perspectives to develop a set of alternative futures for the Food and Drink Industry in the UK. The project was motivated by a lack of multi-stakeholder research into the future of the UK food and drink industry, with the exception of a few detailed projects (for example the Food 2030 report, see DEFRA, 2010).

The project brought together people from agriculture, manufacturing, retailing, the civil service, industrial bodies, and the broader community (consumers and other stakeholders) to explore the major trends and drivers in the industry and develop a set of scenarios into which the food and drink industry could evolve. The project was conducted in 2010 and aimed to project forward to 2025.

It is appropriate here to acknowledge the main contributors to this study. The workshop process development and facilitation were carried out under the auspices of IfM ECS at the University of Cambridge by Dr Finbarr Livesey, Ilaria Frau-Hipps, Dominic Oughton and the author with process development advice from Bill Colquhoun. Apologies extend to any other people who assisted in developing the process who have been omitted from this short list.

5.3 Aim and premise

The first aim of the FDF study was to establish a method for developing scenarios. The previous chapters brought together a scenario planning approach adapted from the various, somewhat vague, approaches discussed in the relevant literature. This study aimed to put these steps into practice and develop a practical way of developing scenarios.
The second aim of the FDF study was to understand how the integration of scenario planning and system dynamics could be achieved. It aimed to understand one aspect of this by testing if, in this instance, influence diagrams could be worked into a scenario planning approach. Developing influence diagrams is a method of mapping the system in system dynamics. By building in this step first it lays the ground work for more comprehensive integration of the techniques, so that the thesis of the dissertation can be tested more comprehensively.

The third aim of the FDF study was to explore developing scenarios and the possibility, feasibility, and benefits of developing influence diagrams using the trends and drivers identified in the scenario planning process (as shown in Figure 5-1 at the beginning of the chapter). The influence diagrams would be developed before the scenarios themselves would be developed in an attempt to understand how well they inform the scenario development process. Figure 5-2 (opposite) shows the process in terms of the steps outlined in Chapter 4. Again the steps from scenario planning are shown in blue and the steps from system dynamics in red. These steps will be explored and used as a guide to convey the study’s result in the following section.

Using influence diagrams to explore the key uncertainties was aimed at developing a better understanding of them and hence developing more internally consistent, complete, and plausible scenarios. By developing influence diagrams, people make their mental models explicit and compare them to other group members’ mental models (Senge, 1992). By making them explicit and using the group to moderate and inform individuals’ mental models it is thought that more robust mental models, reflected here in the influence diagrams, can be developed (Senge, 1992; Vennix, 1996). The understanding developed in this activity can then be drawn into the development of scenarios.
The belief that influence diagrams help develop scenarios that are more internally consistent, complete, and plausible is held by researchers and consultants such as van der Heijden (2005). However, an extensive search of literature in the field found only anecdotal evidence to support this claim and no study has been conducted to test this theory.

This study provided an understanding of how scenarios can be developed. The study developed scenarios that were seen as both relevant and useful by the FDF. It established a scenario development process that was carried forward into the other studies. However, the elements of system dynamics that were included in the study failed to be used or to inform the scenario development process. The type and level of integration attempted was not successful.
5.4 Method, results, and observations

The study involved two large scale multi-stakeholder workshops which were supplemented by desk-based research and analysis and individual and group stakeholder interviews. The workshops were structured as shown in Figure 5-2. These study phases are outlined in more detail below. Accompanying the explanation of the activities are their results and observations made during the activities.
5.4.1 Identifying the client

(Step 1, pre-workshops)
The client was identified as the Food and Drink Federation of the United Kingdom. The federation is a not-for-profit membership organisation. Its members include UK food and drink manufacturers and trade associations. Its function is to liaise between its member organisations and the UK civil service, media, regulators, and consumers.

5.4.2 Identifying the purpose

(Step 2, pre-workshops)
The next step of the process was to identify the purpose of the scenarios. This was done in a series of meetings with the FDF and some of the larger stakeholders in the food and drink industry. In general the FDF wanted to know what the major pressures on the food and drink industry might be and how this might affect its various stakeholders.

5.4.3 Articulating current mindset/mental models

(Step 3, pre-workshops)
The particular issues that were of concern in these meetings were the interrelated issues of global warming, UK’s dependency on imports to the industry, and the availability and sustainability of food production and supply. These were the issues ‘keep[ing] … [them] up at night’ (Simpson, 1992, p.12). However, it was deemed best that these concerns were not brought directly into the workshops so not to reduce the focus of the ‘general drivers’; the belief was their pertinence would give rise to them in the workshop and that the extra drivers would provide a rich context for the investigation of the problem.
5.4.4 Refining the focus and setting horizon year

(Step 4, pre-workshops)

With little refinement to be done, the supplied information allowed the FDF and the Institute for Manufacturing (IfM), University of Cambridge to gain a greater understanding of why the problem must be addressed, who the problem affects, what the options are to solve the problem, and who is best qualified to address it. Scenario planning was chosen to be the most appropriate technique for the FDF project (which is when the author was brought into the project). The workshops were then purposefully structured to appropriately apply scenario planning to the unique application of the FDF and the Food and Drink Industry. The target year was also set at 15 years into the future, in the year 2025.

5.4.5 Identifying the trends and drivers

(Step 5, workshop 1)

Workshop 1
The first workshop involved 26 participants from a range of stakeholder groups in the food and drink industry. The participants included suppliers (agriculturalists), producers (manufacturers and wholesalers), retailers, civil servants, research organisations, industry representative groups, and people from broader society - consumers. The workshop was held over one full day.

Process: Identification of trends and drivers
The first activity in the workshop was to identify the major trends and drivers for the food and drink industry. Participants brainstormed trends and drivers and recorded their ideas. Understanding the trends and drivers around the focus of the scenarios is an important step in scenario planning (Wack, 1985a; Schwartz, 1996; van der Heijden, 2005; Ringland, 2006;
Wright & Cairns, 2011). They help to identify the underlying patterns and causes of events in the world (Forrester, 1961; van der Heijden et al., 2002; van der Heijden et al., 2005; Maani & Cavana, 2007). These patterns and causes contribute to defining the future (van der Heijden et al., 2002; van der Heijden et al., 2005; Maani & Cavana, 2007).

Observations
During this activity participants had thoughtful and productive discussions. Many trends and drivers were suggested on which the group as a whole agreed. Others were suggested that many thought were novel and that had not previously been considered. Some participants were naturally inquisitive or fell into a role of questioning trends and drivers and asking others to expand upon what they were offering. It was noted however, that this mostly led to constructive discussion and not intimidation.

The only intimidation that was present, and noted in feedback, was set by the background of the participants workshops. It was noted that with the presence of particular stakeholder groups in the workshop, others may be reluctant or even avoid offering trends and drivers that could be perceived to be negative towards those groups, especially if it suggested that those behaviours were widely considered adverse for the industry. The way the workshops were designed, the facilitators were able to offer these trends and drivers that might have caused problems to ensure the field was covered comprehensively. Third parties, such as not-for-profit organisations or stakeholders who were removed by degrees of separation in the supply chain, were also able to offer this information. These were important contributions as facilitators, not being experts in the field, did not know of all the trends and drivers of the industry.
Process: Collation of trends and drivers
After the brainstorming exercise the trends and drivers were only ordered roughly on the posters.

Results
The workshop facilitators grouped the trends and drivers into larger groups and named the groups. This allowed closely related issues to be grouped and created a discrete number of trends and drivers that could be easily processed and referenced by the participants. The resulting trends and drivers are shown in their respective categories in Table 5-1 (opposite).
<table>
<thead>
<tr>
<th>Trends and drivers</th>
<th>Trends and drivers</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Political and legal</strong></td>
<td><strong>Technology</strong></td>
</tr>
<tr>
<td>Increasing regulation</td>
<td>Increase efficiency via technology</td>
</tr>
<tr>
<td>Government policy coherence</td>
<td>Funding for research and innovation</td>
</tr>
<tr>
<td>Reduction in fiscal revenues/budget</td>
<td>Legal/ regulatory constraints on technology</td>
</tr>
<tr>
<td>Reforming regulation</td>
<td>Packaging</td>
</tr>
<tr>
<td>Health and welfare costs</td>
<td>Energy sources</td>
</tr>
<tr>
<td>Health concerns and regulations</td>
<td>Use of food in health nutraceuticals</td>
</tr>
<tr>
<td>Party politics vs. people’s aspirations and demands</td>
<td>Party politics vs. people’s aspirations and demands</td>
</tr>
<tr>
<td>Increasing role/ strength of EU</td>
<td>Increasing role/ strength of EU</td>
</tr>
<tr>
<td><strong>Food industry</strong></td>
<td><strong>Environment and resources</strong></td>
</tr>
<tr>
<td>Skill availability</td>
<td>Impact of climate change</td>
</tr>
<tr>
<td>Raising standards</td>
<td>Water stress and management</td>
</tr>
<tr>
<td>Role/ importance of brands</td>
<td>Energy availability</td>
</tr>
<tr>
<td>Fragmentation of MNF globally</td>
<td>Efficient use of raw materials</td>
</tr>
<tr>
<td>Food integrity (and safety)</td>
<td>Loss of biodiversity</td>
</tr>
<tr>
<td>Need to generate value for money</td>
<td>Reduction in inputs for agriculture</td>
</tr>
<tr>
<td>Change perceptions within the industry</td>
<td>Food Scarcity</td>
</tr>
<tr>
<td><strong>Economic</strong></td>
<td><strong>Social and Consumer</strong></td>
</tr>
<tr>
<td>Price of raw materials</td>
<td>Health concerns and issues</td>
</tr>
<tr>
<td>Cost of energy</td>
<td>Population growth</td>
</tr>
<tr>
<td>Availability of finance for investment</td>
<td>Food safety (demand, perceived v actual)</td>
</tr>
<tr>
<td>Waste reduction</td>
<td>Food security (concerns for)</td>
</tr>
<tr>
<td>Low carbon economy</td>
<td>Aging population</td>
</tr>
<tr>
<td>Economic shift (new economy and role of China etc.)</td>
<td>Ethics and behaviour (moral/ ethical consumption, resistance to techs)</td>
</tr>
<tr>
<td>Rising affluence</td>
<td>Skills and education</td>
</tr>
<tr>
<td>Effects and evolution of economic cycle</td>
<td>Social values on fairness, equity etc.</td>
</tr>
<tr>
<td>Comparative advantage of countries not regulating environmental costs</td>
<td>Information (increased access and availability, speed of communication)</td>
</tr>
<tr>
<td>Availability of low cost food</td>
<td></td>
</tr>
<tr>
<td>Acceptability of technologies</td>
<td></td>
</tr>
<tr>
<td>Role of social media</td>
<td></td>
</tr>
</tbody>
</table>

**Table 5-1: Trends and Drivers for the Food and Drink Industry**

**Observations**

Many of these trends and drivers overlap and others are not independent. Overlap exists, for example, between *Water stress and management* and the *Impact of Climate Change* as water stress is a predicted impact of climate change. Other trends and drivers are related, including for example, *Health and welfare costs* and *Health concerns and regulations* are interrelated, where one has a substantial impact on the other. Furthermore, some of the names of trends
are unclear and need interpretation. For example, *Low carbon economy*, on its own is not a trend or driver (it is more of a challenge). The trend behind this is a drive for an economy producing lower carbon emissions through lower energy consumption, alternative energy sources, or both.

However, no problems were observed in the workshops with the issues of overlap, dependence, and poorly worded trends. Overlaps are almost impossible to avoid without the groups becoming so broad that they lose much of their meaning. Dependence is also acceptable, as noted many times by scenario planning authors including Schwartz (1991; 1996) and van der Heijden (1997; 2005) and was the topic of exploration later in the workshop.

Poorly worded trends could cause issues for a scenario planning process. If participants were inclined to think little about the words then they may not uncover the full extent of the trends behind the words. For example, *Skill availability* was about a shortage of skilled personnel in particular areas. As it is stated here the extent of this driver, its causes and consequences could be unclear to people both inside and outside the field. As noted however, in this particular instance this was not an issue.

### 5.4.6 Identifying the predeterminants and uncertainties

*Step 6, workshop 1*

*Process: Separating the trends and drivers into predeterminants and uncertainties*

The trends and drivers were then separated out into predeterminants and uncertainties.

Participants selected the trends and drivers with the greatest impact on the industry. They then selected those with the highest uncertainty to be the uncertainties.
Results

The trends and drivers were mapped against impact and uncertainty (Figure 5-3) to find those with the greatest impact on the industry and the greatest uncertainty (top right corner).

![Diagram of key trends and drivers mapped by uncertainty and impact]

Through a process of cross-multiplying the votes for impact and uncertainty (see Appendix B), 12 trends and drivers were chosen to take forward to form the key uncertainties. These 12 trends and drivers were reviewed and refined and became the final 12 key uncertainties. These can be seen in Table 5-2 (overleaf). An explanation of these uncertainties can be found in Appendix B.
Observation
Despite there being some practical issues with the exercise (see Appendix B) the participants generally agreed with the results yielded. There were some issues with limited voting rights and the pairing off of options. Furthermore, it is evident from the pattern of voting that some participants voted on trends and drivers that they had a vested interest in or they saw as very important to them. The fact that some participants still selected uncertainty levels on trends and drivers with almost a negligible impact on the process supports this claim (see Appendix B). Most participants though executed the activity correctly.

The development of a description of these uncertainties highlights that the uncertainty ‘name’ alone is not enough. It was found that the ‘paper trail’ or audit trail back to the ideas in the brainstorming sessions was essential to supplying the detail of these uncertainties. Stigliani and Ravasi (2012) provide reasons why this is important in the process of group sensemaking.

This step effectively mapped the trends and drivers on an axis of uncertainty (x-axis) and an axis for impact (y-axis) and those with the highest combination of the two (in the upper right of the field defined by the Cartesian coordinates) would be the 12 key uncertainties. However,

<table>
<thead>
<tr>
<th>Uncertainty</th>
</tr>
</thead>
<tbody>
<tr>
<td>Efficiency improvements through technology</td>
</tr>
<tr>
<td>Water stress</td>
</tr>
<tr>
<td>Regulation level and coherency</td>
</tr>
<tr>
<td>Energy security (availability, mix)</td>
</tr>
<tr>
<td>Raw materials cost and availability</td>
</tr>
<tr>
<td>Consumer ethics and behaviour</td>
</tr>
<tr>
<td>Funding for research and innovation</td>
</tr>
<tr>
<td>Health concerns and issues</td>
</tr>
<tr>
<td>Availability of skills</td>
</tr>
<tr>
<td>Impact of climate change</td>
</tr>
<tr>
<td>Cost of energy</td>
</tr>
<tr>
<td>Citizens’ attitude</td>
</tr>
</tbody>
</table>

*Table 5-2: The 12 key uncertainties*
in the time restrictions on the workshop, the facilitators chose the key uncertainties based on estimates of the distribution of votes. Although, when the selection was later checked against the graphical representations it was found the facilitators had chosen correctly, there were some marginal trends and drivers that could have lead the facilitators astray. To avoid possible issues with this process, a more formal and robust process was developed for future workshops. This process included using a scoring system based on the number of votes to develop a cross-multiple of impact and uncertainty, which removed the educated guess of key uncertainties that occurred in this workshop. More detail on the process used in this study can be seen in Appendix B and more information on how it was changed for later studies can be seen in Appendix E and Appendix F.

This process effectively separated the predeterminants from the uncertainties. This is a common step in scenario development as it is unnecessary to speculate on factors that are already relatively determined (Schoemaker, 1995; van der Heijden, 1997; 2005; Schwartz, 1991; 1996; Wack, 1985a; 1985b). However, this activity stopped short of dividing them into two lists, as Schoemaker (1995), Schwarz (1991; 1996), and Wack (1985a; 1985b) do. Instead, it placed the trends and drivers on continuums of impact on the industry and uncertainty, which preserved their relative attributes.

*Process: ‘Extreme’ endstates*

The ‘extreme’ endstates of the key uncertainties were then identified, as discussed in the method (Section 4.2). These endstates outlined the result or ‘situation’ of an uncertainty in the target year for the study.
Results and Observations

The results of this process can be seen in Table 5-3. It is evident from the results that participants did attempt to push their thinking and consider opposing extremes. For example, for Energy security they saw energy as being reliably available and unreliable.

<table>
<thead>
<tr>
<th>Uncertainty</th>
<th>‘Extreme’ A</th>
<th>‘Extreme’ B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Efficiency improvements</td>
<td>Slow/low improvements in production efficiency</td>
<td>Rapid improvements in production efficiency</td>
</tr>
<tr>
<td>through technology</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water stress</td>
<td>Water stress made manageable</td>
<td>High water stress due to lack of action</td>
</tr>
<tr>
<td>Regulation level and</td>
<td>Appropriate and timely regulation of industry</td>
<td>Incoherent policy and regulation across governments</td>
</tr>
<tr>
<td>coherency</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Energy security</td>
<td>Energy reliably available</td>
<td>Unreliable energy supply and constrained mix</td>
</tr>
<tr>
<td>(availability, mix)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Raw materials cost and</td>
<td>Raw materials scarce, availability volatile,</td>
<td>Raw materials are easily available at low cost</td>
</tr>
<tr>
<td>availability</td>
<td>costs increase</td>
<td></td>
</tr>
<tr>
<td>Consumer ethics and</td>
<td>Consumers embrace new technology, informed choice</td>
<td>Consumers lack trust in technology and are confused</td>
</tr>
<tr>
<td>behaviour</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Funding for research and</td>
<td>Public research funding declines, inefficiently applied</td>
<td>Funding leveraged through effective use &amp; cooperation</td>
</tr>
<tr>
<td>innovation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Health concerns and issues</td>
<td>Food is the enemy, blame the food industry</td>
<td>Food can make you better, customers in control</td>
</tr>
<tr>
<td>Availability of skills</td>
<td>Absence of skilled people, unattractive career</td>
<td>Attractive industry/career, successful re-skilling of workforce</td>
</tr>
<tr>
<td>Impact of climate change</td>
<td>Strong adaptation to climate change</td>
<td>Failure to adapt to climate change</td>
</tr>
<tr>
<td>Cost of energy</td>
<td>High cost, unaffordable energy</td>
<td>Cost neutral energy, fossil fuel substitution</td>
</tr>
<tr>
<td>Citizens’ attitude</td>
<td>Individualistic behaviour, disengaged</td>
<td>Engaged, collective attitude and approach</td>
</tr>
</tbody>
</table>

Table 5-3: The 12 key uncertainties and their ‘extremes’

One of the unforeseen benefits of identifying the ‘extremes’ of the uncertainties was that it forced the participants to identify exactly what they meant by the uncertainty. As can be seen in Table 5-2, the uncertainties on their own, without further description, are meaningless and without reference to the dozens of Post-its on the raw results (the posters) that lie behind the uncertainties. However, while the meanings behind these names were fresh, participants
assigned ‘extremes’ that aligned strongly with the raw results (the posters) and helped to define and describe the uncertainties to others.

There are several key uncertainties whose two ‘extremes’ might not be perceived as opposite. However, this is because the participants did not see the furthest extreme possible. Instead, they saw either a lesser extent of the extreme or a neutral (‘zero’) value. For example, the cost of energy has a 'high cost' and a 'neutral cost' but not a low cost because participants could not see a situation where energy became cheaper than it already was.

It is important that appropriate possible ‘extremes’ were identified. One of the main aims of scenario planning is to get decision-makers to suspend disbelief (Schwartz, 1996; Frittaion et al., 2010; Frittaion et al., 2011) and ‘push’ what they consider possible (Wack, 1985a; Schwartz, 1996; van der Heijden, 2005, p.225). These help people to reperceive the world (Wack, 1985b; Senge, 1992). By not considering a relevant ‘extreme’ of a key uncertainty participants could be limiting the potential benefit of scenario planning to stretch their, and decision-makers’, thinking. Considering the key uncertainties in isolation appeared to help this happen. By removing possibly confounding elements participants could focus and continue to ask why they could not consider it further. Some participants made the leap and applied a ‘far out’ extreme immediately, to which other participants had to ‘catch-up’ to. It is up to the tests of internal consistency to ensure that considering them in isolation does not jeopardise the validity of the final scenarios created.

5.4.7 Mapping the system: Developing influence diagrams of 12 key uncertainties

(Step 7, workshop 1)
Process: Mapping the system (influence diagrams only)
Before the implications of each of the endstates were identified, participants were asked to develop influence diagrams around the key uncertainties. The aim of this task was to explore the interrelated nature of many of the influences and factors that were related to the key uncertainties and thereby develop their understanding of the key uncertainties. Participants were asked to focus on the factors that were relevant to the food and drink industry. The 'hexagon' method outlined by Hodgson (1992) and Lane (1992) was adopted for this task (see Section 4.5.3).

The four groups were given three key uncertainties each to be central factors in influence diagrams. However, only nine diagrams were developed; one group placed two closely related factors on the one diagram and another two groups did not develop diagrams from all of their assigned key uncertainties in the allotted time.

Observations and results
As participants began to build the diagrams, they found that using adjacently placed hexagons was too restrictive and did not allow them to capture the direction of the influence, an important element of the exercise. To demonstrate causality, the groups began to place arrows between the factors to show the direction of causality. However, even with the arrows the participants found the complex web of relationships around the key uncertainties could not be captured through situating hexagons adjacent to each other on a two dimensional plain. After a brief discussion between the facilitators the groups were asked to abandon the hexagon process and began placing variables in empty space on the poster and drawing arrows to other variables to show the direction of causality. These diagrams now more closely represented the visual structure of influence diagrams commonly used in system dynamics. Three diagrams from this process are shown below, selected for their ability to show three
different results from the process (all results can be seen in Appendix B). The factor in the box is the key uncertainty selected to be the central factor of the diagram.

Figure 5-4: Water stress

Figure 5-4 demonstrates how participants perceived water stress to be affected by and affect variables relevant to the food and drink industry. This diagram demonstrates how interdisciplinary this uncertainty is. However, it does not provide much more detail. The number of arrows linking the factors show that they are almost all linked, but they provide little information about the cause and effect between them. It appears as though the participants thought of general, aggregate factors and then began to think about the more specific factors within them that influenced more specific factors within the others. For example, Policy regulation affects Diet on very specific terms, which demonstrates a disjointed consideration of aggregation in this diagram.

The diagram is of little use for a system dynamics approach because while the factors are nouns, many of them are difficult to measure. For example, Policy regulation gives no indication as to what part of Policy regulation is important to Consumer attitude. For a general
influence diagram it informs that Policy regulation can influence Consumer attitude, but not how. This could be the very beginning of the development of a diagram to inform a system dynamics approach, but much development is needed.

![Figure 5-5: Social acceptability (of new technologies)](image)

Fewer arrows between the factors in Figure 5-5 demonstrate the factors are less interrelated, stemming from the lower level of aggregation in this diagram. As with Figure 5-4, there are also some factors in this diagram that are difficult to measure, such as Government policy. However, in general the method of influence between the factors is clearer. For example, informed Government policy can improve Education. Chains of causality are also present, which means with those factors there is no feedback. In this diagram there is no feedback at all, rendering a system dynamics approach of little use for this system and other dynamical modelling approaches more appropriate.
Figure 5-6 demonstrated the causes and effects of the level to which humans adapt to climate change. Again there are variables here that are not specific enough to be measurable. For example, Consumer behaviour is measurable, but different dimensions of it influence Regulation and Level of adaptation to climate change differently. Furthermore, what is exactly meant by Research and development is unclear and the influence this has on the other factors, depicted by the arrows, are equally unclear. There are also several feedback loops in this diagram which indicates that behaviour could be endogenously generated. However, the presence of unmeasurable factors makes the diagram difficult to apply to system dynamics.

The purpose of the influence diagrams was to crystallise the participants’ understanding of the influences of the key uncertainties. It was hoped that this information would be used (through reference to the posters) in the following activities. However, the participants did not make reference to the posters in the following activities. Comments were made that the diagrams were too general and obvious and did not provide any clear advice for the activities. The
influence diagrams, despite physically being accessible by the participants for the rest of the day, played no further role in the workshop.

The flexibility of influence diagrams allows very different diagrams to be generated. The influence diagrams that are generated in system dynamics are quite specific: they define a boundary (and thereby a scope), they identify measurable variables that affect one another, and can capture the feedback present in the system. These diagrams are then useful later on in the causal-loop and model development phases of a system dynamics approach. The diagrams shown here are more general, showing links between sectors and more general categories, such as Government policy. If influence diagrams for the purpose of taking a system dynamics approach are to be generated from this process, more specific instruction and training are needed.

5.4.8 Developing initial scenarios

(Step 8, workshop 1)

Process: Scenario development
To begin the development of the scenarios, participants returned to the key uncertainties and identified what the drivers were that may cause each of the ‘extreme’ endstates. The participants then brainstormed the implications of each ‘extreme’ endstate (see Appendix B for an example of results).

Using the ‘hexagon’ influence diagrams, the ‘extreme’ endstates and their drivers and implications, participants were asked to select two uncertainties they felt were most important. Each participant then wrote down their reasons for choosing those uncertainties.
and suggested two axes on which the scenarios should be based. Each axis would be one of their uncertainties, with the ‘extreme’ endstates at each end of the axis.

Participants were told that if they saw two uncertainties as being dependent then they could be combined to create a common axis, but warned against combining too many uncertainties or uncertainties that varied dramatically from each other. The participants’ selections were submitted to the facilitator and the participants then went on an afternoon tea break.

While participants were on a break the workshop facilitators gathered together the selections of uncertainties and performed a tally. Participants were given the instruction that some of the uncertainties could be merged if they were closely related. This vague rule could have caused some problems, but participants were generally reasonable with their mergers. For example, many participants merged Water shortages and Shortages of raw materials into a Shortage of resources (or something similar).

When participants had returned from their tea break, the two axes that had won the tally were presented to the group for feedback. Some small adjustments based on that feedback were then made. The four quadrants generated by the two axes then constituted the scenarios, defined by the descriptions of their ‘extreme’ endstates. The resulting scenarios can be seen in Figure 5-7. For ease of reference the names that were finally settled on in the second workshop are displayed here.
Results and observations

The two axes selected were *Global resources* and *Origin of control*. *Global resources* was a combination of several of the key uncertainties that related to resources, including water, energy, and raw materials. The participants saw this varying from *Sufficient* to *Insufficient* for the industry. *Origin of control* came from the *Regulation level, Coherency and Citizens’ attitudes, and Consumer ethics and behaviour*. It reflects a general concern for government regulation and the beliefs and actions of consumers that continually came up during the workshops. This was seen to vary along a continuous axis where control and the origin of change ranged from top-down from the government through to bottom-up from individuals in society exercising their right of choice. As a consequence of consistency and compatibility of the axes, the participants chose to develop four scenarios. An explanation of the names of the scenarios can be found in Appendix B.

---

19 Axes are often not put on scenarios in the scenario planning literature. The rest of the thesis will be consistent with the literature.
5.4.9 Adding details to the scenarios and naming them

(Step 9, workshop 1)

Process: Assigning ‘values’ to the key uncertainties in each scenario
The process of adding detail to the scenarios began by assigning the likely locations of all the key uncertainties between their ‘extreme’ endstates. A scenario was assigned to each of the small groups. For their scenario the groups allocated the ‘most likely’ position of each of the key uncertainties on a Likert scale between one and five; one being one of the key uncertainty’s ‘extreme’ endstate and seven being the other ‘extreme’ endstate. For some uncertainties their position was pre-defined and for many a range was pre-defined, but for others it was difficult as the uncertainty was independent of the scenario axes. In this case it was an opportunity to vary the scenarios further and ensure they were sufficiently differentiated.

To further add detail to the scenarios, the groups identified the likely consequences for their scenario on each of the stakeholder groups. The stakeholder groups were suppliers (agriculture), retailers, policy makers, processors (such as manufacturers), consumers, and other stakeholders.

Finally, groups thought of a preliminary name for their quadrant. The name was to concisely capture some of the key attributes the food and drink industry would be experiencing in each scenario. The groups then presented their findings to all workshop participants.

Results and Observations
The results of this activity can be found in Figure 5-8. An explanation for the names given to the scenarios, shown in Figure 5-7, can be found in Appendix B.
Combining scenario planning and system dynamics

<table>
<thead>
<tr>
<th>Uncertainty</th>
<th>Extreme A</th>
<th>Likert scale</th>
<th>Extreme B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Efficiency improvements through technology</td>
<td>Slow/low improvements in prod efficiency</td>
<td>1: Rapid improvements in production efficiency</td>
<td></td>
</tr>
<tr>
<td>Water stress</td>
<td>Water stress made manageable</td>
<td>2: High water stress due to lack of action</td>
<td></td>
</tr>
<tr>
<td>Regulation level and coherency (availability, mix)</td>
<td>Appropriate and timely regulation of industry</td>
<td>3: Incoherent policy and regulation across governments</td>
<td></td>
</tr>
<tr>
<td>Raw materials cost and availability</td>
<td>Raw materials scarce, availability volatile, costs $\uparrow$</td>
<td>4: Unreliable energy supply and constrained mix</td>
<td></td>
</tr>
<tr>
<td>Consumer ethics and behaviour</td>
<td>Consumers embrace new technology, informed choice</td>
<td>5: Consumers lack trust in technology and are confused</td>
<td></td>
</tr>
<tr>
<td>Funding for research and innovation</td>
<td>Public research funding declines, inefficiently applied</td>
<td></td>
<td>Funding leveraged through effective use + cooperation</td>
</tr>
<tr>
<td>Health concerns and issues</td>
<td>Food is the enemy, blame the food industry</td>
<td></td>
<td>Food can make you better, customers in control</td>
</tr>
<tr>
<td>Availability of skills</td>
<td>Absence of skilled people, unattractive career</td>
<td></td>
<td>Attractive industry/career, successful re-skilling of workforce</td>
</tr>
<tr>
<td>Impact of climate change</td>
<td>Strong adaptation to climate change</td>
<td></td>
<td>Failure to adapt to climate change</td>
</tr>
<tr>
<td>Cost of energy</td>
<td>High cost, unaffordable energy</td>
<td></td>
<td>Cost neutral energy, fossil fuel substitution</td>
</tr>
<tr>
<td>Citizens’ attitude</td>
<td>Individualistic behaviour, disengaged</td>
<td></td>
<td>Engaged, collective attitude and approach</td>
</tr>
</tbody>
</table>

**Figure 5-8: The uncertainties in each scenario**

This activity added detail to the scenarios. Figure 5-8 provides much information about what participants perceived to be ‘happening’ in the scenarios and what they perceived as being common to all. The availability of skill varies minimally between the scenarios. The reason for the two points (one outlying) in Vision failure is that the participants working on that scenario saw a lower availability of highly skilled people but an abundance of people not trained in the industry for work in lower skilled jobs. Also varying minimally are efficiency improvements through technology, cost of raw materials, and cost of energy. Such close results could indicate that participants cannot perceive situations that vary considerably. For instance, if resources are insufficient it is likely, if all else is equal, that costs will increase. Figure 5-8 does not support this by showing that participants perceive little cost difference between the scenarios, even with heavy government involvement or not.
A key question is the validity and utility of this activity. Many of the uncertainties were either the axes themselves or dependent upon them, so were determined by the scenario. For example, the *scarcity of raw materials* was dependent on the axis of *Global resources* (even part of it by definition) and so determined by it. Others, however, were independent from the scenarios, such as *health concerns and issues*. Participants could make a judgement about what they thought this uncertainty might be in a scenario given the scenarios, the location of the related uncertainties, and the predeterminants.

There were several benefits of this activity. First, assigning the uncertainties provided more detail for the scenario and assisted to elaborate on them. Second, the ‘location’ of the less dependent and independent uncertainties were varied (because they could be ‘invented’), creating other dimensions upon which the scenarios could be differentiated. This could be achieved without adding confusion because the uncertainties were already in the process and their assignment did not complicate it by introducing new elements to be considered.

This activity also acted as a test for internal consistencies. By assigning the ‘levels’ of the key uncertainties, internal consistencies were picked up before they were even inserted into the scenarios. For example, in the scenario Vision Failure, where the industry was experiencing insufficient resources and control was from the bottom up, *readily available energy, manageable water stress, and appropriate regulation of the industry* were inconsistent and participants avoided them as options for their related key uncertainties. Another example is the *cost of energy*. It is likely to be higher in scenarios where resources are insufficient, which is reflected in Figure 5-8. The value and utility of this activity is that it provides detail for the scenarios, extra dimensions on which to explore strategies and policies, and provides a check for some possible internal inconsistencies within the scenarios.
Workshop 1: Discussion and closeout
A summary of the day's findings was then given by the workshop facilitators, followed by a plenary discussion session. Any questions were recorded so they could be documented and followed-up if required.

5.4.10 Developing initial scenario plots

(Step 10, inter-workshop period)

Process
In the inter-workshop period the facilitators collated and formalised the results from the first workshop. They also used the information from the workshop to fill out the scenarios and draft the plots – the stories that described the scenarios. This is often required after workshops to transform the information collected in a workshop into ‘a form that is suitable for presentation and reporting’ (Phaal et al., 2010, p.100).

5.4.11 Iteration and reassessment

(Step 11, workshop 2)

Workshop 2
The second workshop was two weeks after the first. It involved 28 participants from many stakeholder groups in the food and drink industry. The groups included producers (agricultural and manufacturers), retailers, civil servants, research organisations, industry representative groups, and people from broader society – consumers. The workshop was held over one full day.
Process: Iteration and reassessment
To refine the scenarios, participants reviewed and reassessed the results of the last activity of the previous workshop: the ‘most likely’ position of each of the key uncertainties in their scenario. Participants also reviewed the implications of each scenario for the various stakeholder groups, and the scenario name. Changes and revisions were made where necessary.

Results and Observations
The final scenarios and their plots were then generated. The final scenarios are shown in Figure 5-9 (a replica of Figure 5-7). The plots for the scenarios are outlined in the Appendix B.

5.4.12 Backcasting

(Step 12, workshop 2)
Combining scenario planning and system dynamics

**Process: Backcasting and plot development**
Participants then conducted a backcasting exercise for each of the scenarios. Backcasting was an exercise where participants outlined the events, turning-points, and decisions that lead from today to their scenario in 2025.

**Results and observations**
As the results were not a key outcome of the study, they are shown in Appendix B for completeness. Nevertheless, the activity contributed to the knowledge, discussion and collective sensemaking in the exercise and some important observations were made.

The different groups took a variety of approaches to construct the backcasting diagrams. Some groups worked forward from the present, using an almost future-forward planning process, but with a predefined ending point and others worked from the future back.

It was observed that the activity had all three of the implications for the development of the scenarios that were identified in the previous chapter (see Section 4.2). First, the backcasting exercise added detail to the scenarios. The scenarios now included information outside of the key uncertainties. Furthermore, there was a backstory for the scenario too, which could also be worked into the plots. This detail was not only added, but gave timeframes and linked the present environment to that of the scenarios. Second, it provided another check for internal consistency. If participants could not imagine how the future might eventuate, then this would have been flagged in this activity and gave an opportunity for the scenarios' stories or plots to be checked against a timeline and any inconsistencies amended or removed. The aim of adding the detail in context and checking the internal consistency of the scenarios also helped to increase the believability of the scenarios. Third, the events, turning points, and decisions identified could be used to indicate environmental changes to stakeholders in the food and
drink industry. These 'sign-posts' can now be used by policy and strategy developers as early indicators or to alert them to changes in the environment, and the event diagram could be referred to for what participants thought would be the drivers and consequences of such changes.

5.4.13 Assessing impacts and implications

(Step 13, workshop 2)

Process: Exploring the scenarios
Based on the results thus far, the uncertainties, their drivers and implications, the scenarios, and the backcasting exercise, the impact of each scenario on each on the major stakeholder groups were explored. Participants identified how power had changed for each of the stakeholder groups: suppliers (agriculturalists), producers (manufacturers and wholesalers), retailers, and consumers, and how supply chain concentration had changed for suppliers, procurers, and retailers.

The performance in each scenario of seven industry and four consumer metrics were also identified. These metrics were chosen by the FDF because they were topics of interest to the Federation. Participants had to suggest how these metrics might have changed from 2010 to 2025 in their given scenario on a five point Likert scale (discussed in the Chapter 4). The key metrics were:

Key industry metrics
- Carbon footprint of food industry in the UK
- Local control of the UK food producers
- Employment in UK food processing
• Share of raw materials sourced in the UK
• Share of food and drink finished goods made in the UK
• Percentage of brands versus retailer branded goods
• Rate of innovation in technology and products

Key consumer metrics
• Share of household spending on food and drink
• Per cent of eating at home versus eating out of home
• Consumer health (considering factors such as obesity rates)
• Culture around food: Food more of an art rather than a fuel

The purpose of this exercise was to get participants thinking about how the scenarios could be used to help develop policy and strategy. The results are again shown in Appendix B.

Process: Stakeholder impact analysis
Participants were then divided up into their stakeholder groups. The groups present were: suppliers (including agriculturists), producers, retailers, society, and civil servants. They were asked to select which scenario they thought would be the 'best' outcome for:

• Profit for their stakeholder group
• People (general society)
• Planet (environmentally)

It should be noted, for the profit question, the broader society and civil servants stakeholder groups were asked to assess profit for all businesses, rather than a particular stakeholder group.
The highest ranked scenario became the stakeholder group’s ‘desired’ scenario. The total votes were also tallied to find the plenary’s ‘desired’ scenario. A complete set of the results can be found in Appendix B.

5.4.14 Windtunnelling

(*Step 14, workshop 2*)

**Process: Windtunnelling: Developing an action agenda/strategy**

Still in their stakeholder groups, the participants then looked at four questions:

1. What are the actions required to realise the desired scenario?
2. What actions are required to navigate away from the undesired scenarios?
3. What are the downsides of this scenario?
4. What actions are needed to mitigate these downsides?

The stakeholder groups answered these questions for both their desired scenario and the plenary’s desired scenario. The answers to the questions identified actions that outlined future directions for strategy and policy for the different stakeholders and the industry. The purpose of this exercise was to demonstrate how the scenarios could be used to develop strategy and policy and help the different stakeholders to understand the aims and mindsets of the other stakeholder groups, by outlining which was their desired scenario and why. The results of this activity are shown in Appendix B.

**Workshop 2: Discussion and closeout**

All the participants were then brought together to have a general discussion about the process. It became apparent that some stakeholders had similar aims while others’ varied dramatically. It became evident during the discussion that people had common ideas about
the problems facing the industry and about the action that could be taken. Some participants were even acknowledging responsibility. In particular people made reference to what needs to be done in the context of the scenarios, meshing current ‘business as usual’ ideas about what should be done, but reflecting on the consequences of such action in each of the scenarios. Many stakeholders spoke freely and openly during the session, but with consideration for others present.

5.5 Discussion

This section of the chapter begins with a discussion of the scenario planning process used in the study, particularly a discussion of the techniques, activities, and tools used. These are particularly relevant to this work because of its applied nature and thus a need to develop an understanding of how scenario planning can be applied. The discussion then moves on to address the three questions outlined in the aim. The first of these was whether the benchmark process was appropriate, which was assessed by comparing it to the desired process and the scenarios it developed against the desired scenario traits discussed in section 4.6. The second and third aims were the timing of the integration in the process and whether it was useful. These are assessed together because they are so closely related.

5.5.1 Methods of data capture and techniques

The methods of data capture employed in this workshop appeared to be well suited to the task. The posters allowed a large number of people to see the ongoing work, provided an audit trail (see Stigliani & Ravasi, 2012), and had the advantages of ‘visual meetings’ (see Sibbet, 2010; Sibbet, 2011). The Post-its also proved useful. They allow visual, flexible ways to provide opinions onto the posters (see Sibbet, 2011; Sibbet, 2010; O'Brien, 2004). It was observed in
the workshops that participants readily offered ideas Post-its because, after seeing them on the poster, after some discussion or both, they could re-word them or retract them. A similar note was made about voting with the (sticky) dots.

The use of the physical artefacts in the workshops helped to develop and consolidate ideas. Having to write down ideas for them to be recorded forced people to externalise their inferences and mental models, which comes with a number of benefits already expounded (see Senge, 1992; Meadows 2008, p.172). The posters and Post-its helped people to get physical handles on their ideas, as evidenced by their tendency to jot them down quickly and then reassess and rewrite them. The posters also kept the participants focused. The use of categories on the posters, as well as previous work also helped frame and stimulate ideas and organise them in a logical manner. In general, the posters allowed vast amounts of information to be captured and used in the process and provided an audit trail for the ideas. These are all important benefits of using physical artefacts in the process of sensemaking, an essential activity that should occur during a scenario planning process (see Stigliani and Ravasi, 2012).

The use of the Hodgson’s (1992) and Lane’s (1992) Hexagon approach, however, was not as successful. Participants ceased using this technique quickly as they found it too restrictive. Instead they preferred to offer factors on Post-its and drew arrows directly on the posters to link the Post-its. The flexibility of Post-its and arrows allowed ideas to be rearranged on the posters more freely than in the Hexagon approach, assisting the visualisation of the results by grouping common ideas and classifying them. Despite the permanency of this approach, participants preferred it, redrafting the influence diagrams they created several times to produce diagrams they were happy with.
5.5.2 Scenario planning process

As discussed in Chapter 4, no evaluation method for a scenario planning process has been developed. The process measurements offered in that chapter are for focusing on decision problems, some of which apply here. However, since the scenario development exercise had a general focus and not a single decision problem, a discussion of these here would be long and not informative. Instead, focus will be drawn to how the process encouraged some of the scenario traits identified in the scenario evaluation process (see Section 4.6 and Appendix A) and to the general aims of scenario planning (see Chapter 2). To draw out these points, both direct observation and participant observation are used.

‘Pushing’ thinking, the suspension of disbelief, and reperceiving the world are essential characteristics of scenarios and hence of the process that generates them (Wack, 1985b; Schwartz, 1996; van der Heijden, 2005; Frittaion et al., 2010; Frittaion et al., 2011). Once decision-makers have suspended disbelief they can begin to stretch their thinking, reperceive the world, and consider a broader ‘space’ where their strategies and policies must be effective. This was evident during the process. If participants noticed something that they did not believe, they tended to either argue against it or just ignore those particular elements of the process, which supports Frittaion and her colleagues’ (Frittaion et al., 2011, p.424) observations. Defining ‘extreme’ endstates for the key uncertainties contributed greatly to pushing people’s thinking. By pushing those boundaries participants discussed environments they had not previously considered. This ‘pushing’ was kept in check, however, by the reality of the group. It cannot be identified whether the balance between the two was adequate, except to say that generally participants did not find the ‘extremes’ unbelievable and that it did encourage novel discussion.
Wack (1985a; 1985b) describes scenario planning as a process whereby new perspectives of the world are surfaced (the act of reperceiving) and scenarios are the medium by which they are communicated. There is a concern that participants only offer obvious information to the scenario planning process. The risk is that the process only collects, collates, and communicates what the participants already know. It has already been established that the methods in the study promoted novel thinking, but whether this thinking translated to new perceptions is another issue. The consideration of these ‘new limits’ of participants’ thinking have to be reflected in the scenarios. This is evident by the participants assigning some of the uncertainties in the scenarios to their ‘extremes’, by choosing the upper and lower bounds of the Likert scale in Figure 5-8. By choosing these limits, participants are beginning to integrate the new thinking into their mental models.

Perhaps the inclusion of minority reports is another method that could be included to introduce novelty and trigger reperception. Minority reports - similar to Schwartz’s (1991; 1996) ‘fringes’ (p.68-73) – are reports that are only mentioned by one or two people, particularly people on the edge or outside the immediate field, that contribute novel information or ideas to the process. In the FDF study facilitators attempted to bring these into the process, if they noticed them. Facilitators were asked to push these in group discussions and ensure they were rigorously tested by the group before inclusion or rejection. However, a more formal approach for this could be included in the process to ensure their consideration in the process.

Exclusion is a threat to the validity of the scenarios. If an important trend or driver, an appropriate ‘extreme’ endstate for a key uncertainty or appropriate endstate for an uncertainty in a scenario were excluded then it could reduce the ‘space’ covered by scenarios
or make it invalid and redundant (remember scenarios map out a space in which the future may occur). Furthermore, excluding important variables may also reduce the readiness of decision-makers to suspend disbelief, jeopardising the ability to include new thinking into the scenario planning process (the exact requirements of suspending disbelief are not yet known, and research is being done in this area, see for example Frittaion et al., 2010; Frittaion et al., 2011). Ensuring nothing was excluded was important for the process and again the use of a group was relied upon to ensure this did not occur.

Also important to scenarios are their relevance (Schwartz, 1991 & van der Heijden’s 1997 through Chermack et al., 2001, p. 27; Miesing & Van Ness, 2007, p.149; Wack, 1985a; van der Heijden, 2005, p. 225; Schoemaker, 1995, p.30), that they are recognisable (Miesing & Van Ness, 2007, p.149), that they capture people’s imagination (O’Brien, 2004, p.720), and that they encompass both people’s concerns and external reality (Wack, 1985a). The general feeling among participants and the discussion the process generated indicate that these were fulfilled. In particular, the consensus around the discussion that occurred at the end of workshop 2 demonstrated that the scenarios had targeted in on common issues that were pertinent, familiar, and generated discussion. Furthermore, the discussion of action during this session also indicates that participants had used their imagination to engage with the scenarios. Finally, in this discussion, participants discussed the issues in the industry using the language developed in the workshop.

In general, the process appears to have addressed many of the scenario traits identified in the scenario evaluation process (see Section 4.6 and Appendix A). By extension, in this application, the process was adequate and produced desirable results.
5.5.3 Influence diagrams and integration

The influence diagrams developed in this study featured little in the process after they were developed. There are several explanations for this.

As far as a system dynamics approach is concerned, the influence diagrams would not have been useful for a system dynamics approach and, related to this, many did not reflect some aspects of systems thinking. Many of the diagrams lacked feedback, an aspect of systems thinking (Booth Sweeney & Sterman, 2000). Instead of feedback, many diagrams exhibited ‘chains’ of causation (see, for example, Figure 5-5). Without feedback, systems have little endogenous behaviour and their behaviour is driven by exogenous factors. System dynamics is an approach designed to explore endogenous causes of behaviour (Sterman, 2000; Meadows, 2008; Richardson, 2011). Without feedback, system dynamics cannot be applied, and instead other dynamic modelling approaches that do not focus on endogenous behaviour would be more appropriate. To make them more conducive to system dynamics, the relationships in the diagram or its boundary need to be reconsidered.

There are other reasons why the influence diagrams are not conducive to system dynamics. The general nature of many of the factors in the influence diagrams was one such reason. Their general nature provided little useful information about the system’s characteristics. Another reason was that many of the factors in the diagrams were vague or convoluted (many factors in one). If factors are vague and convoluted, then it can be difficult to understand what was meant by them. Furthermore, designing a method for measuring, or applying units to them can be difficult, making them unconducive to system dynamics modelling.
The assessment of the integration can only be done with the consideration of the success of the activity itself. From a system dynamics perspective the success of the influence diagrams have already been discussed. However, this does not exclude the influence diagrams being used for other means, such as informing participants of general cause and effect. Despite their possible general use, the diagrams were not used further; several reasons exist for why this could be the case. The reasons include: they did not produce any unknown insights, the diagrams were still drafts and less clear than presented here, or the activity was too general and did not provide a specific goal or task for participants to complete. Either way, the diagrams were not used again. In the following studies a more informed approach to their development is needed for useful influence diagrams to be developed.

5.6 Chapter conclusions

This study had three central aims. First, it aimed to understand how to apply scenario planning: how to design and run a scenario planning process and develop scenarios. Second, the study aimed to develop an understanding of how scenario planning and system dynamics could be integrated. Third, the FDF study aimed to understand if developing influence diagrams could assist a scenario planning process.

5.6.1 Scenario planning

The scenario planning process used in the FDF study proved to be a successful and useful process. Feedback from participants indicated that they thought the process was considered and constructive. The scenarios themselves were well received by the FDF, who claimed the scenarios were plausible, relevant, and highlighted many issues within the industry, all of which are important traits of scenarios (Chermack et al., 2001, p. 27; Schwartz, 1991; 1996;
van der Heijden’s, 1997; 2005). Unfortunately, the scenario evaluation scheme shown in Chapter 4 was not completed by the time this study was run, so no further evaluation of the scenarios took place. However, the process appeared to build consensus among the participants regarding the major issues facing the industry and common language was observed to begin to arise during the discussion sessions.

5.6.2 Integrating scenario planning and system dynamics using influence diagrams

The method of integration trialled here was an obvious first choice: where systems mapping was used to try to develop participants’ understanding of the key uncertainties. The use of influence diagrams in particular had precedent. Authors, such as van der Heijden (2005) had offered influence diagrams (and causal loop diagrams) as methods of strengthening mental models. While no direct mention was made to system dynamics, the tools are common to both system dynamics and van der Heijden’s (2005) approach to scenario planning.

However, while the mechanics of the development of influence diagrams went well, the diagrams were of little use in the process and many of them would be difficult to take further in a system dynamics exercise. Many factors in the influence diagrams were too general and provided little useful information about the system’s characteristics. Furthermore, many of the factors in the diagrams were vague making it difficult to understand how they could be measured and unconducive to system dynamics modelling. Perhaps the most significant factor lacking the diagrams was, however, feedback. Without feedback, behaviour could not be generated endogenously, making other dynamic modelling techniques more appropriate than system dynamics.
From an integration perspective, and more importantly for this study, the participants did not use or refer to the diagrams after they were developed. Furthermore, comments were made during the process about the diagrams not being useful, implying that they did not help participants crystallise their understanding of the key uncertainty (central variable) and their possible endstates.

The method of integration and the success of the results cannot be treated in isolation. The method of integration can have a strong impact on how well it works. The reverse is also true: the attributes of a process that makes it successful could influence the process used to integrate the approaches. These considerations were taken forward into future integration attempts.
Chapter 6  High Value Manufacturing Study

Figure 6-1: An (over)simplified guide regarding which elements of the two approaches were adopted for this study and the order in which they were commenced.

NB: the Dynamic model development block is pale because it was intended but never realised.

6.1  Key structure elements

This study was designed to develop scenarios and then use these as context for creating system maps. The scenario planning approach used was similar to the FDF study, but differed in the way it was applied: it used the input from multiple engagements, each of which had a different group of stakeholders involved. This was to try to develop scenarios that had input from a larger number of people, with a greater variety of areas of expertise.

The scenario development activities were followed by a system mapping exercise. This was to explore how scenarios and the scenario development process could inform the mapping exercise. It was intended that the system maps would be developed further to create dynamic models, but the shortcomings of the process meant that participants saw little benefit in continuing the exercise to completion.

6.2  Context

The High Value Manufacturing Study (HVM study) was a scenario development exercise that explored possible futures of the UK’s high value manufacturing (HVM) in the target year of
2025. The HVM study was part of the HVM Landscape Project. The HVM Landscape Project explored the current and future environments of HVM in the UK. The project focused on HVM’s trends and drivers, challenges, opportunities, and the industry’s important emerging technologies. In particular it focused on technologies and capabilities to be developed, barriers to be overcome, and enabling actions for the UK to be internationally competitive in HVM. Many of the results of the HVM Landscape project were published in a report issued by the UK’s Technology Strategy Board (TSB, 2012) and by Featherston et al. (2012).

The project was conducted for the Technology Strategy Board (TSB) in conjunction with the IfM at the University of Cambridge. It included broad consultation involving industry, academia, and the UK civil service. The project was designed to help frame and launch the HVM Catapult, a group of research centres that leverage each other’s capabilities and foster the development of new capabilities for the benefit of the UK’s HVM industry. The HVM Catapult was closely involved in the development of the scenarios.

As part of the development of the landscape, this study developed scenarios to explore the future of HVM in the UK. The study aimed to help the HVM Landscape Project collect, collate, and explore the uncertainties facing HVM in the UK and understand their implications.

It is appropriate here to acknowledge the main contributors to this project. The scenario development and facilitation were carried out under the auspices of the Institute for Manufacturing Education and Consultancy Services (IfM ECS) at the University of Cambridge. The scenario development exercise was assisted by Andrew Gill, Jonathan Hughes, and Finbarr Livesey. Apologies extend to any other people who assisted in developing the process who have been omitted from this short list.
6.3 Aim and premise

The HVM study was conducted to test an alternative means for developing scenarios other than the process used in the FDF study. It used multiple workshops, each with different participants, to collect uncertainties using similar techniques to the FDF study. It then deviated from the workshop approach and attempted to develop scenarios through a series of interviews with academics, consultants, and industry personnel. In all, approximately 60 people with varying backgrounds were involved in both the workshops and interviews. The study also aimed to develop an understanding of how elements of a scenario planning process could be used to help generate influence diagrams and dynamic models (artefacts of a system dynamics approach). Finally, it aimed to understand how influence diagrams and dynamic models could be developed and used more effectively than they were in the FDF study.

The introduction of system dynamics into the process occurred again by attempting to map the system. Mapping the system in this instance included influence diagrams and causal loop diagrams. To attempt a different method of integration, the influence diagrams were developed after the scenarios. However, participants still aimed to develop the influence diagrams around the key uncertainties. Participants then attempted to develop these into causal loop diagrams.

Finally, the study aimed to take the influence diagrams further than the FDF study and use them as inputs into the later steps of the process, in particular a more complete system dynamics approach. The influence diagrams were developed further as system mapping tools by emphasising that feedback should be captured in them. The influences in the diagrams were also given polarity (a directional – positive or negative – influence). These two attributes made them more like causal loop diagrams, which are more common, and arguably more
useful, in system dynamics. As will be seen however, the attempt to use the diagrams as inputs into the later steps of the process was not successful because the study itself was ceased (hence the paler step, *Dynamics modelling*, in Figure 6-1 at the beginning of the chapter). The basic steps used in the approach taken in the HVM study can be seen in Figure 6-2, again the steps from scenario planning are shown in blue and the steps from system dynamics in red. The next section, Section 6.4, will discuss these steps in more detail and provide their results and observations made during their execution.

![Figure 6-2: The approach adopted for the HVM study](image)

*Note: Steps on different lines in one box are different steps from Chapter 4 combined in this chapter for convenience*
6.4 Method and results

6.4.1 Identifying the client

(Step 1, pre-engagements/interviews)
The identification of the client, along with the other pre-workshop steps, was conducted as part of the broader HVM Landscape Project. The client was the HVM Catapult, a group of seven research centres from around the UK. Overseeing the HVM Catapult and the HVM Landscape Project was the TSB who provided continual guidance and input into the process.

6.4.2 Identifying the purpose

(Step 2, pre-engagements/interviews)
The purpose of the HVM study was also defined by the broader HVM Landscape Project. The Landscape Project aimed to develop an understanding of the current environment (in 2011) and the possible environment that the HVM industry might observe in the future.

6.4.3 Articulating current mindset/mental models

(Step 3, pre-engagements/interviews)
The articulation of current mindsets and mental models occurred during the opening phases of the HVM Landscape Project. As part of the project a Landscape (the donor of the name for the project) was created, the structure of which was loosely based on that of Technology Roadmapping (see Phaal et al., 2010). This Landscape provided information about the dimensions and characteristics of the HVM environment, its needs and challenges, the characteristics of sectors, technologies and capabilities that may be developed in the future,
and the barriers and enablers to this development. Unfortunately, due to the size and detail of the Landscape, it has not been published.

6.4.4 Refining the focus and setting horizon year

*(Step 4, pre-engagements/ interviews)*

Through this Landscape the purpose of the scenario development exercise was evident: to develop an understanding of the future environment that the UK HVM industry would have to compete in. Specifically, to look at the environment that it would have to develop new technologies and capabilities in. As part of this focus, and as defined by the Landscape Project, the target year of the project was set as 2025.

6.4.5 Identifying the trends and drivers and Identifying the predeterminants and uncertainties

*(Step 5, engagements & interviews)*

**Process**

Steps five and six were conducted in parallel because of the multi-stakeholder, multi-engagement nature of the approach. In each engagement participants were asked to identify the major trends and drivers of HVM globally. They were then asked to separate the uncertainties from the predeterminants, by voting on the trends and drivers with the greatest uncertainty. The list of trends and drivers and their uncertainty votes were carried forward into each engagement. Each engagement was requested to conduct both activities because the participants were not scheduled to re-group during the scenario development exercise. Such an approach makes using the steps defined in Chapter 4 a little difficult, but for clarity they will be retained throughout the chapter.
The initial form of data collection was the process used to develop the Landscape. It was essentially a desk job that collected trends and drivers for HVM from the TSB, available industry reports, and relevant Roadmaps from the IfM’s Roadmapping database (one of Roadmapping’s dimensions is trends and drivers, see Phaal et al., 2010). The trends and drivers identified in this activity were collated for presentation to the first engagement.

In the first engagement, the attendees of an annual Manufacturing Professor’s Conference held in the UK were asked to review and add to the trends and drivers much in the same way as the FDF study. Similar to the FDF study, the professors then selected the trends and drivers whose outcomes they saw were the most uncertain and those they saw as having the greatest impact on the industry. The combination of these two features generated a ranking of the trends and drivers, from the most 'important' (here meaning highest impact and highest uncertainty) to least. After the session with the manufacturing professors, the results were collated and taken into the next engagement. From this process 10 uncertainties that had the greatest impact and uncertainty were selected at the key uncertainties.

The second engagement was a workshop which involved representatives from the research centres involved in the HVM Catapult program. The representatives, who mostly consisted of the centres’ heads as well as other higher level positions within the centres, were asked to review the trends and drivers and contribute any they thought had been overlooked. They were also asked to review the key uncertainties and decide as a group if any trends and drivers should be promoted to this group. In the ensuing discussion, the participants selected two more trends and drivers they thought warranted being labelled key uncertainties. They also decided to group some of the uncertainties because they were closely related. After this
workshop there were 12 key uncertainties, which had been selected from a total of 43 identified trends and drivers (for a full list of the trends and drivers see Appendix C).

Observations and results

The 12 key uncertainties identified from this process were:

- UK workforce skill levels (from now till 2015 and on);
- Subcritical UK manufacturing base to exploit innovation;
- Affluence increases pace of change;
- Continuing evolution of emissions regulations;
- Growing population increases demand, waste;
- Using fewer materials including water for all outputs;
- Global water availability;
- Established countries fragmenting, for example China, India, USA;
- Growth slowing in China and Africa emerging as an industrial centre
- Personal carbon tax

These trends and drivers demonstrate how diverse concerns in HVM are. Those toward the top of the list particularly focus on supplying the resources firms need for manufacturing. Also prevalent in the list is the role of government, with the Personal carbon tax and Continuing evolution of emissions regulations (obviously highly correlated). Of particular importance to the broader HVM project and the TSB were the structural issues identified in these key uncertainties, namely the Subcritical UK manufacturing base to exploit innovation and the Repatriation of manufacturing to the UK due to increased costs, both of which could pose significant threats to the extension of current and development of new HVM capabilities in the UK. An explanation of each of these trends and drivers can be found in Appendix C.
6.4.6 Developing initial scenarios, adding detail to the scenarios and naming them

(Step 6, engagements & interviews)

Process
Unstructured Interviews were then conducted with academics and industry consultants and with the information from the interviews and further desk work, draft scenarios were generated. During the interview the interviewees were given the list of key uncertainties from the previous work and asked to discuss what uncertainties dominated their thinking of HVM. The four that were discussed by all interviewees were:

- Distribution of production – the evolution of preferred production distribution (range: globally distributed to single location)
- Source of market service – markets are served by firms with mostly global operations or mostly local operations
- Resource scarcity
- Availability of skilled workers in the UK

The first two of these uncertainties, Distribution of production and the Source of market service, were identified in the interviews as the most significant and important uncertainties for the industry. During the interviews an assortment of dynamics between the two uncertainties were highlighted and interviewees offered up much information about their mental models of the futures generated by varying these two uncertainties. The draft scenarios were generated to bring some of these dynamics forward and help clarify their consequences. These scenarios were reiterated among the project team to see if there were any insights to be gained from scenarios for HVM and for the HVM Landscape Project. Names were also offered by interviewees for the scenarios. These were taken forward from one
interview to the next and were redrafted until interviewees believed they represented the scenarios.

Results
The resulting scenarios can be seen in Figure 6-3.

![Figure 6-3: The HVM scenarios](image)

Note: the x-axis here is the Location of production and the y-axis is the Location of markets

6.4.7 Developing initial scenario plots

(Step 7, interviews)

Process
After reiteration, the plots were drafted. These were circulated around the team working on the HVM Landscape Project. Edits and suggestions were made which were taken on board.

Results
The resulting plots for the scenarios are below.
Scenario A: An MNE’s World
People globally are served by globally distributed manufacturing networks. Given their distributed production networks, multinational enterprises (MNEs) are in a better position to negate the erratic effects and disturbances of climate change. Global firms make competition in Britain very difficult and British manufacturers feel pressure from firms located in cheaper production markets.

Scenario B: Regional identity served globally
Regulations and oil prices make it too expensive to ship materials many times over. As a consequence fabrication takes place in one firm or a cluster of co-located firms and finished products are shipped globally. Firms leverage their unique location identity and become very important for local governments as they provide many jobs for their local economies. Competition is still tight for British firms; their location gives them a close to market advantage but they are still pressured by other firms who import from cheaper production locations.

Scenario C: Local focus
Global companies have some centralised operations, such as innovation and design, but have a distribution of complete manufacturing facilities to serve local markets. British manufacturers are in a good position to produce manufactured goods for the same cost as MNEs. However, MNEs also take advantage of globally sourcing their centralised services. While the British service sector is among the best in the world, capabilities need to be leveraged to assist British manufacturers.

Note: This was a difficult scenario to envisage and participants’ initial reaction to it was that it would end up being unfeasible due to internal inconsistencies.

Scenario D: Micro Markets
Emissions regulations in the form of carbon taxes and carbon footprint quotas and general transport costs make it expensive to ship any materials overseas. As a consequence companies either produce all in one location or are co-located with upstream and downstream firms and serve only local markets. MNEs take the form of a collection of relatively isolated firms and few manufacturers reap any benefits from being part of such networks. Population densities vary dramatically between rural and city areas as complex needs can only be met in large markets.

6.4.8 Iteration and reassessment

(Step 8, interviews & internal workshop)
Process, observations, and results
The next activity was a process of iteration and reassessment. The scenarios and their accompanying plots were circulated around the HVM Landscape Project team and the client. Reassessments of the scenarios and the plots were suggested which were then integrated into the results. The scenarios and the plots already presented were the results of this process.

6.4.9 Mapping the system: Developing influence diagrams and causal loop diagrams

(Step 9, internal workshop)

Process
A workshop was then run with a group of seven academics and industry consultants who had experience with the HVM industry. Before the workshop participants were given the results of the scenario development process (the scenarios: the matrix and the plots). The afternoon began with some brief training in influence diagram generation. The participants were given the ranked list of trends and drivers and asked to select one as a central factor to focus on. Participants were then asked to individually list the factors that influence that trend and/or driver and the factors it affected. They were then asked to draw arrows with polarity, indicating the direction and impact of the influence. Participants were asked to specifically look to include variables that were measurable nouns – noun phrases that stipulate what about the noun is to be measured – and loops (feedback) in their diagrams.

Pair-blending (discussed in Chapter 4), a method used in the FDF study to identify the axes, was then used to blend individual diagrams in pairs (there was one group of three). In the exercise, participants gathered with a partner who had developed a diagram of the same uncertainty and combined their two depictions of its system. They discussed the factors from the two (or three) diagrams that were being combined and the reasons for their inclusion. Two
of the groups had focused on the same variable in their diagram, so were asked to merge the two resulting diagrams. It was later discovered that this type of pair-blending was the foundation for Collaborative Conceptual Modelling (CCM, see Newell et al., 2008; Newell & Proust, 2009; Newell et al., 2011).

Observations and Results
The process of pair-blending was a method of forcing people to justify the elements in their diagrams. It encouraged inquiry and advocacy, which Senge (1992) believes are essential for developing mental models, particularly in groups. Participants would question each other’s assumptions and inferences made about the relationships in their diagrams. People had to then justify its inclusion or allow it to be omitted from the diagram. The pairs in the room meant that neither person was excluded from the generation process. The group of three also had no exclusion.

During the pair-blending process emphasis was again placed by the facilitator on focused variables that were measurable nouns and feedback. Measurable nouns are desirable because they are conducive to a system dynamics approach. Sterman (2000, p.152) says that variables ‘should be nouns’. If they are measurable (quantifiable), however, they are more easily included in dynamic models. The resulting two diagrams of the activity can be seen in Figure 6-4 and Figure 6-5.
Figure 6-4 is informative but there are elements of it that make it difficult to use further in a system dynamics approach. The diagram does outline the boundaries of the issue of *Using fewer materials* and identifies some of its constraints. For example, *Access to natural resources* has a floor that cannot be passed. The diagram also shows how cross-sectoral the issue is, with social, economic, government, and manufacturing factors mixed in throughout the diagram. However, this diagram is an influence diagram, not a causal loop diagram, as no feedback loops have been identified.

Furthermore, some of the factors in Figure 6-4 are vague and appear to incorporate many different factors. *Government legislation*, for example, is vague and it is difficult to identify how it can be measured. Given the generality of its two inputs it is likely that this represents a convolution of variables – essentially different levels of aggregation. As a consequence the dimensions (units) of these factors and how they affect their connected factors is unclear and not captured in the diagram.
Figure 6-5 similarly outlines the limits of the system, but also shows more feedback and less cross-sector activity. The system includes a vast cross-section of difference factors, including: economic, public policy, resource, and social factors. However, unlike Figure 6-4, Figure 6-5 depicts them as being more isolated, only influencing each other through the central factor: *Critical UK manufacturing base*. From a system dynamics perspective the central factor would be very difficult to calculate, a consequence more related to the definition and uncertainty itself rather than the diagram.

![Diagram](image)

*Figure 6-5: The influences of the manufacturing base of the UK*

Some of the factors in Figure 6-5 have unclear levels of aggregation, but on the whole methods of measurement are easier to identify. For example, it is unclear if *Jobs*, *Prosperity*, and *Tax* are aggregated for the entire UK economy or for manufacturing in the UK only, but once this is established their methods of measurement become clear. The factors here also appear to be more clearly defined. There are some factors whose methods of measurement are unclear, such as *Presence of global leaders*, but only a small amount of manipulation would be needed to interpret such a variable.
Figure 6-5 also captures new elements not previously considered in the scenario planning process. The diagram included a social element, the *Image of UK manufacturing/culture towards the environment*, was not previously discussed in the scenario planning process, but later became a significant reoccurring factor in the broader HVM Landscape project. The consideration of new elements such as this demonstrates the broad thinking that went into the diagram.

### 6.4.10 Comparing results: An attempt at triangulation

*(Step 10, assessment)*

**Process**  
To assess the results of the scenario planning process, a comparison method was adopted. A key goal of scenario planning is to encourage the client to reflect upon and challenge their perceptions (Wack, 1985b). If the trends and drivers and uncertainties captured by the scenario planning process did not match up to those generated by the client, then consideration must be given to why. As the clients from the study were the HVM Catapult’s research centres and the TSB, the HVM Catapult’s research centres were used to create the *comparison other*\textsuperscript{20}. The centres were asked to identify HVM’s trends and drivers and from those select the key uncertainties.

Workshops were run with each of the HVM Catapult’s research centres. The workshops involved between 5 and 12 participants. In each workshop the participants were asked to identify trends and drivers (a list that was taken forward into each workshop) and select the key uncertainties that were most important to HVM, based on the following two criteria:

\textsuperscript{20}The *comparison other* is a term often used in organisational behaviour to refer to the roughly equivalent contemporary against which something is compared (McShane & Travaglione, 2005).
1. Which trends and drivers could have the greatest impact on HVM in the UK?
2. Which trends and drivers have the greatest uncertainty?

This asked for, and an example was supplied to that effect, the elements the participants saw as being in the top right corner of Figure 5-3, shown in the FDF study where they had a high impact and a high uncertainty.

Observations and Results

The resulting ranking from this process is shown in Table 6-1, below.

<table>
<thead>
<tr>
<th>Rank</th>
<th>Trend and drivers</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>UK workforce skill shortages (onto 2015+)</td>
</tr>
<tr>
<td>2</td>
<td>Subcritical UK manufacturing base to exploit innovation</td>
</tr>
<tr>
<td>3</td>
<td>Increasing cost of materials and energy</td>
</tr>
<tr>
<td>4</td>
<td>Security of supply of key resources</td>
</tr>
<tr>
<td>5</td>
<td>Using fewer materials including water for all outputs</td>
</tr>
<tr>
<td>6</td>
<td>Growing population increases demand, waste</td>
</tr>
<tr>
<td>7</td>
<td>Affluence increases pace of change</td>
</tr>
<tr>
<td>8</td>
<td>Continuing evolution of emissions regulations</td>
</tr>
<tr>
<td>9</td>
<td>Government support for research and development</td>
</tr>
<tr>
<td>10</td>
<td>Access to credit</td>
</tr>
<tr>
<td>11</td>
<td>Repatriation of manufacturing to the UK due to increased costs</td>
</tr>
<tr>
<td>12</td>
<td>Personal carbon tax</td>
</tr>
</tbody>
</table>

Table 6-1: The key uncertainties from the workshops with the HVM Catapults research centres

When Table 6-1 is compared with the key uncertainties generated by the scenario planning approach it is apparent that many of the uncertainties are common. For example, skill shortages are present in both (one list this takes the form of UK workforce skill shortages and in the other it is Availability of skilled workers in the UK). However, the two key uncertainties from the scenario planning process, Distribution of production and Source of market service, the ones that the scenarios were constructed around, are not directly prevalent in Table 6-1.
The only exception to this observation is that *Distribution of production* is partially represented by *Repatriation of manufacturing to the UK*.

### 6.4.11 Study conclusion

The scenario development and system dynamics exercises were taken no further. Interest on all sides in using the scenarios created in the HVM Landscape Project diminished. The reasons for this include resource constraints on the HVM Landscape Project and restricted timeframes. However, a contributing reason was the scenarios themselves and their perceived validity. It appeared that despite the breadth of sources used to gather the information, people did not readily adopt or use the scenarios. Possible reasons for this are discussed in the next section.

### 6.5 Discussion

#### 6.5.1 The scenario planning process

As outlined in Chapter 2, scenario planning (as it is defined in this thesis) relies on people being *homo economicus* – rational decision makers. In reality however, the process is prone to biases, effects, fallacies, errors, and bounded rationality. This method attempted to overcome this by gathering information from people with a great variety of backgrounds and perspectives, at different times, and while in different places. When the preliminary work, including the Roadmaps, previous reports, Professors conference, and HVM workshop are all accounted for, the process collected information from more than 150 people to identify the trends and drivers in the HVM industry. It was hoped using such a large number of people would overcome standardised perceptions of the industry, such as the prevalence of common thinking among Detroit automakers in the 1960’s and 1970’s (see Senge, 1992). An example of
overcoming a bias was the use of time between the sets of information collection, which might have helped to negate recency bias (Steiner & Rain, 1989; Heneman & Wexley, 1983).

It was hoped that some of these techniques would help overcome these issues with scenario planning. It was difficult to identify ‘how much’ of an unknown ‘amount’ of a bias, effect, fallacy, or error was present, particularly with the skills available to the researcher. Furthermore no quantitative evaluation was made during the workshops. However, some qualitative observations can be used to assess the process itself and what behavioural aspects were obviously present, rather than perhaps not there.

Observations suggest that one of the reasons for the study being halted was incongruence between the client’s key uncertainties and those used to develop the scenarios. The area mapped out to generate the scenarios used two uncertainties that were barely present in the list generated by the HVM Catapult’s research centres. Because the major axes of the scenarios were not pertinent concerns for the client, interest in the scenarios diminished. There are two possible reasons for the incongruence of these results: the scenarios and the client’s key uncertainties. These are discussed in the next two sections.

**Problems with the scenarios**
There are two possible sources of problems with the scenarios: the sheer number of people involved in the process and the process of developing the scenarios using interviewees. A potential problem with using so many people in the process is that the concerns and terminology of the client could have been sufficiently diluted that the scenarios henceforth generated no longer reflected them. This could have potentially reduced the scenario’s relevance and their evocativeness for the client, important traits in scenarios (Wack, 1985a;
Combining scenario planning and system dynamics


However, the list of key uncertainties used to generate the scenarios and those offered by the client are sufficiently similar to demonstrate that the thinking in the workshops was similar to the client’s. There are only three key uncertainties present in the results from the workshops that are not present in the client’s results: *Global water availability*, *Established countries fragmenting*, and *Growth slowing in China and Africa emerging as an industrial centre*. The other seven are common to both set of results, indicating a fairly high level or correlation.

The multi-engagement approach, however, did have some drawbacks. By holding more workshops the resources required to run the study were higher than that of the FDF study. The multiple engagements also mean that the process of group sensemaking and mental model building was slower and more piecemeal. Discussion is part of the sensemaking process (Weick, 1995; de Geus, 1988) and the discussions in the workshops appeared to be making sense of the material participants had in front of them. However, the same discussions occurred several times over. This appeared to be the nature of building an understanding and consensus when information was provided to participants from previous workshops, they had to come to terms with this information, and so many different people were involved in the process.

There were also disadvantages with the number of people involved in the study. Problems with these included being heard among the crowd (‘voice’) and the implications of agendas on the process. Participants came to the workshops with their own perspectives and agendas and with such a large number of people they felt their position was generally considered less,
which caused some participants to be more forceful with their agenda. Politics, power, and group dynamics are considered little in this thesis (see Further Work in Chapter 11), but the role these play in a scenario planning process cannot be ignored. Perhaps the political factors in this study were more apparent because the HVM Catapult program had origins in UK politics and government.

The second and more likely source of issues with the scenarios was that only some of the interviewees – who were responsible for using the key uncertainties and developing the scenarios – were involved in the workshops. This means that they did not go through the sensemaking and mental model building that occurred in the workshops. As a consequence, the resulting scenarios did not reflect the understanding that had been developed in the workshops. This is demonstrated by the difference between the scenario axes and the key uncertainties identified in the workshops.

The HVM study contrasted greatly with the FDF study. In the study the activities facilitated group sensemaking and people used physical artefacts and discussion to build common mental models of the way the world worked. As de Geus (1988, p.71) says, ‘people change their own mental models and build up a joint model as they talk’. In that study clients and stakeholders were able to use this sensemaking and mental model development that occurred in the workshop to develop the scenarios.

*Problems with the client’s key uncertainties*

The scenarios might have also differed from the client’s key uncertainties because they were less bounded and sort information from a greater audience, part of the benefit of the multi-engagement approach. By collecting a number of different perspectives, the scenarios could
have reflected views not held by the client at all. One of the aims of scenario planning is to challenge perceptions and encourage people to ‘reperceive’ the world (Wack, 1985b, p.150; Schwartz, 1996, 36-7). If the scenarios reflected reality, then this assessment indicates that the key uncertainties identified by the client overlook some pertinent issues. It also indicates that there was an issue with the process because it did not facilitate the client’s sensemaking and develop their mental models and help them consider the domain of the scenarios.

Unfortunately, the complete scenario evaluation process had not been developed when this study was conducted (in fact it was developed because of this study), so no survey evidence exists to support this discussion. This discussion is founded upon direct observation and general participant feedback, all of which are recorded in the Appendix C. The evaluation technique that was developed assesses the attributes of scenarios against those that the literature expounds scenarios should have, assesses the attributes of a process against those that the literature expounds such a process should have, assesses how peoples’ understandings have changed, and assesses how aligned their mental models are. Such an evaluation process could be applied to similar studies in the future.

6.5.2 Data capture and techniques

As already discussed the methods for data capture here were not adequate for scenario planning. The process attempted to overcome bounded rationality and increase the chances of introducing novel information into the process by soliciting information from a large number of people. However, it collected information from such a large number of people, who were divided into so many different groups, that group sensemaking could not occur and common models and consensus could not be built. Furthermore, while the process encouraged the externalisation of mental models, it did not capitalise on the possible group based inquiry and
advocacy that could have occurred, limiting it only to the group immediately present. There was also an absence of common language and definitions. Whether through the mechanics of the technique, the sheer number of people, the number of groups, or all of these, group sensemaking was severely limited (and only assisted by the static results presented to each group at the beginning of their session).

6.5.3 System mapping

This system dynamics approach attempted to improve on the one used in the FDF study by using academics who were more informed about system dynamics and by training them further in system dynamics before attempting to map the system. It also attempted to develop the system maps further, from influence diagrams to causal loop diagrams.

As shown by the results of the approach (Figure 6-4 and Figure 6-5) the diagrams developed were of value, but their utility in a system dynamics approach is limited. They define the boundaries of the systems clearly and portray a variety of variables that influence the central variable; all attributes that are useful in any systems approach. Furthermore, and more specific to system dynamics, the variables appeared to have more easily identifiable units, perhaps from the emphasis placed on the need for measurable nouns. Finally, and perhaps most significantly, the diagrams identified new elements that had not been included in the scenario planning process.

There were still some issues with the diagrams that would make them difficult to take forward in a system dynamics process. The level of feedback thinking evident in the diagrams was still minimal, with only positive loops being identified. This implies that either the system must
grow or collapse continuously, the limits of the diagrams need to be reconsidered, or that there are some feedback loops missing. Furthermore, while there was a consistent level of aggregation in one model, the other had varying levels of aggregation that could prove difficult for system dynamics. Similarly, some factors are unclear. In Figure 6-4, for example, *Government legislation* is not specific enough to understand what it is actually defining.

Reflecting on these observations and the diagrams three conclusions are evident. Firstly, the diagrams need to be reviewed. Variables such as *Consumption* in Figure 6-4, for example, and *Size of the manufacturing base* are not limited by *Access to natural resources*, which is often seen as a limiting factor for these variables (Meadows *et al.*, 1972). Secondly, more information about what makes an influence diagram and a causal loop diagram useful for a system dynamics process would also be advantageous for the process. Finally, despite these observations, these diagrams are more suitable for system dynamics mapping than the ones developed in the FDF study.

All three of these conclusions highlight issues with the methodology. Participants need to be given more time to develop influence diagrams and need to be greater context in which to develop them. This second point is discussed further in the next section. These observations and conclusions had a profound impact on how the activity of developing influence diagrams was designed in the next three studies.

### 6.5.4 Integration

Scenario planning does not appear to have explicitly informed the generation of the system diagrams. During the development of the influence diagrams, participants had at their disposal
the trends and drivers, key uncertainties, and scenarios that had been generated from the process. Despite the facilitator emphasising the supplied materials and urging participants to use them, their only use was to identify the central variable for the influence diagrams, which was a compulsory part of the activity. Instead of using the other information available, participants preferred to delve into their knowledge and experience to develop the diagrams. This could have been for a number of reasons, such as the participants in the systems mapping workshop disagreeing with the information, not having ownership of it, choosing to focus only on information agreed on in this workshop, or any combination of these. Whichever the reason, there was little use of the supplied material in the workshop and any of its inclusion aside from the central variables was coincidental.

However, scenario planning did provide the central variable used in the exercise. By providing a central variable, scenario planning helped to start influence diagram generation - something that started very slowly in the next study: the China Futures Study. It provided a structured way of defining a variable from which to begin the influence diagram process. Using this central variable created a focus for the diagram and, being a key uncertainty, defined a quasi-problem for the diagram (important in a system dynamics exercise as shown in the Grass-Rabbits-Foxes study). Furthermore, it ensured that the central variable was important to HVM.

The idea that the scenarios could have framed the system for what they were mapping and possibly given them ideas about what to include in their system diagrams can also not be neglected. References in the material supplied would have triggered numerous images and memories of the industry in the participants’ minds. This is Kahneman’s (2011, p.50-1) ‘associative machine’ – where words and phrases automatically cause our brains to recall images and memories in an attempt to make sense of the situation. These images and
memories could have helped participants to recall factors that influence their central variable. Furthermore, the trends and drivers, key uncertainties, and scenarios, aside from the central variable, could have helped frame the situation and by the materials’ omission, its boundaries.

Empirical assessments regarding the ability of system dynamics to inform scenario planning and visa-versa in this study ex post is impossible. The above claims are only presumptions and cannot be proved after the fact (see further work in section 11.5). Inversely, it is impossible to assess if the system diagrams could have informed scenario planning. Being a real world application of scenario planning and system dynamics (and also part of a larger project), the process needed the commitment of people and their time to complete. As the results observed so far did not meet people’s expectations, their commitment to this part of the project waned. Despite being designed to do so, the process was taken no further and neither the system diagrams nor the scenarios were used again, so no assessment of their impact can be made. Despite this, the study yielded a number of operational conclusions and some theoretical conclusions that had impacts on both the subsequent studies and on the thesis.

6.6 Chapter conclusions

The scenario planning process does not appear to be a suitable substitute for the approach taken in the FDF study and was not followed through. The method adopted here to conduct a scenario planning activity and develop scenarios brought in many new ideas and perspectives, many more than the FDF study. However, this was done at the sacrifice of detailed discussion and group sensemaking. During the processes used in the FDF study people developed common language, common mental models, and a common understanding (Weick, 1995; de Geus, 1988; Stigliani & Ravasi, 2012). Furthermore, in the FDF study participants came to a consensus about, and had ownership of, the scenarios developed. In this study, the scenarios
themselves were abandoned, in part at least because of their incongruence with the clients concerns and lack of these traits. Ownership of scenarios and their alignment with decision makers’ concerns means that they are more likely to impact on decision makers’ mental models and the decision that they make (Wack, 1985a).

The system maps developed in this activity also appear more useful for a system dynamics approach, but they still need to be developed further. The diagrams more accurately reflect the system’s factors as measurable variables at a more consistent level of aggregation. However, some factors are still unclear and some relationships are omitted. Two elements of the process that could be used to help develop diagrams that are more appropriate for system dynamics are more education in systems mapping for system dynamics and re-editing of the diagrams. Perhaps most significant was the introduction of new elements to the process by the systems mapping. While the process was soon abandoned, these new considerations could be valuable contributions to the redevelopment of scenarios.

Despite it being incomplete, this study does provide some insight into using system dynamics and scenario planning to inform each other. Despite participants not using the scenario planning material provided to inform their systems diagram development, the scenario planning material provided a focus for the influence diagrams and ensured that focus was important for HVM. Furthermore, the material could have helped the process through association and framing. However, similar to the FDF study, the diagrams were again unclear, with vague or convoluted factors. It appears that again the flexibility of influence diagrams meant that they did not create maps of the system that were conducive to system dynamics.
Chapter 7  China Futures Study

Figure 7-1: An (over)simplified guide regarding which elements of the two approaches were adopted for this study and the order in which they were commenced.

NB: the Scenarios block is green because the scenarios were supplied, rather than developed during the study and the Dynamic model development block is pale because it was intended but never realised.

### 7.1 Key structure elements

The China Futures study attempted to develop maps of the systems observed in different scenarios of the same system. The study used professionally developed scenarios to outline how the system changed and then conducted a systems mapping exercise grounded in each of the scenarios. The goal was to see if these system maps could be integrated to form generalised system diagrams and models, with the ultimate goal of developing system maps or even a dynamic model that reflected the observed present system and the routes that the scenarios suggest it might take.

This study and the next, the Grass-Rabbits-Foxes study (Chapter 8), are similar in two regards. The studies are similar in that they attempted to understand if system maps could be developed grounded in different scenarios and explore if they could be integrated. The two studies also used participants drawn from the same pool: The Australian National University’s
(ANU’s) System Dynamics Group21. The two studies are different in all other regards, including their topic, how the scenarios were developed, and the level of aggregation of their focus.

The premise behind the similarities of these studies was to understand if maps of the system and dynamic models in different scenarios could uncover parts of the system not considered in current understanding. For example, system diagrams or a dynamic model that have been constructed based on the system observed in a scenario could highlight pertinent feedback loops or system structures that had not yet been considered. Different perspectives or frames of reference of the same situation can provide unique insights into how the different parts of a system interact and are related (Schön & Rein, 1994; Bolman & Deal, 2003). The different scenarios could provide those different frames. One of the theories tested in these studies was: as different scenarios provide a different view of the future, so might they provide a different perspective of the system on which the scenarios were based. Using this information, it was suggested that a unique and more complete understanding of the system could be attained by blending these perspectives (using pair blending22).

7.2 Context

This study used participants from The Australian National University’s (ANU’s) System Dynamics Group. These individuals were used because they had experience in system dynamics and so training in systems mapping, which was demonstrated in the previous studies to be essential, was not required. The risk of using this group was the potential lack of experience these participants have with business in China. Upon discussing this with the group

21 A group of researchers from the ANU who all conduct research into or using system dynamics. The group can be contacted on sd-owner@cecs.anu.edu.au
22 As discussed in Chapter 2, pair blending is a technique long used in many fields including teaching. CCM (Collaborative Conceptual Modelling) also uses it widely (Newell et al., 2008; Newell & Proust, 2009; Newell et al., 2011). Similar techniques were employed in the FDF study before knowledge of this use was obtained (Livesey et al., 2010).
it was thought that their backgrounds in business and engineering might somewhat mitigate this problem.

7.3 Premise and aim

The aim of this study was to test if system dynamics could inform scenario planning by integrating system maps of the same system in different future states as outlined in different future scenarios. As a system can evolve over time, the study aimed to understand whether system diagrams grounded in different scenarios can be integrated or if they are so different that they are mutually exclusive and extremely difficult, if not impossible, to integrate.

By integrating the different perspectives created by scenarios, new system elements and structures may be introduced into the understanding of the present system. This has three potential benefits. Firstly, it could help people to understand how the scenarios eventuated. If these new structural elements are included in a system map or dynamic model, people can use the model to understand how the scenarios might eventuate and how the system might evolve. Secondly, it could provide a more complete picture of the possible futures. When the diagrams and models are combined with the scenarios, if people can see how the scenarios play out in the system diagrams and dynamic models, then it might make the scenarios more believable, realistic, and recognisable, all important elements of scenarios (Wack, 1985a; Morecroft & van der Heijden, 1992; Bloom & Menefee, 1994; Morecroft, 2007; Miesing & Van Ness, 2007). Finally, it was hoped that by understanding possible future systems, it could help develop understanding of the tipping points in the system. For example, if in the future another loop had to be dominant or the structure of the system had to change for the behaviour outlined in the scenarios to be simulated, then the model could be manipulated to outline the conditions of the switch in dominance or structure. This could create a ‘future
memory’ of the associated signs indicating that the tipping point was approaching and a change in system behaviour was approaching.

Developing system maps and system dynamics models in the scenarios can also demonstrate how well participants understand the scenarios and if there are any internal inconsistencies in them. If the scenarios are poorly developed, communicated, or are difficult for readers to grasp and accept as future possibilities, then they will not be able to develop system diagrams and models grounded in the different scenarios. Furthermore, if the participants find it difficult or impossible to develop diagrams and models of the system, then it could be an indicator that the scenarios are internally inconsistent. These are two further possible benefits for developing system maps and dynamic models grounded in different scenarios.

The aim of this study brings a flood of thoughts, ideas, and ‘feelings’ about why it might or might not work. This study endeavoured to understand if it could work, but more importantly aimed to understand why or why not. This alone could not support or deride the thesis, but would help to understand some of the intricacies of integrating scenario planning and system dynamics, creating lessons to take forward into future studies.

This study was also designed to bring out the differences in nature, scope, and scale between scenario planning and system dynamics. Nature refers to how an approach views and addresses a decision problem. Scope refers to the focus an approach has on the decision problem: whether its definition is general and flexible or it must be specific and ridged. Scale refers to the size of the system and the level of aggregation at which an approach views the system in which a decision problem rests. These three approach traits could hinder the integration of scenario planning and system dynamics and their ability to inform one another.
Finally, this study also aimed to understand the practical feasibility of blending system dynamics artefacts in a workshop and how this might be achieved. The hypothesis is that if system dynamics’ artefacts – system maps and dynamic models – were possible to be blended, it would first be possible with influence diagrams, rather than the other forms of system mapping – causal loop diagrams and stock and flow diagrams – and dynamic models. Influence diagrams capture large amounts of information, but in a more loosely structured and imprecise way. This loose structure might allow influence diagrams to be manipulated more easily to capture multiple perspectives of the relationships between factors. This would make the diagrams easier to mould and integrate into a common vision of the system. Causal loop diagrams, stock and flow diagrams, and dynamic models are more rigid in the way they depict relationships between variables and as such are less likely to be conducive towards integration with different perspectives of the same system. This study aimed to understand if this was true and how this blending might occur.

However, the previous studies demonstrated that the loose structure of influence diagrams can also hinder a system dynamics approach. The diagrams allow more loosely defined, vague and convoluted factors, differences in aggregation, and presumptuous influences (influences that skip a few factors) to be included in the diagrams. Diagrams that include such traits can be poor informants of the system’s structure for system dynamics. This study aimed to understand if the blending process was possible and, if so, if it is helpful for a system dynamics approach or an integrated approach of scenario planning and system dynamics.
7.4 Method and results

7.4.1 Mapping the system: Developing influence diagrams

(Step 1, workshop)

Process
The participants used for the study were drawn from the System Dynamics Research Group at the Australian National University. The group came together regularly to discuss and learn about the methodology and its applications. The academics and students used in the study all had experience and a common interest in system dynamics. This helped to overcome the first of the two obstacles observed in the previous studies: using participants that had little experience in system dynamics. The participants nominated themselves willingly to be part of this study. The disadvantage with selecting participants from this pool was their content knowledge of the topic. All participants had an engineering background, many in manufacturing and business, with knowledge of China and its role in global manufacturing, but few participants had lengthy experience with China. This proved to be a limitation of the study.

Participants were given Randall and Goldhammer's (2006) *Four Futures for China Inc.* (which can be seen in Appendix D) which outlined four possible futures for business in China, which were developed by the Global Business Network. In each scenario, China's business environment was markedly different, which could affect how businesses operated in China, how businesses do business with China, and how Chinese businesses interact with the rest of the world. A matrix depicting the scenarios outlined by Randall and Goldhammer (2006) can be seen in Figure 7-2.
Each participant was assigned a scenario and asked to develop an influence diagram of the business environment they observed in China in their own scenario and asked to specifically look at the environmental factors influencing business success. They were asked to view the environment from an Australian manufacturer’s perspective (a background story was provided, see Appendix D) and try to map out the factors that would affect business success.

The system dynamics approach was emphasised and participants were asked to focus on developing influence diagrams that would be conducive in a system dynamics approach. Influence diagrams existed long before they were introduced to system dynamics by Wolstenholme (1982; 1983) and Coyle (1983a; 1983b, also see Coyle & Wolstenholme, 1983). The potential structure of influence diagrams varies because of their age and wide use and the information they capture is not necessarily conducive to further system dynamics development, as shown in the previous studies. To avoid this, participants were asked to develop influence diagrams using systems thinking elements that are included in system dynamics, with a particular focus on feedback loops, endogenously generated behaviour, and
denoting factors as measureable nouns. This was done to make the development of these diagrams into causal loop diagrams easier and to reduce the number of different structures and syntaxes used. Possibly as a reaction to this, some participants put directional relationships, positive and negative causal indicators, on some of the arrows in their influence diagrams (sometimes considered part of influence diagrams - Wolstenholme, 1982; Wolstenholme, 1983 – and other times not – Hodgson, 1992).

Participants were then paired up with another participant who had been assigned the same scenario and blended their influence diagrams to form a single diagram. This continued until there were four influence diagrams, one for each scenario.

**Observations of the scenarios**
The scenarios outlined by Randall and Goldhammer (2006) do not have a target date. A phrase in the scenarios states, ‘China’s GDP surpasses that of the United States by 2041’ (Randall & Goldhammer, 2006, p.34), which is the only indication of the date in which scenarios were set. By not providing any fixed dates or targets, Randall and Goldhammer (2006) encourage thinking over a fluid timeframe, with no ‘deadline’ for the observed behaviour to arise.

**Results of the activity and observations**
Participants developed influence diagrams based on each of the four scenarios and blended them to a scenario level diagram. The diagrams are shown below. Participants were, however, unable to blend these diagrams to create a map of the system that considered all of the influence diagrams.
In the first scenario described by Randall and Goldhammer (2006), *The Emperor of Business*, China is business friendly and prospers. China overcomes its economic and environmental issues, builds quality infrastructure, and reduces the instances of brand and product piracy. The blended influence diagram for this scenario is shown in Figure 7-3.

![Diagram of Emperor of Business](image)

**Figure 7-3: Emperor of Business**

The variables in Figure 7-3 are measurable nouns, they all appear to have a common level of aggregation, and it depicts feedback, but its major flaw is the behaviour that would be observed from such a system. The participants that built this influence diagram decided to place signs indicating the polarity on all but one of the causal links. These signs indicate the effect a change in one variable would have on the other. The participants did not place a polarity on the bottom most causal link because to them it was unknown. If the polarities on the causal links in Figure 7-3 are correct, then the diagram depicts a system that is in continual growth or decline. This is impractical and unrealistic. For example, a business can only be so reliable (completely reliable) at providing a profit. Such a system structure would suggest the
diagram was incomplete, either the boundaries of the diagram need to be reconsidered or the polarities in the diagram are incorrect.

The second scenario by Randall and Goldhammer (2006), *Emperor’s New Clothes*, describes a situation where China has never really reached its full potential, corruption is rife, and infrastructure is crumbling. It is still a promising place to do business, but it is difficult and local knowledge and networks are vital. The blended diagram from this scenario can be seen in Figure 7-4.

The blended diagram for the *Emperor’s New Clothes* envisaged business success relying on local knowledge and the capacity of the firm to do business. Local knowledge and networks (Gaunxi) provide businesses with access to resources and markets, just as in the rest of the world, which help to improve their performance. The exact meaning of ‘success’ in this influence diagram is unclear. The diagram also shows links between the *Internal issues* within the firm and *Long term growth* and how they can both affect a firm’s ability to do business. It also shows that *Long-term growth and short-term growth* is affected by success, but the knowledge of local business is spurred or hindered by short-term growth rates.
The influence diagram shown in Figure 7-4 demonstrates some of the feedbacks involved in doing business, but it still has many issues. The diagram does demonstrate how Long term growth and Short term growth act through other variables to influence a business success. However, some of the causal links are presumptuous and incorporate a variety of different influences. For example, how Investment in local knowledge influences Internal issues is unclear; such influence could occur through a number of different channels. Some of the variables are also vague and not measurable nouns. For example, Internal issues is ambiguous and would be difficult to measure. These issues make the diagram unconducive for taking forward in a system dynamics approach.

Randall and Goldhammer’s (2006) third scenario, Emperor of Asia, describes a situation of regional tensions between China and its major nations. Within China, Nationalist protests are rife and Chinese businesses dominate. Regional pacts and non-aggression treaties increase regional tensions and Africa and South America are safer places to do business. The blended diagram for this scenario can be seen in Figure 7-5.

![Figure 7-5: Emperor of Asia](image-url)
The participants who developed this diagram of the Chinese business environment chose to focus on *Long term manufacturing* in China as the key indicator of business success. This was fairly pertinent for this scenario as it described a future where tensions were high and the consequences for businesses could vary dramatically. The diagram describes how *Nationalist protests*, which featured significantly in the scenario description, influences *Long term manufacturing* economically, socially, and politically. The *Number of foreign companies* also captures the support structure for foreign firms in China. Without other foreign firms around, it would be more difficult for firms to deal with local companies, a quasi-foreign-firm support network. This directly influences (and perhaps should be affected by) a diaspora of service companies, which is explicitly outlined in the scenario description.

There are, however, also a few issues with this influence diagram. First, *long term manufacturing* in China has no influence on the outer circle of variables. It is possible that the number of foreign companies in China would be somewhat influenced by the ability to manufacture in China over the long term, but further research or expertise in the area would be needed to establish this. Second, and related to the first, the influence diagram does not have any feedback loops. Finally, some of the variables are again not measurable nouns. *National protests*, for example, is one such variable that would have to be altered to a number of protests, a measure of intensity, or an attitude to have some scale applied to it. These issues, as with the last study, mean that this diagram provides only preliminary information for a system dynamics approach.

The final scenario, *Emperor of the World*, Randall and Goldhammer (2006) describes a situation where China becomes the dominant international power and the USA declines due to fiscal problems. China’s way of doing business is the only way of doing business and other
countries must follow. Piracy and intellectual property laws are a thing of the past. Finally, there are tensions between the USA and China and businesses in this scenario may prefer to be based in China rather than the USA. The blended diagram for this scenario can be seen in Figure 7-6.

![Figure 7-6: Emperor of the World](image)

This diagram focused much more closely on manufacturing in China. Central to this blended diagram of the *Emperor of the World* scenario is business success, which is influenced by, in this diagram, manufacturing elements of the Chinese economy such as *Assembly costs* and *Component costs* in China, the *Chinese domestic market*, and *Development complications*. This is a simple breakdown of high level contributors to a product: costs (parts and assembly) and demand generating sales. This diagram also considered the Australian market, which highlights an Australian manufacturer’s operating environment and relates to the domestic versus overseas decisions they make.
Despite having a structure that evidently reflects organisational theory, this diagram has only one feedback loop, through the Australian economy, and has influences that are unclear. Including cost and profit as well as innovation and demand show a fundamental thinking of what generates profit (Schmerhorn et al., 2004; Hanson et al., 2008), which is a feasible measure for the central variable, Business success. However, the links between cost and profit are simple and established; whereas interactions between Business success and the Australian labour market are unclear and potentially convoluted. Furthermore, Australian labour market is not a measurable noun and its units for modelling are unclear. It is however, part of the only feedback loop the participants saw in their scenario, which implies that aside from activities in Australia a firm cannot have any influence on the business environment in China. This partly fits with the scenario attribute of having to ‘play by [China’s] own rules’ (Randall and Goldhammer, 2006, p.36), but it is still an augmented assumption.

All participants were then brought together to attempt to integrate their different diagrams of the Chinese business environment. The participants did not integrate the diagrams. Instead, the participants stated that the diagrams were each useful in their own right and provided different perspectives that were more valuable in parallel, each providing a unique perspective on the system as a whole. In short they saw little additional value in integrating the diagrams. Furthermore, they said that from a system dynamics perspective the diagrams would be difficult to develop further as they did not have a system dynamics structure to them.

Integration observations
Also evident in the workshop and its results was a failure to consider the scenarios to any great degree. Only two influence diagrams brought in variables considered in the scenarios, Figure 7-4 included Internal issues, referring to the internal strife within China in the Emperor’s New Clothes, and Figure 7-5 included Nationalist protests from the Emperor of Asia scenario,
referring directly to the internal unrest outlined in that scenario. The other influence diagrams depict generic business systems that do not reflect the unique elements of China’s future captured in the scenarios.

Application observations
Perhaps the most obvious observation was the lack of focus of the workshop. Requesting influence diagrams of the system around an Australian manufacturer was vague and unclear. Furthermore, it was misleading to ask for the participants to only include measurable nouns, but provide them with a focal variable as vague in terms of measurability as business success. It meant that is had to be interpreted and some participants had trouble even starting the exercise. The above figures demonstrate how differently each group of participants interpreted business 'success'. These varying definitions suggest that there were issues with how the process was posed.

As shown, many of the influence diagrams were incomplete. Many of them did not reflect all evident causal links or, when observed more closely, had structures that were unsustainable and potentially unfeasible. Several reasons for their inaccuracy were observed. First, the diagrams themselves need to be redrafted; in particular, their boundaries, causal links, the polarities of the causal links, and the variables in the diagrams. For example, in Figure 7-3, the positive link between Investment in China and the Reliability of profits made in China does not convey the range of general and industry environmental conditions and demand required for ‘reliable’ profits. These revisions did not occur in this study because of time limits. With more time the participants would have had the latitude to review the diagrams they had developed. This will have to be considered in future studies.
Despite the presumed knowledge of participants in Chinese business, the lack of content knowledge was still evident in the workshop and its results. This is evident in the incomplete nature of the diagrams and the omission of some key variables as already discussed. Evidence of the lack of content knowledge is also evident in the type of system some participants endeavoured to depict. Some participants reverted to a generic capitalist system with little consideration of the uniqueness of China (see, for example, Figure 7-4).

**Observations of scenario planning and system dynamics**

Despite the application issues observed, several approach traits became apparent during the workshop. The influence diagrams appear to be non-conducive for system dynamics because they are so general, both in the problem they are addressing (Business success), their focus on the relationships, and their scale. These observations call into question the compatibility of scenario planning and system dynamics in terms of the view the approaches take, their scope (focus), and the scale or levels of aggregation they adopt when addressing a decision problem.

Further methodological issues were also observed, including missing links, implying that the expertise was not present or that further research was needed. These will be drawn out more in the discussion.

### 7.5 Discussion

#### 7.5.1 Discussion of theory

The process issues observed in the workshops indicate a possible problem with, and requirement to, define the system more rigorously before adopting a system dynamics approach. The varying levels of aggregation and the inclusion of the *Australian labour market* in Figure 7-6 while no other influence diagram considered Australia demonstrate a failure to
define the system. Defining the limits of the system and the ‘level’ of consideration appear to be important. Defining the limits help to outline the breadth of information participants should call on to construct the system. Defining the ‘level’ of aggregation (consider again Boyer, 2001, who’s figure in Chapter 3 outlines the levels in a hierarchy) to be considered when mapping a system may also assist participants. In this study the failure to define Business success and the breadth of possible interpretations meant that there was no such clarity.

Stemming from the failure to define the task more clearly, and define Business success, is the notion that the system diagrams in this study attempted to map the system rather than a problem. The study focused on the desire to generate influence diagrams that mapped out the whole system, rather than focus on a particular problem within the system. System dynamics is a methodology that helps to identify the reasons for systemic behaviour (Sterman, 2000). It is a methodology designed to explore problems rather than the map out the entire system. The study should have applied system dynamics to a problem rather than the system, a fact that contributed to the resulting influence diagrams being non-conducive for a system dynamics approach.

The different structures of the diagrams that resulted from this study demonstrate the ability of influence diagrams to capture and reflect systems from different perspectives, with different interpretations of ‘business success’, at varying levels of aggregation, and with different system boundaries. Different perspectives of slightly different systems could have compounded the difficulties of integration. However, it is unlikely that this was the case. There are few tools that are as flexible as influence diagrams. They allow influences and causal relationships to be captured in a number of ways by allowing the user to define their own variables and draw their own links. By readjusting variable names or redefining them, an
influence diagram can be manipulated to include a vast array of different (but not opposing) relationships and perspectives. In blending the influence diagrams, negotiation and discussion about mental models and ideas of causality are made, even where opposing ideas can be revealed, discussed, and tested. Besides belligerent opposition (to either fundamental or more minor assumptions), influence diagrams, almost more than any other tool, should have been able to allow the integration of the different influence diagrams because of their flexibility, not in spite of it.

Despite the issues with the process relating to vagueness, there is evidence from the study that suggests there are theoretical limitations to developing influence diagrams grounded in the different scenarios and then combining them that are more plausible than the limitations of influence diagrams themselves. To develop the influence diagrams, the participants drew on the scenarios and the vast number of variables to which the scenario plots made reference. The diversity and breadth of these variables are demonstrated by Figure 7-3 through Figure 7-6 which exhibit very few common variables, and none that are common in all. This implies that the flexibility of influence diagrams was needed to reflect their perspective of the system. With this range of different structures it is unlikely that all the diagrams would be conducive to system dynamics.

Put another way, the variables captured by the scenarios are just as ‘vague’ as those reflected in the influence diagrams. For example, terms such as Long-term investment and National protests are present both in the influence diagrams and in Randall and Goldhammer’s (2006) scenarios on which the study was based. The scenarios appear to be as general as the influence diagrams and do not consider system elements as specifically as would be conducive to system dynamics.
This conclusion suggests differences of scopes between scenario planning and system dynamics. Drawing on the description of the purpose of scenario planning and system dynamics given in Chapter 4, this is fairly apparent. System dynamics aims to inform people about the reasons for the behaviour of the system, the behaviour being the specific issue that motivated taking the approach (Forrester, 1961; Sterman, 2000; Richardson, 2011). Scenario planning aims to inform a user of the state of a system and how it may change by mapping out a space into which it might evolve (Wack, 1985a; Schwartz, 1996; van der Heijden, 2005). The influence diagrams of the study contained the more general scope equivalent to that of scenario planning, a reason for their inappropriateness for system dynamics.

Despite a scope difference between the scenario planning and system dynamics, they do not have differences in scale, contrary to evidence in the study. The term scale refers to the specificity or generality of a system in two ways, its variables (to here called aggregation), and its relationships. First the scale of variables (aggregation) will be addressed. A variable can be specific, such as investment in automotive manufacturing in China, or very general, such as total investment in China. The scenarios used in the study were broad and focused on generalised relationships between variables with a range of ‘scales’. System dynamics, while having a focus on problems, can also be applied to variables with a similar range of ‘scales’. Industrial Dynamics (Forrester, 1961), Urban Dynamics (Forrester, 1969), World Dynamics (Forrester, 1971a), and The Limits to Growth (Meadows et al., 1972) all provide evidence of how ‘broad’ and inclusive variables can be, demonstrating an ability to match those of scenario planning. Therefore, there is no misalignment between scenario planning and system dynamics in terms of the scale of variables.
Differences in the scale of relationships between the two approaches are also evident in the study. The scenarios describe broad relationships between elements of the Chinese business environment, for example political issues, and are reflected as such in the influence diagrams. These were referred to in the observations of the results as a convolution of causal links or a collection of different causal links that have been incorporated into the one influence. During a system dynamics approach however, these relationships need to be delineated and broken down into specific, hopefully mathematical, relationships between the variables. Influence diagrams are useful for dealing with this misalignment in perspective as they can be revised to reflect more specific relationships. It is unlikely, unless in the simplest of situations, that people’s mental models of a system simultaneously contain both the breadth of information of a system and the detail of the relationships with it, as Checkland (1981, p.103) wrote, ‘we pay for generality by sacrificing content’. Influence diagrams allow people to map out the breadth of a system before they delve into the detail of individual relationships, a step that usually occurs first during the development of causal loop diagrams – asking which direction the relationships are – and then in the development of a dynamics model – which is about the mathematics of the relationships. Using these tools the generality of relationships observed in scenario planning and in our own mental models can be circumnavigated in a system dynamics approach.

7.5.2 Implications on process

The observations made and theoretical conclusions drawn have many consequences for a combined process of scenario planning and system dynamics. First, a combined process must accommodate the differing scopes of scenario planning and system dynamics. Scenario planning has a more general focus. As outlined in Chapter 2 and supported by the scope of Randall and Goldhammer’s (2006) scenarios, scenario planning has a more general focus than
system dynamics, which focuses on a specific problem that is given rise to by the structure of the system. Care must then be given to address a system dynamics problem in a combined approach, rather than just applying system dynamics. That is, the ‘Law of the instrument’ must be avoided (Kaplan, 1964; Maslow, 1966). As Maslow’s (1966, p.15) adage goes, ‘if the only tool you have is a hammer, [you tend] to treat everything as if it were a nail’ must be avoided.

Second, and related to the first, a combined process must circumnavigate differences in causal link scale between scenario planning and system dynamics. As shown, the scale of variables (aggregation) is not an issue, as several studies have been done in system dynamics and scenario planning at similar levels of aggregation. However, a process must facilitate participants to break down the causal relationships (how much they ‘encompass’) observed in scenario planning to apply it to a system dynamics process.

Third, time is essential. Time restrictions did not allow for the revision of the influence diagrams. The blending process is a ‘garbage in, garbage out’ process that will not provide anything insightful unless time is allowed for participants to reassess their work.

Another implication is that more involvement in the scenario planning process might have encouraged participants to use more of the scenarios in the model development. Involvement in the strategic conversation is important for decision makers (van der Heijden, 2005). The process of scenario planning is a learning process (de Geus, 1988), by not being involved in the process much of this learning must come from the scenario themselves. However, if decision makers are only presented the scenarios with little ability to interact then their potential impact could be impaired (van der Heijden, 2005). This learning, that Randall and Goldhammer
would have stepped through to create the scenarios, was missing among the participants and evident in the lack of scenario specific information in the system diagrams.

Finally, a combined approach needs to use content experts rather than experts in the approaches used. The lack of content specific information in the influence diagrams was evident in their lack of China business specificity and by some obvious missing links in the diagrams. System dynamics is also a ‘garbage in, garbage out’ process. These deficiencies highlight the need for experts or for a multi-session approach that allows participants to research important influences and critical links; the best case methodology would include both of these. By having the expertise in the process and providing time participants to address deficiencies in that expertise if they arise, the quality of information used in the process can be improved. Without well informed understandings of the structure of the system going into the process, it is unlikely that the causes of the behaviour observed in the system can be understood. This problem was overcome when content specific experts were used in the previous studies. However, the need to train people extensively in system dynamics, as found in the FDF and HVM studies (Chapter 5 and Chapter 6 respectively) is still a pertinent issue, and cannot be overcome by using experts in the approach as attempted here.

7.6 Chapter conclusions

The diagrams generated in this workshop appear to be of little use for a system dynamics process for four reasons. First, they are not finished. Editing and development could make them more conducive to assisting a system dynamics approach and help circumnavigate issues of scale. Second, they lack content information. Third, they focus on an entire system rather than a problem. Their broad scope, as a consequence, made them appear to participants as unconducive to a system dynamics approach. Finally, they capture causal relationships as
defined by the scenarios, which are broad in scope. They need to be revised down to be useful
to a system dynamics approach. Some of these issues arose from issues with the application of
the approaches. The method adopted in this study was somewhat naïve.

Despite this some significant implications for a combined approach were uncovered.
Consideration in a combined approach must be given to the different scopes of scenario
planning and system dynamics. When extrapolating from scenarios into a system dynamics
approach, consideration must also be given to the causal relationships observed and time must
be given to break down causal relationships from scenario planning to allow apt exploration of
them for systems mapping for a system dynamics approach. Furthermore, time must be given
to revise influence diagrams and develop accurate maps of the system. Finally, greater
consideration must be used to select people for the process. The FDF and HVM studies
(Chapter 5 and Chapter 6 respectively) employed participants versed in content and this study
employed participants versed in the approach. While experts in both are desirable, this study
suggests that if one were to be sacrificed for the other, then participants should be content
experts rather than approach experts.

As outlined at the beginning of this chapter, from a theoretical perspective, an influence
diagram integrating all of the systems from the different scenarios is theoretically possible. In
this study, participants saw little value in integrating the different system diagrams.
Furthermore, there were compatibility issues with the diagrams, making such a task difficult to
complete. It is likely, from the evidence provided by this study, that the theory drawn on is not
wrong, but incomplete. Theoretical problems are evident, but not insurmountable. A process
needs to be developed that overcomes these issues to test this theory more comprehensively.
A simpler test may prove this, but a simpler test may avoid other issues, such as that of insufficient contextual knowledge and scope. This will be explored in the next chapter.
Chapter 8  The Grass-Rabbits-Foxes Study

8.1  Key structure elements

The Grass-Rabbits-Foxes study tested a more complete integration of scenario planning and system dynamics. While scenarios have been developed in the studies thus far, the system dynamics approaches have been unfinished and no dynamic model has been developed. This study aimed to fully develop a dynamic model and use it to develop scenarios.

The Grass-Rabbits-Foxes study aimed to take a system dynamics approach and then from this information develop scenarios (see Figure 8-1 at the beginning of the chapter). It developed system maps and a dynamic model of the predator-prey case study, a commonly used example in system dynamics. The study then developed scenarios using the information collected in the system dynamics approach. It varied from the China Futures Study in that the system dynamics approach occurred before the scenarios were developed. It also differed because participants in the study were involved in the development of the scenarios. It was similar to the China Futures study because system maps were developed based on the systems observed in the scenarios. These were then integrated to create system maps and a dynamic model of

---

23 This study developed its own system dynamics model of the predator-prey system.
the system that could reflect the development of all the developed scenarios. The potential benefits of doing this are discussed in Chapter 7.

The process adopted for this study used the scenario planning approach from the FDF study to develop the scenarios, but was the first complete test of the benchmark system dynamics approach. These two approaches were woven into each other to satisfy the desired pattern of activities described above.

8.2 Context

Despite the conclusion drawn in the last chapter, that content experts need to be used in such a process rather than process experts, participants were again drawn from the ANU’s System Dynamics Group. The predator-prey model of Grass-Rabbits-Foxes was chosen to obviate the need for subject experts. The participants were familiar with this system because of its common use as an example in system dynamics. Furthermore, as this was a synthetic system, participants were involved in developing, and were supplied with, system maps and a dynamic model of the system to help expedite their education of it. These attributes were part of the design of the study to help overcome participants’ lack of content knowledge in grass, rabbits, and foxes.

8.3 Premise and aim

The Grass-Rabbits-Foxes study was an application of the predator-prey system. This study had a broader aim than the China Futures study. While it looked at the integration of influence diagrams, causal loop diagrams, and dynamic models grounded in different scenarios, the
The Grass-Rabbits-Foxes Study

The study also explored developing a dynamic model grounded in the current system and then generating scenarios with the assistance of the model.

The study’s two aims were based on two correlating premises. The first premise was the same as the China Futures study: that different perspectives of the same situation can provide unique insights into how the different parts of a system interact and are related (Schön & Rein, 1994; Bolman & Deal, 2003). This case study would provide more evidence to support or deride the conclusions drawn from the China Future study. The second premise was to explore how participants would use the outputs of a system dynamics process in a scenario planning process. System dynamics has the potential to provide information for a scenario planning process. Van der Heijden (2005) recommends using influence diagrams and some feedback thinking to develop scenarios. This study aimed to explore how participants would use system dynamics ‘artefacts’ and thinking in a scenario development exercise. More specifically, it aimed to explore how participants would use a system dynamics model to develop scenarios.

The Grass-Rabbits-Foxes study was also used to test other elements of the scenario development and system dynamics processes and their integration. It offered an opportunity to assess the effectiveness of the surveys developed in Chapter 4 as a technique for collecting further participant feedback. It also provided the opportunity to test the scenario development process used in the FDF study. Finally, it gave an opportunity to understand how a limited amount of dynamic modelling could take place in a group driven activity (help on this point was taken from Vennix, 1996).
8.4 Method summary

The study was run over four workshops with self-selected participants from the ANU’s System Dynamics Group. Many of the participants were involved in all of the workshops. The workshops were two hours long and were held one week apart.

The study began by taking a system dynamics approach on the predator-prey system. In the first workshop a process similar to that employed in the FDF study was then employed to develop the draft scenarios. The second workshop focused on and compared backcasting and a variation of that activity using the model – model-casting. The third workshop mapped the system observed in the different scenarios using influence diagrams and causal loop diagrams and then attempted to integrate them. The final workshops explored mapping the systems observed in different scenarios using stock and flow diagrams and integrated them. After the workshops the maps were taken and a system dynamics model reflecting different scenarios was developed. Figure 8-2 outlines the main steps taken in the study. These steps will be explored and used as a guide to convey the study’s result in the following section.
### Figure 8-2: The approach adopted for the Grass-Rabbits-Foxes study

Note: Steps on different lines in one box are different steps from Chapter 4 combined in this chapter for convenience

<table>
<thead>
<tr>
<th>Study phase</th>
<th>Activity/ process step</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-workshops</td>
<td>1. Identify purpose and problem, Articulate of current mindset (mental models), &amp; Refine the focus and set horizon year</td>
</tr>
<tr>
<td></td>
<td>2. Develop understanding and collect information, Collect reference modes, &amp; Develop dynamic hypothesis</td>
</tr>
<tr>
<td></td>
<td>3. Map the system &amp; Developing a system dynamics model</td>
</tr>
<tr>
<td>Workshop 1:</td>
<td>4. Reiteration &amp; Compare to reference modes</td>
</tr>
<tr>
<td>Scenario development</td>
<td>5. Identify driving forces: trends and drivers &amp; Identify predeterminants and uncertainties</td>
</tr>
<tr>
<td></td>
<td>6. Explore the key uncertainties &amp; Develop initial scenarios</td>
</tr>
<tr>
<td>Inter-workshop</td>
<td>7. Develop initial scenario plots</td>
</tr>
<tr>
<td>Workshop 2:</td>
<td>8. Iteration and reassessment &amp; Name the scenarios</td>
</tr>
<tr>
<td>Scenario development</td>
<td>9. Backcasting and model-casting</td>
</tr>
<tr>
<td></td>
<td>10. Develop influence diagrams of the systems in the scenarios</td>
</tr>
<tr>
<td></td>
<td>11. Integrate influence diagrams of the systems in the scenarios</td>
</tr>
<tr>
<td></td>
<td>12. Develop causal loops of the system in the scenarios</td>
</tr>
<tr>
<td>Workshop 3:</td>
<td>13. Integrate causal loop diagrams of the systems in the scenarios</td>
</tr>
<tr>
<td>Developing influence</td>
<td>14. Develop &amp; integrate stock &amp; flow diagrams of the scenarios</td>
</tr>
<tr>
<td>diagrams and causal</td>
<td>15. Feedback and development</td>
</tr>
<tr>
<td>loop diagrams</td>
<td>16. Develop a dynamic model able to reflect different scenarios</td>
</tr>
<tr>
<td>Workshop 4:</td>
<td></td>
</tr>
<tr>
<td>Develop &amp; integrate</td>
<td></td>
</tr>
<tr>
<td>stock &amp; flow</td>
<td></td>
</tr>
<tr>
<td>Post-workshops</td>
<td></td>
</tr>
</tbody>
</table>
8.5 Method, results, and observations

8.5.1 Identifying the purpose and problem, articulating current mindset (mental models), and refining focus and setting horizon year

*(Step 1, pre-workshops)*

Before the workshops began a scene was set for the study. Since it was a real system (based on statistical data) but had an invented context, the design of the setting was very important because of the repercussions it would have throughout the study. The scene was Easter Island, with some changes. The first change was that there were no human inhabitants. The second change was that the Island had a land mass of 100,000km², approximately the area of Iceland. The third important change was that the Island was treeless, covered in (a hypothetical) grass and was devoid of all natural wildlife except one species of bird (the Petrel) and normal Pacific Ocean underwater aquatic fauna. For a complete explanation of the situation see Appendix E. The target year was set at 2025.

8.5.2 Developing understanding, collecting information and reference modes, and developing a dynamic hypothesis

*(Step 2, pre-workshops)*

To develop a dynamic model using a system dynamics approach the steps outlined in Chapter 4 were followed. Time was spent understanding how rabbits and foxes behaved and interacted in the real world. This was mostly through other research into their behaviour (see Appendix E). Since this was a semi-synthetic study, no reference mode was used. Instead, it was decided that the data and information from research would build a model accurate enough to reality
that it could become the reference mode for the study. A similar approach was taken for the
dynamic hypothesis.

8.5.3 Mapping the system and developing a system dynamics model

(Step 3, pre-workshops)

A system dynamics approach was used to develop influence diagrams, causal loop diagrams,
and a dynamic model that described the current understanding of how grass, rabbits, and
foxes interacted. These were developed through contact with the participants, other models
previously developed of a predator-prey system, and researched information on grass, rabbits,
and foxes. The system diagrams and model generated, known in the study as the base model,
defined the initial understanding of how these three stocks interacted and created the context
for the exercise. A simplified causal loop diagram of the base model can be seen in Figure 8-3.
The delays between the hunting and finding effectiveness are for gestation periods and the
delays between fractional birth rates and the population are to compensate for young not
eating as much as their elders (see Appendix E).
8.5.4 Reiteration and comparing to reference mode

(Step 4, workshop 1: scenario development)

Process: Revision and comparison to reference mode

In the first workshop, participants were given the influence diagram, causal loop diagram, and dynamic model of the initial system that had been developed and were told that these were drafts of the current understanding of how these three stocks interact. They reassessed, altered, and verified the diagrams and model and became familiar with its structure and endogenous behaviour. This was done first by explaining the diagrams and model to the group and then allowing them to explore the model by playing with it, while the facilitator (and the central model developer and author of this dissertation) answered any questions the
participants had. Following this, the participants were brought back together and introduced to scenario planning, its aims, techniques, and limitations.

The participants were then supplied with the ‘Easter Island’ like setting and were posed with the core task of the workshops:

‘These diagrams and model describe how we understand these stocks to influence each other today. Two ships from Australia pull up at the island and 30 foxes and 3000 rabbits are disembarked. The ships then depart for 12 years, returning in 2025. Our goal is to try to understand what might the populations of grass, rabbits and foxes look like upon their return’

Results and observations
Given these figures the initial model was run and the results seen in Figure 8-4 were observed. The stock of grass crashed because it supported an increasing number of rabbits and then stabilised. The foxes grew much faster than the rabbits, overshooting their food source somewhat and then coming back down with the number of rabbits. The stocks of rabbits and foxes then oscillated around before settling in equilibrium. It is stressed that much of the data used to generate the model was based on real data of births, deaths and the amount of food required by each species. An explanation of the model and the model itself can be seen in Appendix E. Since this was a semi-synthetic study, this became the reference mode for the study.
Combining scenario planning and system dynamics

Figure 8-4: The initial run of the Grass-Rabbits-Foxes base model

If the amount of grass is removed from this graph and the fox population put on a different axis, how the rabbit and fox population vary comparatively can more clearly be seen. This is shown in Figure 8-5.

Figure 8-5: The initial run of the Grass-Rabbits-Foxes base model (with the grass stock excluded from the graph only)
8.5.5 Identify trends and drivers and identifying predeterminants and uncertainties

(*Step 5, workshop 1: scenario development*)

Process: Identifying trends and drivers and dividing them into predeterminants and uncertainties

The first task was to develop scenarios of the stocks on the island. The participants began by identifying the trends and drivers in the same manner as the FDF study. Three categories were used to group the trends and drivers: environmental and botanical (flora), climatic, and animalia (fauna). Then, again like the FDF study (Chapter 5), they assessed which of these had the greatest uncertainty and which had the greatest impact on the stocks of the system. The trends and drivers were then ranked based on their uncertainty and impact. A cross-product method (see Appendix B and Appendix E) was used to calculate the ranking.

Results and observations

The results of this process can be seen in Table 8-1.

<table>
<thead>
<tr>
<th>Rank</th>
<th>Trends and drivers</th>
<th>Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Effects of climate change on temperatures</td>
<td>Climate</td>
</tr>
<tr>
<td>2</td>
<td>Diseases introduced by birds</td>
<td>Environment and botanical</td>
</tr>
<tr>
<td>3</td>
<td>Greater seasonal variability</td>
<td>Climate</td>
</tr>
<tr>
<td>4</td>
<td>Food availability for rabbits</td>
<td>Animalia</td>
</tr>
<tr>
<td>5</td>
<td>Biological changes: Inbreeding, learning &amp; adapting</td>
<td>Animalia</td>
</tr>
<tr>
<td>6</td>
<td>Food availability for foxes</td>
<td>Animalia</td>
</tr>
<tr>
<td>7</td>
<td>Soil erosion</td>
<td>Environment and botanical</td>
</tr>
<tr>
<td>8</td>
<td>Changing soil fertility</td>
<td>Environment and botanical</td>
</tr>
<tr>
<td>9</td>
<td>Decreasing land area</td>
<td>Environment and botanical</td>
</tr>
<tr>
<td>10</td>
<td>Pollution and disease from humans</td>
<td>Environment and botanical</td>
</tr>
<tr>
<td>11</td>
<td>Availability of fresh water</td>
<td>Environment and botanical</td>
</tr>
<tr>
<td>12</td>
<td>Variable rainfall</td>
<td>Climate</td>
</tr>
<tr>
<td>13</td>
<td>Birds as a source of food</td>
<td>Animalia</td>
</tr>
<tr>
<td>14</td>
<td>Botanical diversity: Introduction of foreign plants</td>
<td>Environment and botanical</td>
</tr>
<tr>
<td>15</td>
<td>Increasing soil fauna diversity</td>
<td>Environment and botanical</td>
</tr>
<tr>
<td>16</td>
<td>Sun exposure</td>
<td>Climate</td>
</tr>
<tr>
<td>17</td>
<td>Variable wind patterns</td>
<td>Climate</td>
</tr>
</tbody>
</table>

*Table 8-1: The trends and drivers with the greatest uncertainty and with the greatest impact on the system*
Table 8-1 shows the trends and drivers were spread fairly evenly across all three categories.

Participants focused on what they could interpret from the setting, what they could see impacting the system, and what they imagined could reasonably happen. As the island was in equilibrium and was disrupted by a pulse – an influx of rabbits and foxes – participants identified few trends – constantly changing system traits. The participants saw few steady changes to the system outside of the pulse itself. Instead they focused on drivers – traits that change the state of the system – and focused on what the changes would cause. The trends that were present were global trends, such as the impacts of climate change.

Participants did try to disentangle some of the more complicated trends and drivers such as climate change. Several uncertainties, such as Variable rainfall, Availability of fresh water, Variable wind patterns, and Effects of climate change on temperatures are all related to climate change. Participants acknowledged they did not have the knowledge or time to understand complicated models of climate change, so they chose to break it up into influencing components that impact the system. These influencing components were rainfall, wind, fresh water, and temperature. Discussion acknowledged that more work was needed to understand these impacts, something the next activity assisted with.

As there were only 17 trends and drivers only the top five trends and drivers, when ranked on both uncertainty and impact, were selected as the key uncertainties. These were explored in more detail in the next section.

**8.5.6 Exploring the key uncertainties and developing the initial scenarios**

*(Step 6, workshop 1: scenario development)*
Process: Exploring key uncertainties and developing initial scenarios
Participants then explored the five trends and drivers that had the greatest uncertainty and the greatest impact on the system in more detail. They discussed each of the top five at length and selected two to be the axis for a scenario matrix.

Results and observations
Participants discussed the implications of climate change at length. In the previous exercise they attempted to disentangle the impacts of climate change by separating out its consequences on the climate. This is why Effects of climate change on temperatures, Greater seasonal variability, and Variable rainfall were separate trends. In this discussion they acknowledged that they did not have the expertise in climate change to identify what the impact of the various consequences of climate change would be. Indeed, they acknowledged that even some climate models were unsure of its impact. For example, participants could see Effects of climate change on temperatures, Greater seasonal variability, and Variable rainfall as both increasing and decreasing food availability for rabbits. To reflect possible movements in either direction participants chose an axis of the scenario matrix to be Food availability for rabbits. The participants saw this as being a driver that would be directly affected by the factors of climate change that had a high potential impact on the system.

Participants then set about selecting the second axis for the scenarios. As climate change had already partially been captured through Food availability for rabbits (also high when ranked on impact and uncertainty), they looked at the second highest trend or driver when ranked on impact and uncertainty: Diseases introduced by birds. They combined this with other disease related trends and drivers to create an axis called Diseases, which referred to deadly diseases inflicted upon the populations. It was seen that a deadly disease in general, not just from birds, would have direct implications for the population stocks and participants believed it would be
beneficial to understand the effect of disease on different populations. This combined driver was selected as the second axis. The participants then choose preliminary extremes for the axes to vary over. The preliminary axes and their ‘extremes’ are shown in Table 8-2. They were reassessed in the second workshop. The results of the exploration activity and the draft scenarios are shown in Appendix E.

<table>
<thead>
<tr>
<th>Selected trends and drivers</th>
<th>Extreme A</th>
<th>Extreme B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Food availability for rabbits</td>
<td>A shortage</td>
<td>More than enough</td>
</tr>
<tr>
<td>Diseases introduced by birds</td>
<td>Fox population collapse</td>
<td>Bird population collapse</td>
</tr>
</tbody>
</table>

Table 8-2: The preliminary axes and their extremes

8.5.7 Developing initial scenario plots

(Step 7, inter-workshop period)

Process: Drafting the plots
During the inter-workshop period draft plots – the ‘stories’ of the scenarios – were drafted based on the preliminary scenarios. These were also reassessed with the scenarios in the next workshop. The redrafted results are shown in the next section.

8.5.8 Iteration, reassessment and naming the scenarios

(Step 8, workshop 2: scenario development, backcasting and model-casting)

Process: Iteration, reassessment, and naming the scenarios
The second workshop began by reassessing the draft scenarios. After thinking about the scenarios over the previous week, the participants discussed the limits placed on the axes and decided to alter them slightly, finding that the previously adopted extremes were internally inconsistent. Specifically, the change was to the Food availability for rabbits. The idea that there was more than enough food did not bode well with the idea that rabbits would expand
to fill the space required (sometimes known as the ‘Gold Fish’ effect). Furthermore, as More than enough implies more than ample, this may even stipulate the island has to be bigger than it is. As a consequence this extreme was changed to plenty of food, which reflected a situation where the island only had normal (base model) constraints in its ability to grow grass.

Names were then given to the scenarios and the plots accompanying the scenarios were also reassessed.

Results and observations
The selected scenarios and their names are shown in Figure 8-6, overleaf. The plots developed about the scenarios are it.

It was observed that the ‘axis’ of disease was actually two different axes combined. One of these axes was a disease for birds, which varied between to their collapse and no disease for birds. The second of these axes was a disease for foxes, which varied between their collapse and no disease for foxes. Using these with the other axis, Food for rabbits would generate eight scenarios (many more than recommended, see Bloom & Menefee, 1994; Genta et al., 1994; Mercer, 1995; Schwartz, 1996; van der Heijden, 2005). However, many of these scenarios would not provide much novelty. For example, no disease for both populations would only differ by the amount of rabbit fodder available, differences that could be covered by just four scenarios. To decrease the number of scenarios, but retain the amount of their variation, the two disease axes were kept as one.
Breeding like rabbits
The foxes and rabbits go forth and multiply. The island turns out to provide highly nutritious food for the rabbits and they do not need to consume as much as anticipated. The rabbits multiply beyond previous expectations as the island proves to have a greater carrying capacity for them. The foxes bring with them a deadly disease that eventually affects the whole fox population. The fox population collapses, reducing the number of rabbits that die through predation.

Clipped wings
The foxes and rabbits are released on the island and again the food is plenty for the rabbits and does not inhibit their ability to multiply. A disease brought by the newcomers to the island affects the bird population. The disease has no effect on the new-comers but is devastating for the birds. The disease spreads and decimates the bird population.

It’s a hard knock life
As the foxes and rabbits begin to settle into the island, it quickly becomes apparent that the tough reed like grass on Easter Island is not a good food for rabbits. This does not mean that the rabbits consume less area of grass per month, but it does affect their rates of reproduction. The foxes, however, brought a deadly disease with them which affects the entire fox population. As a consequence the population declines and is eventually wiped out.
Short and sour
The rabbits that disembark the ship and find that the grass on the island is too low in nutrients for them and they begin consuming much more that they did in Australia. The rabbits expand but to a much lower level than predicted. This is compounded by a healthy fox population, which keenly hunts the rabbits. However, the new-comers bring a disease which, dormant in them, affects the native Petrels on the island. The disease is deadly to the bird population, who, because of isolation, has not built up the same immunities as the new-comers to the island. The bird population collapses from the new disease.

8.5.9 Backcasting and model-casting

(Step 9, workshop 2: scenario development, backcasting, and model-casting)

Process: Backcasting and model-casting
The participants were then divided into two groups and who then set out to explore the events and systemic changes that occurred to reach one of the scenarios. One group were assigned the backcasting method used in the FDF study. The other group used the system dynamics model as a guide and explored possible changes that could occur to the structure or what variables could have altered to lead to the scenario. This activity was called model-casting. Both groups focused on the one scenario: Breeding like rabbits.

Results and observations
The group that went through the backcasting exercise thought that, to get to a Breeding like Rabbits future, the fox population would bring the disease with them. Both populations when they got to the island would initially grow. The fox disease would spread slowly throughout the fox population, and it would not begin to decline till the early 2020’s. In reaction to this the rabbit population, with increasingly fewer predators, would continue to increase exponentially. By 2025 the rabbit population would be well over double its initial amount, and be growing at an exponential rate. The raw diagram from the workshops that depict this behaviour is shown in Figure 8-7.
The group that used the model to assess the events, trends, patterns, and system behaviour that could lead to *Breeding like rabbits* took a similar approach. After ensuring they understood the structure of the system, the participants adopted a trial and error approach to see what was needed to affect the system and reproduce the behaviour observed in the scenario (during the trial and error exercise, every change to the model was recorded). After an hour with the model the participants had decided to simulate the system observed in *Breeding like rabbits* by adding a *disease* variable to the model and using it to increase the death rate of foxes and slightly decreasing the land area needed by rabbits (from $10m^2$ to $9m^2$) to indicate an increase in the nutritional value of the grass. The results of these changes lead to a complete crash of the fox population after approximately 13 years and a rise in the rabbit population of 1,800 rabbits when in equilibrium. The graphs from these runs can be seen in Figure 8-8 and Figure 8-9.
The two groups then presented their results to each other, discussed them and identified two significant differences between the backcasting and model-casting exercises. First was that the
backcasters applied an exponentially growing deathrate from disease to the foxes to reflect infectious disease dynamics, whereas the model-casters applied a constant deathrate from disease to the foxes. The second difference was that the backcasters estimated a population of rabbits much higher than the model-casters.

The first major difference between the backcasters and model-casters was in relation to the deathrate of foxes from disease. The back-casters applied an infectious disease dynamic to the situation, a commonly observed dynamic (see Kermack & McKendrick, 1927\textsuperscript{24}), and decreased the fox population at an increasing rate. The application of this simple model meant that, if the disease was infectious, that the population of foxes in their exercise was more likely to reflected reality more closely. However, model-casters simply applied the disease as a constant fractional death rate that affected the death rate of the population, a structure that does not consider the slow-start and increasing infection-rate of infectious diseases (Kermack & McKendrick, 1927). The model-casters cited a desire to keep the model simple and a reluctance to think about such complex behaviour when asked why this behaviour mode was not included in the model.

The second major difference between the groups’ results was varying estimates of rabbit population, which was for two reasons. First, the backcasters did not consider carrying capacity of the island. This was caused by satisficing (see Simon, 1956). The backcasters satisficed because they could not grasp the non-linear rabbit population response of fox elimination, so they turned to the widely-known population model of exponential growth. This model reflects the exponential growth of the human race over the last two thousand years. However, the simple population model adopted does not demonstrate what happens when a

\textsuperscript{24} Because the disease was deadly, participants only applied the Susceptible-Infectious (SI) portion of Kermack and McKendrick’s (1927) Susceptible-Infectious-Recovered (SIR) model, a widely used model in epidemiology (Sterman, 2000). The SI model (portion) exhibits S-shaped growth.
The Grass-Rabbits-Foxes Study

population reaches its environment’s carrying capacity, as shown in many models including Limits to Growth (Meadows et al., 1972). The resulting S-shaped growth would have had the population stabilising after a period of time and when super-imposed onto the current model’s behaviour would have had the initial rabbit population increasing further than it did but then stabilising at a higher level. The group did not identify this as the case before the target date, or even consider it at all.

The second reason for the varied estimates of rabbit population was the change in availability of food for the rabbits. The amount of grass on the island, a function of the area of the island, defined its carrying capacity. The Breeding like rabbits scenario defined a situation where there was plenty of food. To simulate this the group that used the model changed the area of grass required for a rabbit from 10m² a month to 9m², which in effect simulated an increase in the nutritional value of the grass (therefore rabbits needed less grass). The effect of this change was an increase of the number of rabbits when the model was in equilibrium. The backcasters however, did not consider the change of food at all.

The failure to consider the change of food would have kept the backcasters’ estimations lower, but this was not enough to offset the failure to consider the carrying capacity of the island. In the discussion, and after reflecting on the model-casters’ results, the backcasters admitted that their estimation of rabbit population in the scenario was too big and would probably need to be scaled down to accommodate carrying capacity.

A different interpretation of the scenario was one of the causes of the different approaches. In the discussion after the exercise the back-casters acknowledged that they did not think of changing the amount of grass in the model or its nutritional value. The groups then discussed
why this may have been the case and the backcasters argued that they did not interpret ‘plenty of food’ to mean greater food availability than the base model. As is evident by their adjustments to the model, the model-casters interpreted ‘Plenty of food’ as meaning there was more food than the base model.

This indicated that there was a possible problem with the definition and clarity of the scenario. The scenarios perhaps should have outlined a move in the nutritional value or availability of food rather than an ambiguous term like ‘Plenty of food’. Had the scenario been more clearly defined, the differences in interpretation may not have been an issue in the backcasting exercise. This is an example of using system dynamics to reflect back and reassess the scenarios. Furthermore, system dynamics was used to identify variables that may have not yet been considered by the group of back-casters.

The motivation for taking these two different approaches is reflected in these results. The model assisted participants to think non-linearly and include a complex range of factors when calculating the implications changes had on the population. The backcasting encouraged participants to think more broadly and incorporate complex ideas not already included in the model. It also restricted the complexity of relationships assessed. Needing to define these complex notions and articulate them mathematically discouraged the model-casters from including these concepts. However, only simple changes to the model were implemented, such as variables and direct influence, no additional feedback structures were identified. Perhaps if more time was given this would have been different, or perhaps the model provided a predefined structure that participants were not willing to question. This is will be discussed at great length in section 8.6.
8.5.10 Developing influence diagrams of the systems in different scenarios

(Step 10, workshop 3: developing influence diagrams and causal loop diagrams)

Process: Developing influence diagrams of the systems in different scenarios
In workshop 3, after revisiting the scenarios and the model, participants were set the task of developing influence diagrams grounded in the different scenarios. Participants were broken into different groups and each group was assigned a scenario. Individuals then developed influence diagrams of the predator-prey system they observed in their scenario. Pair-blending (see Chapter 4) was then used to blend their individual diagrams with a partner’s and generate a single diagram that reflected the participants’ mental models of the scenario.

Only two scenarios were chosen as a focus for activity: Breeding like rabbits and Short and sour. Only two scenarios were selected because there were only four participants that had been to both of the previous workshops. Therefore, to ensure there were at least two of these participants in each scenario, only two scenarios could be selected for this activity. Two participants with previous experience in each scenario was deemed desirable because they would have a more detailed understanding of the system and would have a normative effect on each other in the blending process (before the integration). The two scenarios were chosen because they represented the different extremes in the scenario matrix (that is, they were diagonally opposite).

Results and observations
The resulting blended influence diagrams for the scenarios can be seen in Figure 8-10 for the Breeding like rabbits scenario and Figure 8-11 for the Short and sour scenario.
The *Breeding like rabbits* influence diagram demonstrates a clear focus on feedback. In the previous chapter, the China Futures study, the exercise produced few feedbacks. The focus on feedback shown above is likely to be due to the availability of materials that reflect feedback thinking (the base system diagrams and models) as this was the difference between the China Futures study and this study. Another explanation is that the participants were system dynamists who focus on feedback, but it was demonstrated in the China Futures study that this is not necessarily the case.

This diagram has two variables not included in the base model, *Nutritional level of grass* and the *Density of rabbits*. The *Nutritional level of grass* was included to reflect the scenario’s ‘plenty of food for rabbits’, as was done in the back-casting exercise. However, Figure 8-10 shows it being directly applied to *Rabbit births*, implying that the amount of *Grass eaten*, and perhaps some other variables, are packed into that one variable.
The second variable included was the *Density of rabbits*. The base model implicitly used a density measurement, using the number of rabbits per fox in the calculation for *Foxes’ rabbit hunting effectiveness* (Appendix E). This is one interpretation of the *Density of rabbits* variable above. However, if this variable’s units are Rabbits per square kilometre, then this is a new variable that was assumed to be irrelevant in the base model, as outlined in its list of assumptions (Appendix E). Unfortunately there is no way to tell in retrospect which it is.

When compared to the base model, it appears that Figure 8-10 does not reflect the way the system would really work. There are a number of different elements packed into the variables in the diagram, for example the inclusion of amount of *Grass eaten* in *Rabbit births*. But these do not make the model wrong, harder to understand, and follow, but it could still reflect the correct behaviour. The problem comes when looking at some of the other relationships and those factors excluded from influence. For example, the *Rabbit population* has a direct influence on *Fox births* without any reference to the number of *Rabbits eaten*. Furthermore, the number of rabbits has no influence on *Foxes hunting effectiveness*, meaning that *Fox hunting effectiveness* and the number of *Rabbits eaten* would be the same regardless of the number of rabbits on the island. This demonstrates some of the short comings of this figure.
The relationships in the *Short and sour* influence diagram (Figure 8-11) are clear and well composed. As shown, the participants felt the need to be specific about the relationships and put the direction of influence on the arrows. This diagram also demonstrates that the participants had a clear focus on feedback, demonstrated by the number of feedback loops in the diagram.

As with the previous influence diagram, this diagram has two variables not included in the base model, *Nutritional value of grass* and the *Rabbit density*. However, the *Nutritional value of grass* is used here to reflect a shortage of food, rather than an excess and is applied directly to the amount of *Grass required* to feed the rabbit population, rather than being packed up in the Rabbit birth rates.
There are two other differences between this diagram and the base model. The first is that participants either did not believe or did not note a possible influence between the number of rabbits eaten by foxes and the Foxes’ birth rate, implying that if no rabbits were caught then the Foxes would multiply regardless. The second difference is the assumption in Figure 8-11 that rabbits could find all the grass on the island. This is perhaps feasible as rabbits could be fairly evenly distributed to find all the grass and, of course, grass cannot run or hide from rabbits like the rabbits can from foxes.

8.5.11 Integrating influence diagrams of the systems in different scenarios

(Step 11, workshop 3: developing influence diagrams and causal loop diagrams)

Process: Integrating influence diagrams of the systems in different scenarios
The groups then came together and attempted to integrate the influence diagrams from each of the scenarios into one that considered both the scenarios.

Results and observations
The result of this blending exercise can be seen in Figure 8-12.

Figure 8-12: Integrated influence diagram of the Grass-rabbits-foxes scenarios
The integrated influence diagram of the two scenarios reflects the feedback thinking that dominated the influence diagrams that went into forming it. It also reflects the two introduced variables – albeit with them slightly varied – from its constituting diagrams: Grass nutrition availability and Rabbit density. The influence diagram also includes other variables not yet seen, including Fox disease deaths, Fox health, and Rabbit health. Fox deaths from disease was included to reflect the infection of the Fox population in Short and sour. Fox health and Rabbit health were included as measures of the level of starvation of the population.

When compared to the base model, this influence diagram appears fairly robust. It includes many of the stocks and feedbacks in the base model. However, all the influence diagrams exclude the Grass stock. This would have significant implications on the system, removing the limiting factor for rabbits and allowing the populations of rabbits, and following them foxes, to explode.

This influence diagram highlights some of the exclusions of the base model, which were assumptions made during its development. The participants’ insistence on including density lead to some discussion about its role in hunting. Indeed, foxes’ ability to find rabbits is based upon their numbers (rabbits per foxes), but only so much as their numbers are related to their overall density (rabbits per square kilometer) and that there are enough rabbits to feed the foxes. Perhaps this discrepancy between the two models highlights an error in judgement when the base case was developed. A similar argument could be made for the grass, but its inability to run and hide from rabbits makes the density unit Grass per rabbit an acceptable exclusion.
8.5.12 Developing causal loop diagrams of the systems in different scenarios

(Step 12, workshop 3: developing influence diagrams and causal loop diagrams)

Process: Developing causal loop diagrams of the systems in different scenarios
The participants were then asked to develop causal loop diagrams to reflect the same two scenarios.

Results and observations
The participants had difficulties executing this task. Individually they took on a range of different approaches, including not reflecting on the influence diagram and starting from scratch. When they came together in their groups to blend their different diagrams of the same scenario one approach prevailed which influenced the result the group submitted. One group focused on the base model and simply added the variables they thought the model needed to reflect their scenario (Figure 8-13). The other group simply resubmitted (Figure 8-14) their influence diagram (Figure 8-11) with the loops now named as balancing or reinforcing and dropped out one loop identified earlier because it was reflected in the base model (Figure 8-3). Figure 8-13 and Figure 8-14 are both below.

![Diagram](image)

*Figure 8-13: The additional structure to add to the base model from Breeding like rabbits*
*Note: this was the result produced by participants who saw it as an addition to the base model*

Figure 8-13 shows the variable added to the base model to enable it to simulate the system identified in *Breeding like rabbits*. The addition of a *Nutrition value of grass* was designed to allow the model to capture an effective increase in food availability by simulating a reduction
in the quantity of grass required. The group visualised the increase in food coming from the possibility that the hypothetical grass on Easter Island had a higher nutritional value than that of normal grass, positively affecting the *Fractional rabbit birth rate*. In the discussion session after the exercise, the group acknowledged that the link here was a generalisation and missed out some key details. To render this the variable needed to influence the *Grass needed* variable, rather than the fractional birth rate directly. Furthermore, by making this change the diagram would also describe the impact that a change in nutrition would have on the (amount of) *Grass eaten* (see balancing loop B2 in Figure 8-3), which otherwise would have been misrepresented.

![Figure 8-14: The additional structure to add to the base model from Short and sour](image)

Figure 8-14 bares significant resemblance to Figure 8-11 for reasons already stated. Some small changes have been made. Firstly, as stated, the third feedback loop has been dropped, because the participants saw it has being better reflected in the base model. Secondly, the Rabbit fractional birth rate has changed to *Net fractional birth/death rate* to reflect the
The terminology agreed on by the participants in the integrated influence diagram (Figure 8-12). This is simply the incorporation of a few different variables into the one name. Finally, the amount of Grass required has been packed into the Nutritional availability of grass variable. This inclusion works for this diagram because of the boundary of the system set. The amount of Grass eaten is not needed as an output to any other variable and does not need to be its own variable. This is only because the diagram does not include a stock of grass. If a stock of grass was in the diagram, the amount of Grass eaten would be needed as a drain from the stock. The lack of a grass stock in this diagram, any of the other causal loop diagrams or even the influence diagrams, raises questions about the participants’ perception of the system.

The absence of grass in any of the causal loop and influence diagrams (except of course where they are simply ‘additions’ to the base model) can be due to a number of reasons. Firstly, it could reflect an aversion to increasing the complexity of the diagrams. Participants could have had little motivation to make their task harder by including an extra stock, particularly if its impacts on the system had already been recorded in the base model. Secondly, it could have been because of their reduction in focus. By attempting to focus on the differences in the scenarios, some of the similarities could have past recollection. When asked about the omission, participants’ responses appeared to be of recollection, followed by justification, implying both reasons were partially true, or rather that they contributed to each other.

**8.5.13 Integrating causal loop diagrams of the systems in different scenarios**

*(Step 13, workshop 3: developing influence diagrams and causal loop diagrams)*

*Process: Integrating the causal loop diagrams of the systems in different scenarios*

The participants were then asked to integrate their two causal loop diagrams of the system.
Results and observations
When the groups came together they observed that the addition to the base model shown in Figure 8-13 was already included in the variable Nutritional availability of grass and agreed that their task was already complete.

A limitation of this workshop was its severely limited time frame. This timeframe meant that the activities had to proceed with haste and provides an explanation for the shortcuts taken in the activity and provide possible explanations for the oversights that are evident in the results. A shortcut that was taken was the use of the base model and developing only variables ‘in addition’ to it. Oversights in the results include the lack of grass stock in the influence and causal loop diagrams, and limited time in the workshop could provide a partial explanation of its omission.

8.5.14 Developing and integrating stock and flow diagrams of the systems in different scenarios
(Step 14, workshop 4: developing and integrating stock and flow diagrams)

Process: Developing and integrating stock and flow diagrams of the systems in different scenarios
In workshop 4, participants were asked to use the base model, influence diagrams, and causal loop diagrams developed in the previous workshops to develop stock and flow diagrams of the system. As the previous workshop had only focused on two scenarios, this workshop would focus on the same two scenarios. However, time allowances were more generous for this workshop, so it allowed the participants to work on both scenarios, creating a diagram for one scenario and then moving onto the other.
Results and observations

Progress in this workshop was very slow as participants spent much of their time grappling with the system, asking questions about it and struggling to understand its intricacies, even with the supplement of the base model. Participants ended up using the base model as a starting point and adding the variables they saw were needed to reflect the scenarios, similar to the method used to develop the causal loop diagrams.

Again, participants generated individual diagrams and then blended them to form a scenario diagram. This was done first for Breeding like rabbits and then repeated for Short and sour. They then integrated these diagrams. The results from these activities were very piecemeal as participants used Post-its to develop their own ‘additions’ to the model and then moved these around during the blending and integration phases. By the end of the workshop, participants had settled on just three changes to the base model that would assist it to simulate the systems believed to be observed in the two scenarios.

1. The inclusion of a nutritional value of grass. The inclusion of a nutritional value of grass variable allowed for the consideration of plenty of food or shortage of food on the uncertainty axis. Participants did not delve into the reasons for the nutritional value of grass changing because of their desire to only reflect the scenarios and not attempt to understand why. As discussed earlier there were many reasons these could come about, such as a varying number of the different consequences of climate change.

2. The inclusion of a fox death rate from disease. A fox death rate from disease was also added to the model. Participants seemed to forget the discussions in previous sessions about infectious-disease diffusion rates and just applied it as a constant.
3. **The inclusion of a birds stock.** The inclusion of a birds stock changed the model more significantly than the other additions. Instead of only eating rabbits, foxes could now eat birds and rabbits.

Despite its presence in all of the influence diagrams and one of the causal loop diagrams, *Rabbit density* was completely abandoned in this workshop. There was no real explanation provided for this departure from previous doctrine. It is likely that it was abandoned because of the focus on the base model. Taking the base model as an unquestionable starting point, the participants were not in a frame of mind to question its assumptions, inferences, and structure. As a consequence they would have not tried to apply the variable to the stock and flow diagram.

Probably also due to their focus on the base model, the grass stock returned to the diagrams. The grass was integral to the model and, as a stock, it had been neglected completely in the previous workshop. Its reintroduction was not only that it was in the base model and other variables were being added, or as a reference to it, but as an explicit item in the participants’ stock and flow diagrams.

This was the first time that a bird stock was considered in the system dynamics side of the study, despite it having been set in the scene from the beginning. In the scenario development exercise, participants had considered the birds as additional fodder for the foxes. However, during the influence and causal loop diagram development workshop the birds were mentioned but not included. However, the focus on stocks in stock and flow diagrams, drew participants into thinking about specific populations, for example the number of rabbits and number of foxes, which provided an easier step to the consideration of the number of birds
and what might influence that stock. This was a significant development in this workshop and participants emphasised their desire to include birds as fodder for foxes in the next draft of the scenarios (see Appendix E).

8.5.15 Feedback and development

(Step 15, workshop 4: developing and integrating stock and flow diagrams)

The participants were then asked to complete surveys based on the workshops. The surveys can be seen in Appendix A. After they completed the surveys, a discussion session was held for the participants to provide feedback and make suggestions about the process. Feedback and suggestions about the process included:

- Perhaps developing an understanding of a single basic stock level (e.g. just grass) and then building other stocks onto it would be a more efficient way of developing the model.
- It is important in group model building exercises that a group ranks all the influences explicitly so the group does waste time discussing unimportant variables.
- It is also best to explicitly list all assumptions
- It would also be good to have:
  - A list of assumptions before the process (and then compare it to)
  - A list of assumptions after the process

The participants also provided feedback about the structure of the survey, its length and how the facilitators’ relationship with them could have influenced their answers.

8.5.16 Developing a dynamic model to reflect all the scenarios

(Step 16, post-workshops)
Process: Developing a dynamic model to reflect all the scenarios

After the workshops the facilitator sat down with the results from the workshop and put them together with the base model. The modeller built the three major suggestions from the workshops – the inclusion of a nutritional value of grass, a fox death rate from disease, and the bird stock – into the model.

Results and observations

The first two suggestions, the inclusions of a nutritional value of grass and a fox death rate from disease where simple additions of variables. However, the inclusion of a bird stock required much restructuring. Instead of only eating rabbits, the foxes now had to have a meat ‘quota’ which was filled first by rabbits and then, if not filled, by birds. As foxes have a hunting effectiveness for both animals, there are instances when this quota is not completely filled which culminates in either a short-fall of food and possible fox deaths from starvation (loop B6). Furthermore, the birds, outlined from the beginning as the native Petrel, have population birth and death rates as per researched information (see Appendix E). The causal loop diagram from this process can be seen in Figure 8-15.
With a starting stock of 1,000 birds and information about how Petrels relate to the rest of the system (Appendix E), the resulting behaviour of the system can be seen in Figure 8-16.
Combining scenario planning and system dynamics

Figure 8-16: The amount of grass and the rabbit, fox, and bird populations

Again, with the grass stock taken out of the figure, how the three populations move relative to each other can be observed (Figure 8-17).

Figure 8-17: The rabbit, fox, and bird populations
As can be seen in these two figures, the rabbit population initially climbs, overshoots the carrying capacity of the island and falls. Foxes similarly overshoot the carry capacity rabbits place upon their population and then fall. The population of birds shows a unique characteristic. It overshoots but then declines not because they reach carrying capacity, but because the foxes, running out of rabbits to eat, turn to them for food. This is not significant on its own, but does demonstrate still one problem with the model not dealt with in the workshops: that there is no inherent carrying capacity for the birds in the model. Despite this flaw, the model does appear to be capable of modelling both the Breeding like rabbits and Short and sour scenarios, as can be seen in the next two sections.

Breeding like rabbits
To simulate breeding like rabbits the facilitator used all of the information from the workshops. The nutritional value of grass was effectively increased by reducing the amount of grass rabbits needed, from 10m² per month to 7m² per month. A death rate from disease was also included, which adopted an infectious disease rate mode of behaviour, despite it not being mentioned in the final workshop. This was applied as shown in Figure 8-18.

![Figure 8-18: Fractional death rate of foxes based on an infectious disease dynamic](image-url)
The resulting simulation can be seen in Figure 8-19 and Figure 8-20.

**Breeding like rabbits: Amount of grass and animal populations**

These figures show the story that was expected from the backcasting exercise. The fox population collapses, albeit at a different rate. Without predators, the rabbit population
settles at a substantially higher level and the bird population, without a limit put on by a carrying capacity, continue to climb. This shows a problem with the model. Without a carrying capacity the bird population would continue to climb indefinitely.

Short and sour
Changes were also made to the model to simulate *Short and sour*. To simulate a situation of less food than anticipated, the grass growth rate was reduced. This had the effect of a continually lower amount of food on the island. The maximum grass growth rate was reduced from 70,000m² per month to 40,000m² per month. The scenario also explores disease for the bird population. This was not added in any of the workshops, probably because the bird stock was only added during the final workshop and no reflection on the scenarios occurred till after. The facilitator applied a bird fractional death rate from disease similar to that applied to foxes in the previous scenario (Figure 8-18). The results of the simulation can be seen in Figure 8-21.

![Figure 8-21: Amount of grass and animal populations in a simulation of Short and sour](image)
Figure 8-22 shows the behaviour of the animal stocks relatively without the scaling caused by the grass stock.

![Short and sour: Rabbit, fox, and bird populations](image)

These diagrams show, albeit with different specific numbers, what was predicted from the backcasting exercise. The bird population completely collapses and, with less fodder, the rabbits also settle at a lower level. With fewer rabbits for prey, the foxes settle at a low population level also.

### 8.5.17 General Observations

The scenarios themselves were founded on an imminent step change to the system, but the modelling based on the different scenarios included some trends that begin to occur because of those step changes. The scenarios, built from an understanding of the base model and outside knowledge about the environment and climate, were based on a step change to the system. A step change is also present in one of the most commonly cited examples of scenario
planning: Royal Dutch/Shell’s development of scenarios in the early 1970’s that depicted a pending energy crisis (Wack, 1985a; Schwartz, 1996; Wright, 2004; van der Heijden, 2005). This step change was about some oil supplying countries taking control of their oil fields, moving much of the control of oil production to the Organization of the Petroleum Exporting Countries (OPEC). Despite this step change, the modelling still included trends that were triggered by the change, such as the infectious disease dynamic. This demonstrates system dynamics’ ability to deal with both. However, there is no evidence in this study to support or deride the conclusion that scenario planning can also deal with both.

The system could be seen as a little too simple for the participants and not at all reflecting the complexity of real world situations. Furthermore, knowing the interactions between the stocks exactly before scenario development may have further simplified the task for the participants. However, this was not the case. It was observed that the participants still did not completely understand the system, despite fairly comprehensive information about it being readily available. Participants continued to ask questions about the system during the final workshop. This was partly due to participants’ unfamiliarity with the system and partly to the detail complexity of the system. Furthermore, the complex dynamics identified suggests that although simple on the surface the system is sufficiently complex to test the different aspects of integrating scenario planning and system dynamics.
8.6 Discussion of methodology and theory

8.6.1 Backcasting versus model-casting

The backcasting and model-casting exercises each had their own benefits and helped to reflect upon the scenarios. The backcasting activity let participants incorporate complex ideas, such as the infectious disease dynamic, without being turned off by the complexity of its inclusion. The qualitative nature of the exercise helped participants to include rich, relevant information that may not have otherwise been drawn into the process. The model-casting exercise, however, helped participants to understand the system and encouraged participants to keep a systems thinking perspective in the exercise. Using the model kept systems thinking dimensions such as feedback, the complex non-linear relationships of the system, stocks and flows, and delays in the exercise and at the fore of participants’ considerations. Using the two activities highlighted different interpretations of the system and both had valuable insights into the scenarios.

8.6.2 Supplying the base model and limits

By supplying participants with the base model information their thinking could have been bound by the information provided. The consequence of such bounded thinking would have been an inability to suspend disbelief, ‘think peripherally’, and create scenarios that truly pushed the limits of what people would have thought were possible. The consequence of this on the process was perhaps that the scenarios were not as challenging to the norm as would have been the case if that information hadn’t been supplied.

Not supplying this information was not an option. The participants had little knowledge of the real system and so had to be informed of its structure. Furthermore, the participants had been
exposed to several different predator-prey models before the workshops, and the clarification was needed before development.

Evidence that the process adopted for the study did help to expand the participants’ thinking is mixed. Participants did identify trends and drivers that were not covered in the base model (both in the system maps and the dynamic model). These were all exogenous to the system and expansion on the understanding used to develop the base model. However, participants also did not question the elements internal to the system, particularly the equations defining the relationships between variables, the boundaries of the base system maps and models, and some of the underlying assumptions and structure. In this respect the use of system dynamics appears to have limited their thinking.

The consequence of the exogenous nature of the trends and drivers and the unquestioning validity of the base model’s equations has mixed consequences for the system’s uncertainty. Referring questions to the model appears to have clarified the participants’ thinking of the models’ variables and their relationships so they no longer deemed these as uncertainties, or even as trends or drivers. This appeared to ‘move’ uncertainty to variable values, both exogenous and endogenous. While there is uncertainty with variables, uncertainty can also be present in the equations, boundaries, assumptions, and structure. These were only questioned during the study when the introduction of external elements called for their review, for example, when the bird stock was included in the model. By not questioning these, participants were neglecting potential sources of uncertainty and the causes of possible variations in the system.
The reason for this oversight is probably methodological error. When the participants were provided with the base model and assessed and adjusted it, they were told that the result was our perspective of how these stocks interact in the rest of the world today. After this the participants did not question the structure of the model (they only asked questions about the model) and now saw the models’ relationships and constants as unquestionable and temporally static, as evidenced by the failure to include trends and drivers that affected these elements of the model. There are two possible reasons for this. First, the change in task that created a mental barrier across which the participants did not venture; they did not question nor explore the models’ structure when brainstorming for the trends and drivers of the system. Second, the participants perceived the relationships and constants as universal truth, not as a perspective, and did not question or imagine them changing. The cause of the second possible explanation is likely to be the framing of the model, where the wording or phrasing led the participants to believe the model was correct. Either way, it appears that the lack of trends and drivers internal to the system was due to methodological error.

This raises the issue of model assumptions and their questionable and temporal nature.

System dynamics is a learning tool (Sterman, 2000; Forrester, 1985). It is designed to help people explicitly identify a system and question the influencing factors and their relationships that drive the systems’ behaviour. Thus, the assumptions made should be questioned. It was also identified in Chapter 2 that system dynamics is not a tool for predicting the future, it is, again, about learning about the system. The only form of prediction that a model generated using system dynamics (or any model for that matter) can make is a Popperian technological prediction. In a Popperian technological prediction, assumptions are the clauses that need to hold for the predication to be correct (Popper, 1966a; 1966b). Therefore, in a futures exercise, questioning the assumptions of any model and ensuring they hold true over time is a key task.
However, in theory, and not disproved in this study, some uncertainty can be simplified. For example, in stock and flow diagrams and dynamic models, by definition only rates can affect stocks. Therefore, when discussing trends and drivers, while people may talk about changes in population, from a dynamical modelling perspective they are really talking about changing the rates. The consequence of bringing dynamic modelling into a scenario development exercise is that participants may begin to talk about influences on rates rather than influences on stocks. This could help to unpack some of the complexities and remove some of the confusion present when variables are combined and their relationships convoluted, ultimately simplifying some uncertainties.

Defining elements in the model in this way, demonstrates how apparent uncertainties can be reduced by the assumptions made. For example, if the amount of Grass needed by rabbits is by definition the number of rabbits multiplied by the amount of grass they need to consume to live, then uncertainty in this number is shifted to uncertainty in amount of grass they need to consume and the rates of change of Rabbit population. Whether it is assumptions that determine the perspectives taken or the perspective taken that determine the assumptions made is not important, it is the assumptions and perspectives that are taken that decide and regulate how uncertainty can be shifted around a model.

### 8.6.3 Assessment of scenarios

As stated earlier, one of the greatest barriers for scenario planning as a field of research is the development of a method of scenario assessment. To create a quasi-assessment method the literature was scoured for traits that scenario researchers believe scenarios should have.
As discussed in Chapter 2 and Chapter 4, scenario planning literature suggests many different traits that scenarios should have. These traits have been partitioned and merged to form the criteria shown in Table 8-3 (for more information see Appendix A). Table 8-3 (opposite) shows the scenarios assessed against this criteria using direct observation.

These traits were identified in the literature as the traits scenarios should have. However, scenarios are only productive if they are used and carried forward. Furthermore, the activity is only fruitful if it challenges norms and encourages change or affirms current action. This study was a synthetic study with little context and no application, so these attributes could not be assessed. However, scenarios should also develop a users’ understanding and participants did learn about rabbits and foxes and their interaction.
The scenarios vary over two dimensions, implying they are relatively simple. They have extra detail in them from the exploration of the trends and drivers, but this does not add much complexity to them.

The scenarios appear reasonable given the initial case and what might occur.

As a consequence of the synthetic nature of the study, the scenarios are not realistic. It is unlikely that an island similar to Easter Island, but 100,000m² with no human inhabitants will be found and populated with rabbits and foxes.

The scenarios are not probable for similar reasons to the previous point.

The scenarios are not relevant, except to the execution of this study.

The scenarios have some elements of recognition. Diseases striking populations and changing climate impacting food can be observed in many different real life examples.

The detail in the scenario plots is fairly comprehensive.

The scenarios encouraged participants to think about the extent of the system and what could cause it to change

The scenarios provide a novel view of what could happen to the amount of grass and the populations of rabbits and foxes on the island.

The scenarios all have short names.

By capturing the multi-faceted impact of climate change in food availability, the scenarios have captured a number of different uncertainties.

The scenarios appear to be internally consistent.

This trait cannot be assessed as there are no decision makers about a system like this.

---

### Table 8-3: A qualitative assessment of the scenarios by direct observation

<table>
<thead>
<tr>
<th>Criterion</th>
<th>Assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simple</td>
<td>The scenarios vary over two dimensions, implying they are relatively simple. They have extra detail in them from the exploration of the trends and drivers, but this does not add much complexity to them.</td>
</tr>
<tr>
<td>Reasonable</td>
<td>The scenarios appear reasonable given the initial case and what might occur.</td>
</tr>
<tr>
<td>Believable</td>
<td>The scenarios appear believable, if this type of situation were to actually arise.</td>
</tr>
<tr>
<td>Realistic</td>
<td>As a consequence of the synthetic nature of the study, the scenarios are not realistic. It is unlikely that an island similar to Easter Island, but 100,000m² with no human inhabitants will be found and populated with rabbits and foxes.</td>
</tr>
<tr>
<td>Probable</td>
<td>The scenarios are not probable for similar reasons to the previous point.</td>
</tr>
<tr>
<td>Relevant</td>
<td>The scenarios are not relevant, except to the execution of this study.</td>
</tr>
<tr>
<td>Recognisable</td>
<td>The scenarios have some elements of recognition. Diseases striking populations and changing climate impacting food can be observed in many different real life examples.</td>
</tr>
<tr>
<td>Complete</td>
<td>The detail in the scenario plots is fairly comprehensive.</td>
</tr>
<tr>
<td>Evocative</td>
<td>The scenarios encouraged participants to think about the extent of the system and what could cause it to change</td>
</tr>
<tr>
<td>Novel and unique</td>
<td>The scenarios provide a novel view of what could happen to the amount of grass and the populations of rabbits and foxes on the island.</td>
</tr>
<tr>
<td>Have a short name</td>
<td>The scenarios all have short names.</td>
</tr>
<tr>
<td>Capture a number of different uncertainties</td>
<td>By capturing the multi-faceted impact of climate change in food availability, the scenarios have captured a number of different uncertainties.</td>
</tr>
<tr>
<td>Internally consistent</td>
<td>The scenarios appear to be internally consistent.</td>
</tr>
<tr>
<td>Able to capture a decision makers’ imagination</td>
<td>This trait cannot be assessed as there are no decision makers about a system like this.</td>
</tr>
</tbody>
</table>

---

### 8.6.4 Using the influence, causal loop, and stock and flow diagrams

The system diagrams provided novel information not considered previously. They suggested information that was not already considered in the model. An example of this information is the inclusion of birds in the model. However, the diagrams developed in the final two workshops (as opposed to those developed before and during the first) did not prompt or motivate participants to re-assess the scenarios. If the information incorporated in the final
model had been given to the participants perhaps it may have provided information that would have prompted them to do so, but this is speculative.

Using the final model to reflect on the scenario only had minor insights. The most significant of these was something forgotten in the model and in the scenarios: that the birds had no predefined limit to their population. The model highlighted that consideration should have been given to what defines the islands’ carrying capacity of birds in the scenarios, because of the bird’s ability to be a food stock for the foxes.

The system diagrams did motivate a re-assessment of the base model. The activity did change the variables that the participants saw important to model in the base model. The addition of the birds stock was to be expected. The base model explored the system without the context of the Easter Island setting. When the setting introduced the birds stock, it was likely that participants might see this as an element that could be added to make the model more realistic. It is however, unusual that the inclusion of the birds did not happen until late in the series of workshops. The addition of the fox death rate from disease and the nutritional value of grass, however, were novel introductions not induced by the scene that was set. Even from the outset, with little knowledge of the nutritional value of grass, its inclusion as a variable appears to be a wise measure.

8.6.5 Assumptions

The model, like all models, is incomplete (Meadows et al., 1972). Assumptions have been made so that the system can be simulated. However, these assumptions could have been elements assessed in the scenarios; especially when, over time, assumptions that are made
change and can be completely incorrect. The supplement of the model appeared to have made the assumptions unassailable to participants. The only questions asked about the assumptions were about rabbit density and its impact on hunting effectiveness. Unfortunately, these were quickly abandoned. Perhaps more is needed to encourage participants to question the assumptions in the model, to create a more robust reflection of reality.

The tendency of the participants to jump between sets of assumptions in the workshops is one cause for concern. Through the development of influence diagrams, causal loop diagrams, and finally the stock and flow diagrams, the participants changed their assumptions about some factors including rabbit density as a variable necessary to describe the system and the late inclusion of birds. The abandonment of rabbit density could have come from the move between freely identifying their own variables in the influence diagrams to only outlining the additions to the base model in the stock and flow exercise, a move they made independently. The move made the assumption that the assumptions in the base model were correct. The move was motivated in part by time restrictions but also by the desire to reduce cognitive strain and remain in a lower state of cognitive exertion. It meant that the emphasis moved from internal structure to external variables. The birds stock was attached because it was external to the existing structure and was seen as important by the participants.

8.6.6 Engagement with the model and integrating system maps and models of different scenarios

The desire to reduce cognitive exertion explains some behaviour witnessed during some of the workshops. In the workshops, many participants exhibited an aversion to go into the model in detail. For example, the back-modelling group was deterred from applying infectious disease dynamics to the model (despite how easily this was done in the scenario runs, even if they
were approximations). This behaviour could not only be seen in their focus on exogenous variables in the stock and flow exercise, and their penchant for not questioning the assumptions, but also during the identification of trends and drivers. Cognitive ease and the desire to remain in a state of low cognitive strain (see Kahneman, 2011) is one possible explanation for this observation. It was not until they were given a task that required them to engage in the model, did they do so, for example in the model casting exercise. Even this activity exemplified the desire to stay in a state of low cognitive strain, with the participants reluctant to apply the infectious disease dynamic to the model.

None of this discussion addresses the premise of whether system diagrams generated in different scenarios can be integrated. The participants in this study had very little difficulty integrating the influence diagrams. The causal loop diagrams were also quite easy, with one of the causal loop diagrams (Figure 8-13) already being incorporated into the other (Figure 8-14). Finally, the stock and flows were also easy to integrate. However, the causal loop diagrams and the stock and flow diagrams were easy to integrate because they were based on a common model. Furthermore, the loose structure that the stock and flow diagrams took, more-or-less just a list of additions to the model, meant that they were easier to integrate.

8.6.7 Iteration

The iterative approach used here demonstrates possibly the greatest benefit of using scenario planning and system dynamics in parallel. The system maps and dynamic model assisted to develop the scenarios by defining the trends and drivers. Discussion around the scenarios introduced information into the system maps and dynamic model, for example infectious disease dynamics. Attempting to develop system maps and dynamic models the different scenarios introduced elements that were not previously considered, such as the birds stock.
Finally, using the model to run simulations about the scenarios uncovered further information not previously considered, such as questioning the islands’ carrying capacity of Petrels. Each step provided new and unique information about the system, which had not been considered before.

8.6.8 Limitations

This synthetic, ‘laboratory’-like study abounds with limitations. Probably the most significant of these was that the base model was not of the actual system, it was of a similar, more general system. It therefore allowed for obvious additions to be made to the model. Secondly, the base model led participants and, despite some discussion of assumptions such as rabbit density, the participants accepted it. Despite these limitations, the findings of the study support the use of system dynamics and scenario planning in tandem.

8.7 Chapter conclusions

This study added considerably to the understanding already established about the integration of scenario planning and system dynamics. Methodologically it demonstrated that the backcasting exercise helped to reflect upon the scenarios, the language used in them, and their specificity. From an information perspective, backcasting introduced qualitative assessments that participants otherwise resisted, possibly due to the cognitive work needed. Furthermore, developing system maps based in the scenarios helped to add forgotten and not considered information to the scenarios.

Unfortunately, the use of a dynamic model appeared to create unquestionable boundaries and assumptions (including equations) for the exercise. Participants unequivocally accepted the
assumptions of the model and all uncertainties generated were exogenous to the base system maps and model. Despite this, the model did clarify the system for them in their development of scenarios. These were the implications of using system maps and a dynamic model to assist a scenario planning approach. Caution must be used when combining these approaches and participants should be encouraged to question all elements of a dynamic model, not just the variables, but also their relationships.

System maps and a dynamic model were developed that could reflect multiple scenarios. For the dynamic model at least this could be because it was used to develop the scenarios. Despite this, developing a model that reflects all the scenarios was possible. Furthermore, such a model and its simulations pointed to some shortcomings of both the model and scenarios that were not previously considered, for example the inclusion of birds as a source of food for the foxes.
Chapter 9   L’Arche Genesaret Study

9.1 Key structure elements

In this study a comprehensively integrated method of scenario planning and system dynamics was employed, similar to the Grass-Rabbits-Foxes study (Chapter 8). However, unlike the Grass-Rabbits-Foxes study it was applied to a real world situation. Learning from the lessons in the previous studies and to test a different method of integration, a different approach was designed. Instead of system diagrams being generated before the scenarios were developed, in line with the FDF study (Chapter 5), this study developed them after draft scenarios had been formulated. The intention was then to pursue a system dynamics approach on the problem as far as it could be taken before returning to the scenarios. In this way, the designed approach aimed to be more like in the Grass-Rabbits-Foxes study, where system dynamics could then inform the scenarios developed.

9.2 Context

The process of selecting a topic for the study was crucial. The China Futures study and the Grass-Rabbits-Foxes study both highlighted the importance of a focal problem for system dynamics. Furthermore, as a real world application, access to the organisation and its

---

25 Note that a return to the scenarios is not shown in Figure 9-1, because it is only a rough guide of the process adopted. This detail is shown in Figure 9-2 (see section 9.4).
employees were essential so domain experts could be used and data could be appropriately gathered. The ability to hold workshops was also essential as the approach was again based on group activities. Organisations were approached and issues discussed to find an appropriate focus for the case study. One of the benefits of system dynamics and scenario planning are their flexibility and the organisations could have been public, private or not-for-profit and at any stage of their development – from start-up to a mature organisation or even one in decline.

9.2.1 L’Arche Genesaret, ACT

The organisation selected for the study was a small not-for-profit organisation called L’Arche Genesaret, ACT (Australian Capital Territory). L’Arche Genesaret is an organisation that cares for people with intellectual disabilities. L’Arche Genesaret ACT (hereon L’Arche) is one of 131 L’Arche communities worldwide, seven of which are located in Australia. The communities around the world together form the Federation of L’Arche Communities.

L’Arche provides housing and support for 13 people, known as core community members (hereon core members), in the ACT. It runs three houses and a support network made up of a three house coordinators and a number of other assistants and volunteer assistants (known as live-in assistants). These personnel provide care for L’Arche’s core members based on rostered times. The houses and their staff are supported by an administration team made up of a Community Leader, a Homes Coordinator and a General Administrator, who answer to a board that makes the key decisions for the organisation and is led by a General Manager.
9.2.2 L’Arche’s philosophy

L’Arche’s defining feature is that it does not view itself as a service provider, but rather as a community. It perceives the care it offers others more as ‘doing it with someone’ rather than ‘doing it for someone’. L’Arche’s emphasis on community means it sees the people in the organisation, all staff and core members, as a network of support for each other to encourage and develop the independence of the core members. These ideas are built into L’Arche’s structure, captured in its charter, and are perpetuated by its culture. This philosophy permeates the way it operates, influences how the board makes decisions, and defines the way it treats its core members, employees, and volunteers. It even effects the way it interacts with its contextual and external environment, including its donors (as will become evident later on).

9.2.3 L’Arche and this study

L’Arche was appropriate for the study because it provided a clear decision problem upon which to focus. L’Arche, like many organisations, has the desire to grow and incorporate more people with intellectual disability into its community. The organisation wanted to understand what constraints there were to its expansion. This problem provided focus for both the development of scenarios, system diagrams and dynamic models.

However, having a decision problem was not all that was required. System dynamics is a tool for investigating the endogenous causes of behaviour; behaviour that arises from the structure of the system itself (Richardson, 2011). To properly test if scenario planning and system dynamics can inform each other, the problem needed to be one that applied suitably to both approaches: the right ‘type’ of problem was needed. The decision problem initially appeared to be the right ‘type’ of problem. From a series of initial meetings it appeared as though
L’Arche was suffering from the limitations of the structure of the system in which it existed. Its attempts to grow were not being influenced by exogenous factors, but by factors from within the system. While this could not be confirmed until a system dynamics approach could be taken on the problem, this initially looked like it could be the right ‘type’ of problem to study.

Other reasons existed for selecting L’Arche for the study, these included the access it gave to staff, board members, and core members and that these groups, including some broader stakeholder groups, were willing to make the investment of time needed for the study. Access to board members, employees, and core members was essential to enable all levels of the organisation to have input into the process. An investment of time was also needed to capture their inputs. A selection of L’Arche’s staff, board members, core members, philanthropists, and core members’ families were willing to set aside time for the workshops needed to develop scenarios, system diagrams, and dynamic models.

L’Arche’s philosophy also defines the organisations unique ‘business idea’ and creates a complex context for its operation, which made the models somewhat more complex to conceive and build. However, the philosophies lent themselves to being incorporated into the rich, qualitative nature of the scenario planning approach adopted. This was also a consideration in L’Arche’s selection for the study.

The study was run as a consultation project with L’Arche. L’Arche was treated as a client of a process that could potentially be applied elsewhere. This gave the study a more applied focus than the Grass-Rabbits-Foxes study, something that was reflected in its design. As part of a consulting project, the results of the scenario planning phase were detailed in a report released to L’Arche (see Featherston & Doolan, 2011).
9.3 Premise and aim

The aim of this study was to apply a more integrated approach of scenario planning and system dynamics in a real world application. In particular, this study aimed to explore two aspects of the integration of scenario planning and system dynamics. Firstly, this study aimed to explore if the scenarios and the scenario planning process were useful when developing system maps and system dynamics models. It was believed that the scenarios and scenario planning process would provide context and have started the discussion about system structure that could be carried forward into the system dynamics portion of the study.

The second aim was to see if the system maps and system dynamics model and the process used to generate them would cause a reassessment of the scenarios. This could establish if the system dynamics approach informed participants’ mental models and the impacts of these on the scenarios.

9.4 Method summary

Participants were drawn from many of L’Arche’s stakeholder group. Board members, staff, core members, external philanthropists, core members’ family members, and long-term-community members (people who were staff members or board members long ago who still loosely involved with L’Arche and are brought in on occasion to provide advice) were involved in the workshops. The number of different stakeholders involved ensured each stakeholder group was represented and that a number of perspectives would be considered in the process. Perhaps the most glaring omission from this group was the lack of representation from ACT Health, the local Government’s agency that provides the bulk of L’Arche’s funding. ACT Health were invited to be involved in the study by were unable to attend.
A process similar to that employed in the FDF study was adopted to develop the draft scenarios in the first two workshops. The third workshop employed a different approach to those used in other studies to develop maps of the system. The fourth workshop explored some of the implications of the findings and provided participants time and a structured approach for developing strategies for L’Arche from the results of the previous workshops. Figure 9-2 outlines the main steps taken in the study. These steps will be explored and their result given in the following sections, but are broken up by project phase.
Figure 9-2: An overview of the method adopted for the L’Arche study

Note: Steps on different lines in one box are steps (from Chapter 4) combined in this chapter for convenience.
9.5 Pre-workshops

9.5.1 Identifying the client

(Step 1, pre-workshops)

The first step was to identify a specific client for the study. L’Arche’s board was identified as the client. In particular it was the General Manager, the Community leader and the finance director. The aims of these individuals were to expand the number of core members in L’Arche’s community, without jeopardising its philosophy or financial security. During the project the General Manager’s tenure expired and a new Community Leader was elected. Furthermore, in the later part of the study, half of the board’s tenure expired and they were replaced. These changes were extra obstacles for the study and delayed its final delivery.

9.5.2 Identifying the purpose, articulation of mindsets, and refine the focus and set horizon year

(Step 2, pre-workshops)

The purpose of the project was mostly outlined in the initial meetings before L’Arche was specifically selected for the study. Its desire to grow appeared to be an appropriate problem for the study. Two semi-driven meetings were conducted with the Community Leader and the General Manager to further define the problem. These meetings clarified the focus of the approach.

Another aim of the meetings was to understand what the clients currently understood about L’Arche and its system. Much time was spent discussing and understanding L’Arche’s current position, structure, and modus operandi. To assist understanding development rough cognitive maps were developed. Cognitive maps are informal diagrams that help to clarify the situation,
uncover many of the influencing factors that participating people believe affect the problem and act as a check to ensure there are no simple solutions that have been overlooked (Eden and Simpson, 1989). Cognitive maps are the first step in Eden and Simpson’s (1989) strategic options development and analysis (SODA) and have many common elements with both scenario planning and system dynamics.

The meeting also addressed the issue of scope. Before a scenario planning process can begin, the scope of the scenarios should be chosen (Schnaars, 1987). Simpson (1992, p.11) believes that scenarios should only be focused on a business’s external environment and Schoemaker (1995) focused on the external environment for his scenarios. Despite this, it was felt that the scope of the scenarios would be defined by the problem and that early specification of this could stem the information gathered in the workshop. The only scoping that did occur was the identification of a target year for scenarios, this was set at 2025.

The meetings also helped to clarify whose opinions were best to be caught and involved in the workshops. It was decided that a wide range of people from the various stakeholder groups in L’Arche would be approached. The list of people to involve in the workshops included: core members, board members, administration staff, house coordinators, assistants, core member’s family members (hereon family members), philanthropists, and government representatives. L’Arche already had a group that it had put together to work on a different problem recently and it was decided that this group could form the core of the workshop participants. It was noted that this broad selection of people would bring a number of different perspectives and sources of information together for the workshop, as diversity of information provides unique views and helps the conversation that occurs during scenario development to look into blind-spots (van der Heijden, 1997; 2005).
Finally, a schedule for the workshops and the major steps in the project was created in the meetings. This was based on the organisation and the people who were desirable to have involved in the project. The schedule was based on timing and availability, and developed a common understanding of the goals of the workshops and the resources required.

9.6 Workshop 1: Uncertainty identification

The first workshop involved seven participants from a range of L’Arche’s stakeholder groups. The participants included core members, their family members, staff, philanthropists and long term community members. The workshop was held as an evening session at L’Arche’s offices in the ACT.

Before the workshop began, participants were asked to fill out a survey (survey A in Appendix A). The aim of this survey was to document their understanding of L’Arche and its general and operating environment before the workshops.

9.6.1 Identifying driving forces: trends and drivers, and identifying predeterminants and uncertainties

(Step 3, workshop 1: identifying predeterminants and uncertainties)

Process: Identify the trends and drivers
In the same manner as the FDF study, participants listed L’Arche’s trends and drivers. These were then divided into predeterminants and uncertainties.
Results and observations

The results were mapped after the workshops. The result of this process can be seen in Figure 9-3.

![Mapping L'Arche's trends & drivers on impact and uncertainty](image)

*Figure 9-3: L'Arche's trends and drivers plotted on impact and uncertainty*

*Note: CMs are core members*

It should be noted that the *Productivity Commission report* was a report conducted by the Australian Government called *Disability Care and Support* (see Productivity Commission, 2011a; 2011b). The report could have had several impacts on L’Arche, most significantly on assistants’ wages. The outcome of this report was very uncertain at the time of the workshops.

Taking the top 12 trends and drivers on this scale to be the key uncertainties is historically the case with scenario planning. O’Brien (2004, p.711), for example, found 12 to be a practical number that allowed a certain level of complexity without flooding the participants with

---

26 www.pc.gov.au
variables to consider. As only 25 trends and drivers were identified in the process, taking half seemed a little excessive, so only the top eight were selected. These eight key uncertainties can be seen in Table 9-1.

<table>
<thead>
<tr>
<th>Rank</th>
<th>Key uncertainty</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>New sources of assistants</td>
</tr>
<tr>
<td>2</td>
<td>Productivity commission report</td>
</tr>
<tr>
<td>3</td>
<td>Decreasing funding</td>
</tr>
<tr>
<td>4</td>
<td>Threat to sources of overseas assistants</td>
</tr>
<tr>
<td>5</td>
<td>Encouragement of philanthropy</td>
</tr>
<tr>
<td>6</td>
<td>Aging core members</td>
</tr>
<tr>
<td>7</td>
<td>Increasing cost with increasing number of core members</td>
</tr>
<tr>
<td>8</td>
<td>ACT Government relationship</td>
</tr>
</tbody>
</table>

Table 9-1: The key uncertainties from the first L’Arche workshop

The strong representation of resource related key uncertainties reflect L’Arche’s position as a not-for-profit organisation. Assistants (New sources of assistants and Threat to sources of overseas assistants) and funding (Decreasing funding and Encouragement of philanthropy) are focused on the acquisition of resources and Productivity commission report (impacting the wages of assistants), Aging core members (as they grow older their needs increase, increasing the funds and assistance needed for their care) and Increasing costs are all related to the draining of resources. The only non-resource related uncertainty was L’Arche’s Relationship with the ACT government. Furthermore, the uncertainties explore both the cost and access, indicating that money is not the organisation’s only concern. As such, the focus on
resources is more driven by the organisation’s desire to incorporate as many core members in its community as it can manage, rather than a reflection of financial hardship. L’Arche’s unflinching attitude towards its philosophy is the reason for its absence.

9.7 Workshop 2: Scenario development

The second workshop was an all day workshop that involved twelve participants from all of L’Arche’s stakeholder groups, with the exception of government representatives. The workshop opened with an introduction to the problem and scenario planning and a summary of the results of the process thus far.

9.7.1 Exploration of key uncertainties

(Step 4, workshop 2: scenario development)

Process: Exploring the key uncertainties
The participants were then broken up into four groups and were given two of the eight key uncertainties to explore. Similar to the FDF study, the participants were asked to identify ‘extreme’ endstates, descriptions for them, their drivers and their implications. This began to define the uncertainties more clearly and got participants thinking about the interrelated nature of some of the causes of the endstates and their consequences. The results of this activity can be seen in Appendix F.

9.7.2 Developing initial scenarios and iteration and reassessment

(Step 5, workshop 2: scenario development)

27 This term is used with the same qualifications that were outlined in Chapter 4
Process: Develop initial scenarios
Each participant was given a card with a scenario matrix on it. The participants were asked to use the information from the previous activities and select two key uncertainties that they thought would be most important to L’Arche. Important was defined here as its impact, its uncertainty, or a combination of the two. Participants were also asked to select key uncertainties and that would be of value for L’Arche to investigate. They were also told to consider the different uncertainties in combination and that if a dichotomy that was a combination of some of the uncertainties was particularly evident and pertinent, they could be combined to form an axis.

In pairs the participants then compared the axes they had chosen and blended their selections to form a new set of scenarios. The participants were told that if the axes were closely related enough they could merge them, but were warned about the dangers of going too far with this. Some participants did merge their axes, but many found they had much the same axes. These were written on a new card with a scenario matrix on it and presented to the group before the participants went on a lunch break.

The facilitators collated the pairs’ cards and treated each axes selected on the card as a vote for that uncertainty or that merger of uncertainties. As with the FDF study, two orthogonal axes were clear winners and a scenario matrix was generated. The facilitators presented the selected scenarios to the participants after lunch, who reviewed and discussed the scenarios. Some changes were discussed, agreed upon by the group and the changes were made accordingly.
Results and observations

The resulting scenarios can be seen in Figure 9-5. The figure uses the final names chosen for the scenarios, which will be discussed in the next section.

The major change between the draft scenarios and these was the removal of two scenarios from the matrix. The matrix that the facilitators generated was a two by three matrix, with the vertical axis Availability of assistants and the horizontal axis Funding sources. The Availability of assistants varied between Ample and Shortage, as L’Arche would likely react quickly to reduce assistants if they ever had too many. The axis Funding sources had been seen by participants to vary between mostly Government sources, mostly Philanthropic sources and a chronic Shortage. However, upon reflection, the participants did not find a Shortage of funds different enough to Government and Philanthropic. Instead, they saw L’Arche always having a ‘shortage’ of funds. If they were ample they would take on more core members and if they had to little they would struggle or fold, whether the primary source of funds was the government.

Figure 9-5: L’Arche’s scenarios

Note: the x-axis is the Source of the majority of funding for L’Arche and the y-axis is the Availability of assistants.
or philanthropic. To reflect this view of the world, the *Shortage* option was removed from the axis.

### 9.7.3 Adding detail to the scenarios and naming them

*(Step 6, workshop 2: scenario development)*

**Process: Environment identification and naming the scenarios**

The participants were divided into four cross-stakeholder groups and each group was assigned one of the scenarios. Each group identified what the world would be like for L’Arche in their environment by assigning environmental traits to the four environment categories used earlier: political, economic, socio-cultural and L’Arche community.

The purpose of this activity was to provide a more complete understanding of the world in that environment. This was a different approach to the ‘assignment’ of values to the uncertainties that was done in the FDF study. The participants were asked to think about what environmental attributes would co-exist with their scenario, rather than be restricted to only the uncertainties. To do this, participants relied heavily on their mental model to understand what would cause their scenario and what other consequences these would have in the four categories. This activity was designed to be a first pass before their mental models were further surfaced and tested using system dynamics in the next workshop. The results of this activity can be seen in Appendix F.

Based on the environment, the groups were then asked to allocate a name to their scenario that summarised and described the environment L’Arche was facing in their scenario. The results from this activity were presented by the groups to all workshop participants. These
results were re-assessed by the participants before they began the system dynamics activities at the beginning of the next workshop. The resulting names were shown in Figure 9-5.

The participants were then given a summary of the scenarios and how the results of the workshop were to be used. They were briefed on the next two workshops and were asked to fill out complete a workshop feedback form (see Appendix A). The workshop was then closed.

9.8 Inter-workshop period: scenario narrative development

9.8.1 Developing initial scenarios

(Step 7, inter-workshop period)

Process: Draft plots
In the intervening period the information from the workshop was used to generate the narratives that described the scenarios. The results of the final activity form the previous workshop were particularly useful in developing the narrative. The narratives were revised at the beginning of the next workshop and again in the final workshop. Their final version is listed here as the bulk of the work occurred between these workshops. Furthermore, these narratives were put in a pre-pack that was given to participants to read before the next workshop and complete the information that the participants had to work from in the third workshop.

Results
The final results of this process of drafting and iteration can be found on the next page.
'Dreams can come true'
Funding Source: Mostly Government
Availability of assistants: Ample

The Australian economy has remained strong since the early 2010's despite troubles in the Euro-zone and in the USA. This growth has had high yields for the Australian government and voters, who have developed greater empathy for the needs of disadvantaged people, have driven the government to acknowledge these needs and spend more money on providing those services.

Despite this renewed interest, organisations, such as L'Arche, are still finding their financial situation difficult. Fragmentation of the community service providing industry is seeing this money spread thinly and individual organisations realise little of the apparent increases. Furthermore, aging core community members, housing and transport facilities and a shortage of support from private philanthropists are stretching the budget further and putting strains on core community members, assistants and board members.

Voter empathy has, however, encouraged the government to promote volunteering both through the relaxing of visa lengths and cutting of delays to encourage volunteers from overseas as well as programs, such as gap years, to encourage Australian's to volunteer. The flux of volunteers provides some relief, but finances are still a severe concern.

Out of balance
Funding Source: Mostly Government
Availability of assistants: Shortage

Voter empathy has increased but this alone has had a marginal effect on government spending or on the government's desire to develop favourable policies to make it easier for overseas volunteers to come to Australia. Instead, a healthy economy and a general increase in public spending on welfare had favourable effects on organisations such as L'Arche. The lack of initiative to increase volunteering by the Australian government, changes in non-Australian governments' gap-year and national service programs and the strong economy have led to a drying up of volunteers. People have also begun to work longer, which compounds the issue by draining the vital source of volunteering retirees.

To combat the shortage, organisations have tried to attract more volunteers and assistants by offering higher stipends and benefits. However, this has had little effect as these changes have
not been able to compete with other sectors in the healthy economy. As a consequence, community service organisations are relying upon casual wages, which is a problem in organisations like L'Arche were routine is important.

Organisations such as L'Arche continue to press the government and private philanthropists for more funding to deal with aging individuals and infrastructure, but only the government is responding. Despite this, government support is still minimal: an aging population in Australia has stretched the benefits of a strong economy and general budget stress continues.

**Keep breathing**

Funding Source: Mostly Non-government

Availability of assistants: Shortage

Global warming and other matters of international concern have diverted the Australian government’s attention and expenditure, reducing funding for social programs and community organisations. These organisations have reacted by turning to private philanthropists to fill their funding needs and who now provide most of the funds for such services. Despite this, funding is short and aging populations and infrastructure pose large threats to the survival of many organisations.

Government activity is, however, successful in keeping the economy buoyant and unemployment is low. This is putting further strain on community organisations who are finding it increasingly difficult to find assistants and volunteers for work. A strong Australian dollar makes working in Australia attractive, but with no government action on reducing red tape on visas and making access easier, the source of overseas assistants and volunteers is beginning to dry up too.

**Creative sustainability**

Funding Source: Mostly Non-government

Availability of assistants: Ample

Contagion from other economies has led to stagnation in the Australian economy. Beginning in the mid 2010's, the Australian government tried to stimulate the economy by increasing expenditure. However, after a long period of slow growth, the Australian government was forced to reduced its expenditure to try to keep a burgeoning public debt under control.
Community service organisations were among the first to feel the squeeze and have been forced to turn to private companies for the majority of their funding. The economic downturn has also affected private companies and organisations that did not have an edge in fundraising, announcement, and getting exposure for their benefactors do not survive. In these hard times people in the community have become sensitive to the strains on services to disadvantaged people and social responsibility has become important to many private organisations who wish to get ahead.

The economic slowdown has also increased unemployment, which has made it easier for community organisations to fill positions they previously had trouble filling. Furthermore, travelling agreements with the international L'Arche community allows for movement of people between various L'Arche communities, who see it as a good way to travel and see the world.

Observations
The scenarios reflect four very different operating environments for L'Arche. They also highlight some of the opportunities and threats for L’Arche, some that are not considered a great deal already in the organisation. For example, the scenario name ‘Dreams can come true’ was applied by participants because while this appears a desirable future state for the organisation, they realised they must be cautious because of their dependence on the government, a body whose own policies can change. Participants began to view this dependence as a risk for the organisation and wanted to reflect this in the name, hence the quotation marks.

9.9 Workshop 3: System dynamics

The third workshop was held over one full day and engaged ten people from a variety of L’Arche’s stakeholder groups. The workshop began with a brief summary of the work done so far and a description of the problem. The participants then re-assessed the results from the
last activity in the previous workshop before being given a detailed introduction to system dynamics.

### 9.9.1 Developing understanding and collecting information

*(Step 8, workshop 3: system dynamics)*

**Process: Getting a feel for the system**

A general discussion about the problem was then held. This was to give the participants time and space as a group to consider the problem, its causes and its implications. The discussion was open and frank and some participants gained insight about areas of L’Arche to which they were not usually exposed.

### 9.9.2 Mapping the system

*(Step 9, workshop 3: system dynamics)*

**Process: Developing influence diagrams**

The participants then began to develop influence diagrams. They broke into four groups of three and each group was given a scenario. Individually, the participants constructed influence diagrams of the system they believed was driving their group’s scenario. The participants placed one of the key uncertainties in the middle of an A3 page and listed the factors that influence it on the left and the factors that were influenced by it on the right. The next step was to identify any feedback; that is, if any factors on the right influenced factors on the left, forming loops. Finally, they identified if there were any causal links between factors within each list. All causal links were denoted by arrows. The participants then gathered in their groups and blended their influence diagrams.
Results and observations
The blended diagrams were presented to all workshop participants. Only one of the diagrams is shown here, the one generated in the context of the scenario *Creative sustainability* (Figure 9-6), for the other diagrams please see Appendix F.

*Figure 9-6: Influence diagram from the scenario Creative sustainability*
These diagrams defined the boundary of the system well and showed links between factors that influence each other. Many also reflected the interrelated nature of the factors within the system. However, many of the links were vague and unclear. Furthermore, the diagrams had gaps and many more iterations would have been needed to form complete diagrams of the system and fill the major omissions. But the purpose of the diagrams was more than just an accurate representation of the system. First, the activity was to get them thinking causally, about feedback and about the boundaries within the system. Second, the activity introduced participants with surfacing their mental models in such a way and questioning and challenging what was on the posters. Third, the activity got participants using the notation that is common in system dynamics. Finally, many of the links drawn in the influence diagrams were to be used in the next activity.

Process: Developing stock and flow diagrams
Participants were then given a lesson on stock and flow diagrams: what they were, their representative purpose and their notation. As a group, an example was run through that used a bank account as a stock and deposits and withdrawals as flows. In their four groups, participants were then asked to choose a major stock from their influence diagrams and begin to identify the factors that influenced its flows. This session ran all afternoon, with an afternoon tea break, and relied heavily upon the facilitators to inform the participants as they went.

The purpose of this exercise was three fold. First, it aimed to surface and test many of the assumptions the participants had about the behaviour of the stocks and what caused such behaviour. To this end, the participants did make their mental models explicit and reproduced it in a material form for other participants in the group to test against their own mental models and discuss the discrepancies. Secondly, it continued to develop the causal links that had been
drawn in the first exercise. With the more structured format of stocks and flows, participants broke their thinking down and thought about causality step by step. The statement, ‘let’s think about this’ was heard more than once during the exercise and the logical, incremental thinking that followed often clarified many questions participants had about the system. The key outcome here was that participants had begun to un-confound variables and put more structure to their mental models. This structure meant their mental models would be less ‘slippery’, preparing them to be closely compared to reality (Meadows, 2008, p.172).

**Results and observations**
The four stocks selected by the groups were: Number of core members, Amount of annual government funding, Amount of philanthropy and the Number of sources of assistants. The resulting diagrams can be seen in Appendix F.

The first three stocks were directly related to the issues L’Arche was facing and were important for the study, but the final stock – Number of sources of assistants – did not seem to get to the core of L’Arche’s problem. The number of sources of assistants was not necessarily proportional to the number of assistants, which was identified in the scenarios as a key uncertainty for the organisation. It is likely that the number of assistants would have been a better selection. The participants realised this issue towards the end of the workshop and requested that the focus in the next workshop be on number of assistants, rather than the number of sources of assistants.

Again the diagrams clearly outlined a system boundary and demonstrated just how many factors influenced these crucial flows for L’Arche. The participants also became more adept at offering ideas and discussing changes regarding their graphical representations of their mental
models. However, many of the variables in the stock and flow diagrams were factors that were
difficult to measure and the way many of them influenced the flows was unclear, making their
development into a system dynamics stock and flow diagram difficult. Furthermore, the
participants lost their focus on feedback and focused on chains of causality, with only two
feedback loops being identified in all four diagrams (see Appendix F), both in the same
diagram. Such causal chains make modelling such a dynamic system more appropriate in non-
system dynamics software, like Microsoft Excel™, rather than system dynamics specific
software.

System dynamics discussion & closeout
The participants were then brought back together to discuss the session. They believed that
the session was very productive and that they had learnt much about L’Arche. They felt that
the diagrams did not reflect all the learning that had occurred during the workshop. However,
they were confident that the facilitators, now quite familiar with L’Arche, would be able to
apply what they had learnt to the diagrams to ‘tidy’ them up for them. They were eager to
have another go at these diagrams once this had been done to try to fill in some of the gaps
that they could already begin to see.

Participants also discussed the desire to bring the two funding stocks together and treat them
as the rates of a stock of Funds. Merging Government funds and Philanthropic funds would
create a single stock that would more closely represent their accounts. Furthermore, the two
diagrams had many of the same ‘drains’ on the stocks. Participants asked if this could be done
in the intervening period between the workshops, both during and after the workshop.
The participants were asked to complete the survey B (see Appendix A) and the workshop feedback form (also in Appendix A) and they were briefed on how the results would be used and on the next workshop. The workshop was then closed.

9.10 Inter-workshop period: Dynamic model development

9.10.1 Further system mapping

*Step 10, inter-workshop period: dynamic model development*

**Process: Stock and flow diagram development**

Using the outputs from the workshops and the understanding of L’Arche gained during the meetings and workshops, the facilitators then set about developing the stock and flow diagrams from the workshops further. The facilitators arranged meetings with L’Arche personnel when clarification was needed and edited the diagrams to reflect participants’ views surfaced in the final workshop.

**Results and observations**

The stock and flow diagrams around Government funds and Philanthropic funds were merged. The resulting stock and flow diagram was easier to understand than its ancestors. The ancestors had stocks that were rates and their resulting rates had to be conceived as rates of change of a rate. This had led to some confusion in the workshop. However, the merged diagram had a stock, Funds, that was simple to understand and had two inflows, government and philanthropy, and one outflow, expenditure. The participants had pointed out that these changes would have the effect of making the diagrams easier to understand. Perhaps they had been influenced by the example of the bank account, which provided a good analogue to
which they could more closely relate the activity to the theoretical source domain (see Lakoff and Johnson, 2003).

From the stock and flow diagrams the facilitators began to develop dynamic models. These models were simple and only reflected what could be witnessed in the stock and flow diagrams. Dynamic modelling software, such as STELLA™ (Stella) and ExtendSim AT™, were used to develop the models.

This activity deviated from the planned flow of activities for the study. It was hoped that by this stage the facilitators would be developing dynamic models, but only simple ones could be developed from the stock and flow diagrams provided. It was clear that more time was needed with L’Arche and its stakeholders to develop dynamics models from which some learning could occur.

Planning the final workshop
Before the final workshop, L’Arche’s community leader and general manager were involved in a meeting to decide what they wanted strategically from the final workshop. They were briefed about the different activities that could take place, including the backcasting and stakeholder analysis that occurred in the FDF study. The client chose two activities for the final workshop: a leverage point identification exercise and an exercise similar to windtunnelling. These would both occur after a review of the stock and flow diagram.

---

28 Stella™ is produced by isee systems, inc. www.iseesystems.com
29 ExtendSim AT™ is produced by Imagine That! www.extendsim.com
9.11 Workshop 4: Scenario & Systems Analysis

The final workshop involved 12 people from L’Arche and its other stakeholder groups. It was an evening workshop held at L’Arche’s offices in the ACT. The workshop began by outlining the focal problem and by summarising scenario planning and the work completed in and out of the previous workshops. This front end material took some time as it had been accumulating over the previous workshops. Each time the material was given participants had a better understanding of the theory and the purpose of the workshops. To develop their understanding further, each time the front-end material was given it was more detailed and advanced in its description. The development of understanding was evident in participant’s behaviour, as they began to take what was learnt in these sessions and apply them more actively in the workshops.

9.11.1 Reviewing the system maps

(Step 11, workshops 4: scenario & systems analysis)

Process: Review of the stock and flow diagrams
The first activity of the session was a review of the stock and flow diagrams from the last workshop with the changes that had been developed by the facilitators. Participants were given a refresh lesson on stock and flow diagrams (for two participants this was new material) and then were taken through the stock and flow diagrams as they currently stood. They broke into groups of four for a carousel around each of the three stock and flow diagrams (see the Glossary for more on carrouselling). The participants assessed diagrams and amended them to reflect their mental models.

Results and observations
The resulting diagrams can be seen opposite.
Figure 9-7 shows the influences on the stock of assistants employed by L’Arche. The diagram clearly defines the boundary of the influences that affect the Number of assistants employed by L’Arche. The influences are mostly factors internal to L’Arche and are built into its operating structure. The participants have identified many measurable nouns, only lapsing back to language that must be heavily interpreted for system dynamics in some places, such as Lack of communication. Participants have also identified the limiting factors for changes in the stock, such as Forecast surplus, demonstrating an attempt to be as comprehensive as possible. It is evident however, that there are some issues with the diagram, including the omission of an influence demonstrating the impact the fixed costs of houses have on the Total costs (implying there should be a link between Number of houses and Total costs). The diagram does have feedback, showing that the diagram is beginning to reflect some systems thinking.
The diagram for the stock *Number of core members* in L’Arche is shown in Figure 9-8. This diagram exhibits a number of feedback loops and extends the boundaries of the system beyond L’Arche (challenging boundaries), both examples of systems thinking (Booth Sweeney & Sterman, 2000). The figure also defined many different measurable quantities, however, some non-measurable variables are still present. The figure is a detailed map of the system and shows where the three stock and flow diagrams overlap.
Figure 9-9 shows how the participants perceive the influences around L’Arche’s funds and how they define L’Arche’s financial position. There are many different influences in the figure which reflects the effort that was put into it. Such effort and the number of variables demonstrate how much the participants consider L’Arche’s financial position and how important it is to them. Interestingly there is only one feedback that goes into the sources of funding. Much of the feedback participants perceive is through expenses only. This could reflect the focus they have on the locus of control. From day to day the operations of the organisation focus largely on expenses, since government funding, shown here to be largely out of their control, makes up a very large portion of their income. Some locus of control is demonstrated by the activity
that L’Arche conducts to push the organisations philanthropic donations, but this is minimal.
Again, Figure 9-9 show the overlaps between the three stock and flow diagrams.

In the system dynamics phase of the project, the models were used as a basis for dynamic
modelling. Several changes had to be made to the models during this phase. The changes that
were made are outlined in Appendix G.

9.11.2 Identifying the leverage points

(Step 12, workshops 4: scenario & systems analysis)

Process: What can L’Arche do to affect desirable change from the system
An activity selected by L’Arche, the next exercise identified L’Arche’s leverage points of the
systems outlined by the three stock and flow diagrams. Meadow’s (2004) identified 12 types
leverage points that can be used to influence the behaviour of a system. These leverage points,
in order from highest capability to change the systems behaviour to lowest are:

1. Transcending paradigms
2. Paradigms
3. Goals
4. Self-Organisation
5. Rules
6. Information flows
7. Reinforcing feedback loops
8. Balancing feedback loops
9. Delays
10. Stock and flow structures
11. Buffers
12. Numbers
Participants in the workshop were briefed on leverage points and given examples of what they are and how they influence a system’s behaviour. They were introduced to Meadow’s (2004) classifications of leverage points as shown above and asked to use this as a guide for comparing leverage points in the activity. The participants were asked to select the factors in the diagrams they thought L’Arche had the greatest influence on in the system and can use to influence the systems behaviour most effectively. The leverage points were ranked based on their ability to be influenced by L’Arche and beneficially alter the system’s behaviour.

The purpose of this activity was to get participants to clarify for L’Arche what they thought L’Arche could influence in the system; what factors L’Arche could be investing resources in to affect desirable behaviour out of the system. The introduction of the leverage points was designed to get participants to compare leverage points and which would be used to achieve greater results for L’Arche.

Results and observations

The results of this activity can be seen in Table 9-2.

<table>
<thead>
<tr>
<th>Rank</th>
<th>Leverage points</th>
<th>Stock and flow diagram of leverage point</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Attractiveness of L’Arche</td>
<td>Number of assistants &amp; funds</td>
</tr>
<tr>
<td>2</td>
<td>Life-cycle for assistants (e.g. students)</td>
<td>Number of assistants</td>
</tr>
<tr>
<td>3</td>
<td>Long term assistants feel the demand when transition occurs (e.g. when live-ins leave)</td>
<td>Number of assistants</td>
</tr>
<tr>
<td>4</td>
<td>Commitment to L’Arche vision</td>
<td>Funds</td>
</tr>
<tr>
<td>5</td>
<td>Public talks</td>
<td>Funds</td>
</tr>
<tr>
<td>6</td>
<td>Number of houses</td>
<td>Number of core members</td>
</tr>
<tr>
<td>7</td>
<td>Media pressure</td>
<td>Funds</td>
</tr>
<tr>
<td>8</td>
<td>Political lobbying</td>
<td>Funds</td>
</tr>
<tr>
<td>9</td>
<td>Invitations to community events</td>
<td>Funds</td>
</tr>
<tr>
<td>10</td>
<td>Success of announcing</td>
<td>Funds</td>
</tr>
<tr>
<td>11</td>
<td>Number of housing spots</td>
<td>Number of core members</td>
</tr>
<tr>
<td>12</td>
<td>Community lifestyle</td>
<td>Number of core members</td>
</tr>
</tbody>
</table>

Table 9-2: The 12 most effective leverage points participants saw for L’Arche
Participants identified the Attractiveness of L’Arche (as a place of employment) as the most effective leverage point for L’Arche. Participants believed that if L’Arche’s increased the attractiveness of employment, then they will be able to attract more assistants to the organisation.

There is a pattern evident in the leverage points shown in the third column of Table 9-2. The top three leverage points were all present in the Number of assistants stock and flow diagram (and the Attractiveness of L’Arche was present in both that diagram and the Funds stock and flow diagram) and the next six, with the exception of one, were all from the Funds stock and flow diagram. This could be random. However, it more likely reflects the more controllable nature of the soft employment side of L’Arche.

This activity mostly only identified leverage points in the bottom, less effective types of Meadow’s (2008) leverage points. In fact they all fall into the bottom, ‘number’, category. The higher up the list of leverage points the greater the amount of abstraction of the system is needed. The participants had only just begun to think about L’Arche from a systems perspective, and the variables and stocks and flows – those with lower levels of abstraction and lower levels of capability on Meadows’ (2008) list – are easier concepts to grasp for application, making such levels of abstraction needed for the identification of higher capability leverage points difficult. However, the structure of the activity is likely to have at least contributed, even encouraged, the identification of leverage points in only the lowest category. Participants were asked to vote on leverage points on the posters, and when they approached the posters they saw the Post-its – the variables – as the possible contenders, rather than delays, loops, goals or any other of the leverage point types. This grounded their thinking and added to the difficulty of attaining the level of abstraction needed to perceive the
higher capability leverage points. Whether a different approach could have overcome this and assisted the level of abstraction attained is unclear.

9.11.3 Windtunnelling

(Step 13, workshops 4: scenario & systems analysis)

Process: Windtunnelling ideas – developing an action agenda/strategy

Participants reviewed the scenarios and selected three ‘shifts’ in scenarios on which to conduct the windtunnelling exercise. The ‘shifts’ focused on how L’Arche could influence its environment to cause a change from one scenario to another. They did this on a timeline where they outlined the attributes of the initial scenario and the attributes of the final scenario. They then identified the evolution of the original attributes to those of the final scenario. Along the way participants identified enablers, or the actions L’Arche could take to help influence the evolution of the scenarios. The three scenario ‘shifts’ were: from Out of balance to ‘Dreams can come true’ (a), from Keep breathing to Creative sustainability (b), and from ‘Dreams can come true’ to Creative sustainability (c), as shown in Figure 9-10.

Figure 9-10: Shifts for the windtunnelling exercise
The purpose of this activity was to use the scenarios to get L’Arche to begin to think strategically. It identified actions that L’Arche could take to attempt to influence the emergent strategy of the organisation, or its realised strategy (see Mintzberg, 1987a; Mintzberg, 1994a; Mintzberg, 2007). As the perceptions of the participants had begun to shift during the workshops, this step tried to encourage the employment of the learning from the scenarios in a tangible and applicable activity with the hope that it would crystallise the learning and demonstrate how it could be applied.

Results and observations
A lengthy discussion could be made regarding the strategic implications and the validity of the task, however, only the points relevant to the thesis will be discussed here (see Appendix F for the results of the activity). Firstly, participants took to the application of the activity well, identifying clear actions that L’Arche could take to help influence the evolution of the conditions of its environment. Second, it was observed the participants used their knowledge from the workshops in the activity. Third, the enablers (actions) identified by the participants were all, by definition, in its contextual environment – the part of the environment that can be influenced (van der Heijden, 2005). Finally, participants identified strategic actions that were different to the actions L’Arche had employed in the past; these actions demonstrated novel strategic thinking among the participants. However, whether the understanding used and
actions identified only reflected the conditions outlining the scenarios on their posters or
because they had been internalised during the workshops is unclear.

Process: Discussion and closeout
Following the windtunnelling, a discussion was held. The session had a strong strategic focus
and looked at what the participants had learnt in the workshop and how they could use it.
There was discussion of the implications of the different scenarios, with reference to the
scenario names, but little on discussion of their content. There was a general agreement about
the validity of the scenarios and their relevance to L’Arche’s current position.

Workshop participants were then asked to complete a survey about the workshops and what
they got from them (see Survey C in Appendix F) and a general workshop feedback form (also
in see Appendix F). They were briefed on how the results would be used to generate a report
for L’Arche and to continue to work on modelling the system. The workshop was then closed.

9.11.4 Scenario reporting

(Step 14, post-workshops: scenario reporting)
A report of the results of the workshops was then released to L’Arche (see Featherston &
Doolan, 2011). This report outlined the key uncertainties, the scenarios, the preliminary
system diagrams and the results of the wind-tunnelling exercise.
9.12 Dynamic modelling and taking a system dynamics approach

9.12.1 Further develop understanding and collect information (iteration) and traditional (non-system dynamics) dynamic model development

(Step 15, post-workshops dynamic model development)

Process: System dynamics clarification
Reality forced a revision of how and when the steps of a system dynamics approach could be taken. It became clear in Workshop 3 that the information gathered in the workshop would only help the preliminary stages of a system dynamics approach. The information gathered in the initial phase of the project and the workshops constituted a lengthy period of problem identification, familiarisation with the system and understanding its structure and ‘beat’, and the development of a dynamic hypothesis. Information for this stage was gathered from the scenario planning workshops, through meetings with L’Arche personnel, and from annual reports.

Results and observations
Several changes were made to the raw system maps from the workshops in order to reflect the real system. These changes were made by the client and by the modeller in collaboration as their understanding of the system and their understanding of how it might be reflected by the system maps developed. These changes are discussed at length in Appendix G. Once they were redrafted, the system maps were used as an incomplete source of information about the system. The information from these diagrams proved useful, but in places was misleading. The diagrams helped develop the understanding of the modeller, who then had to supplement the understanding with further questionnaires and interviews to extract the information needed for modelling.
Two models were developed from the information gathered in the workshop, one continuous and one discrete. These helped the modeller to develop an understanding of the structure of L’Arche and the reason for the decisions it made. They also identified that a new house is L’Arche’s obvious non-monetary limiting factor for expansion, which allowed this to be prioritised in the modelling phase of the study.

The discrete model was a dynamic model that cannot be considered a system dynamics model. The model was developed in ExtendSim AT™. It dynamically simulates L’Arche’s activity. It has five central stocks, including Core members, funds, house coordinators, assistants, and volunteers. There are numerous auxiliary stocks that have been used to assist and run the simulation. The simulation calculates how much time is needed from the assistants and how much extra is needed from casuals. These costs, plus the others generated by the core members, contribute to draining the accounts. The accounts are increased by government funds, philanthropic contributions and core member fees and are reported on a continuous basis. The model has a user interface, where they can choose to purchase a new house and accept new core members.

The discrete model is not a system dynamics model per se because it implicitly includes feedback in its structure. By reporting the major statistics to the user and allowing the user to play with some of the major inputs, the model does not include the major decision making structures of the system and relies on these from users’ perspective. This form of modelling has value as a generator of Game-based learning, by supplying interpretative, experimental and (partially) reflective support (see Reid et al., 2003, p.11). However, it provided little guidance as to the systemic nature of the behaviour being observed.
The continuous model was a model that attempted to capture the decision making structures. It reflected the system diagrams generated in the workshop more closely, thus including some feedback in the model. However, the decision structures behind purchasing a new house for the purpose of expansion were not included in the system maps and was lacking in the models.

### 9.13 System dynamics

#### 9.13.1 Problem specification, developing a dynamic hypothesis, and collecting reference modes

*(Step 16, post-workshops: system dynamics model development)*

**Process: problem specification**

In Chapter 4 this step was termed *problem identification*. However, by this stage of the study, the problem was known. What was needed was the problem needed to be more specific, as shown in the China Futures study.

**Results and observations**

The ‘traditional’ (non-system dynamics) dynamic models that were developed assisted in the clarification of the problem, its surrounding system, and the generation of a dynamic hypothesis. The problem addressed in the study was L’Arche’s growth. However, after several meetings with the client it became clear that there was a misalignment between L’Arche’s desire to grow, the confidence to grow, and its ability to grow. This caused more specific questions to be asked: what made the decision to buy a new house, take on a new house, or both and what caused the decision to be made.
The immediate ability to answer these questions differed significantly. The answer to the first question was clear when following the trail of a planning process: accounting models. When L’Arche went through a process of deciding whether to purchase a new house or not, much of the decision was left to accounting models, which investigated if L’Arche could afford to buy a new house. The accounting models also looked at whether L’Arche could afford the ongoing costs of occupying a new house, through accounting forecasting. The difference between purchase and occupation was generated by an offer from the government to buy a new house for L’Arche, so in both instances the focus for L’Arche was the on-going costs of a new house.

The answer to the second question, however, was unclear and became the focus of the study.

*Process: Developing a dynamic hypothesis*
Based on the information collected a dynamic hypothesis was developed.

*Results and observations*
As stated, there appeared to be a misalignment between L’Arche’s desire to grow, confidence to grow and ability to grow. Understanding this dynamic was the aim of this system dynamics approach. The desire to grow is omnipresent in L’Arche and as stated the ability to grow is limited by funds. However, the confidence of the board is one thing that was not yet understood. This confidence was seen to possibly be the reason why these decisions were being made and became the root of the dynamic hypothesis generated. It was hypothesised that the misalignment between desire, confidence and funds could be described by the confidence of L’Arche’s board. This was the motivation and focus of the system dynamics portion of the study.
**Process: Collection of reference modes**
Reference modes were collected to compare to the system dynamics model (hereon the dynamic model) that was generated.

**Results and observations**
As the reference modes collected will be compared to the system dynamics model that was developed, the reference modes collected in this step will be discussed with the results of the model that was developed later in this section.

### 9.13.2 Mapping the system with the new focus and Developing a system dynamics model

(Step 17, post-workshops: system dynamics model development)

**Process: Conceptualisation and formulation**
This process involved understanding, mapping and modelling the confidence of L’Arche’s board.

**Results and observations**
To model the board’s confidence, a stock of confidence was created. Confidence, C, lay in the range $0 \leq C \leq 1$. Confidence was set as a unitless stock and it accumulated as confidence increases (a function of budget surpluses and supporting discussion) and eroded as confidence decreases (a function of budget surpluses and confidence diminishing discussion). The stock of confidence was defined as:

$$
\frac{dC(t)}{dt} = \rho C(t) - \phi (1 - C(t))
$$

Equation 9-1: The 'stock' of board's confidence
Where,

\[
\rho (\text{rho}) = \text{the accumulation of confidence} \\
\phi (\text{phi}) = \text{the eroding of confidence} \\
C = 1: \text{is complete confidence of buying a house} \\
C = 0: \text{is complete lack of confidence in buying a house}
\]

Another ‘stock’, D, was also created. D reflected the reverse of confidence: no confidence or doubt. D was defined as:

\[
D(t) = 1 - C(t) \\
\text{Equation 9-2: Doubt}
\]

D = 1: no confidence in buying a house
D = 0: complete confidence in buying a house

Therefore,

\[
\frac{dC(t)}{dt} = \rho C(t) - \phi D(t) \\
\text{Equation 9-3: The 'stock' of the board’s confidence}
\]

The sum of the no confidence and confidence stocks is one, which can be viewed as the adoption of a positive attitude (confidence) or a negative attitude (no confidence or doubt). Confidence is accumulated by supportive discussion and the depleted through doubtful or confidence diminishing discussion. The structure of the stocks Confidence and No confidence and the Supportive and Confidence diminishing discussions can be seen in Figure 9-12. Some might argue that modelling a variable like confidence is arbitrary because it is difficult to
Combining scenario planning and system dynamics quantity, but as Meadow’s (2008, p.176) says in reference to the inclusion of a similar difficult to quantify variable, prejudice, ‘it would have been much more unscientific to leave “prejudice” out of that study, than to try to include it’.

![Figure 9-12: The confidence model, a similar structure to the Bass model (Bass, 1969)](image)

This visual structure is similar to the Bass diffusion model (see Bass, 1969), but there are two major differences. Firstly, the flow is bi-flow. Secondly, and related to the first, the ‘balancing’ loop (B1) behaves differently. If the level of doubt is high, the confidence diminishing discussion encourages it to stay that way. In a way, it is a reinforcing loop for the No confidence stock. However, it is a balancing loop for the Confidence stock and is only defined as a balancing loop because of the pre-defined positive direction of the flow towards the Confidence stock. This highlights a shortcoming in combining causal loop diagrams and stock and flow diagrams with bi-flow dynamics such as is used here.

Driving the flow of confidence is the influence of the organisations’ surpluses and deficits, which can increase the adoption of positive attitudes, decrease it and reverse it (increasing and decreasing the adoption of negative attitudes). Confidence increases as L’Arche’s board, the key decision making body, observe high levels of financial health in the organisation and confidence erodes if they observe ailing financial health. Financial health, as it is observed by individuals on the board, can be indicated by financial surpluses or deficits. Individuals
informally use surpluses and deficits to assess the financial health of the organisation by assessing their absolute amount. They also assess if this level of financial health is enduring by comparing them to previous years. Confidence in acquiring a new house increases if an absolute surplus is large enough to cover the ongoing cost of a new house and if good financial health appears to be long term (three years).

When confidence is high enough, a discrete planning phase takes place. This creates an effective drain on the confidence in the model because the results of the planning phase – based on accounting models – will determine the board’s confidence, rather than conversation, informal financial planning, and informal forecasting. During this phase the costs of a new house are examined in detail and set against the forecasted future surpluses and deficits. During this process, the surpluses must remain high enough for financial health to remain sound. As the planning process looks at hypothetical surpluses, there is a break between a decision and the surpluses. System dynamics is not about predicting the future (as argued in Chapter 3), so this line must be very clear.

Instead, this time discontinuity is crossed only by the accounting models used in the planning process. They forecast L’Arche’s ability to afford the ongoing costs of a house. The forecasted surpluses, and the effect they have on the confidence which is also theoretical, determines the decision – essentially they are an alternative future. This theoretical alternative future is more appropriately assessed, as L’Arche does, using accounting rather than system dynamics models.

The reasons why the accounting models are more appropriate are plentiful. L’Arche is more capable and has more experience with accounting models. More importantly, however,
through their experience with them, they are more aware of the limitations of accounting models. There is a risk that the board would take a prediction from system dynamics as more than a technological prediction (see Popper 1966a; 1966b; 1957; Chapter 3) and over-estimate its ability to foretell the future. By seeing the results as a prediction, L’Arche could find itself overinvesting in situations where assumptions have changed and the model no longer applies.

A confidence-diffusion model with the discrete planning loop and with the outlined accounting phase can be seen in Figure 9-13.

![Figure 9-13: A diagram of how L’Arche builds and loses confidence in buying a new house](image)

Note: * denotes a qualification to its evaluation as a balancing loop (see below)

Notation is similarly difficult here within the guidelines of causal loop diagrams. Again, the bi-flow causes loops to be balancing for one stock and reinforcing for the other. However, discrete elements have also been introduced further complicating the diagram. The arrows of influence associated with discrete events do not have a direction (positive or negative) because they are discrete and do not exhibit the same behaviour as continuous influences (or at least, as continuous as they can be in modelling). The discrete loop (B*2) running through Planning phase (which more accurately triggers the planning phase) is that it is driven by a goal...
and thus has a balancing influence on the model. When a planning phase is triggered, it acts to reduce confidence to zero, because the decision made through accounting will be either to confirm their confidence, hence they will start at zero confidence for the next house, or it will show their confidence wrong, hence reducing it to zero anyway. This goal driven behaviour reflects negative feedback as it is defined in servo-mechanism theory, the origins of the feedback theory in system dynamics (Richardson, 1991). As such the loop has been assigned as a balancing loop, but with qualification due to its discrete nature and its differing influences on the two stocks.

In Figure 9-13 the box enclosing the red influences depict a small part of the planning process that uses accounting models and tools, where the forecasted surpluses help to make the decision. The *Time discontinuity* note pointing to the top of the box indicates that the inclusion of the influence is with qualification and should be asserted with prudence. The decision influences future surpluses, but these future surpluses are not present in the model. The surpluses used in the model are historical surpluses, included to help understand present behaviour. Thus far, no new house has been acquired by L’Arche and to model the acquisition of one would require forecasted surpluses, which is the role of accounting. It is included, though, to demonstrate the actual influence a decision to take on a new house would have. In a way, the red arrow between *Decision* and *Surplus* indicates a future path of influence that could occur and is forecasted by accounting tools and models.

Data is a pivotal part of the system dynamics approach (as expounded by many authors, including Sterman, 2000; Meadows, 2008). The data was used to understand the complexity of the system. L’Arche’s financial information for the last eleven years was used as input for the
model (see Appendix G). However, the data provided little help for reference modes, as is discussed in the next section.

9.13.3 **Comparison to reference modes**

(*Step 18, post-workshops: system dynamics model development*)

**Process: Comparison to reference modes**

The reference modes for this model were difficult to ascertain. The general attitude and feeling of confidence was the obvious reference data, but this would require surveys to have been conducted over the entire timeframe of the model. The timing of acquiring a house was similarly futile as it has not happened over the time covered by the model.

It was concluded the best reference mode was the occurrence of planning phases. These would indicate when confidence was the highest as this is the trigger of the planning phase. There is, however, one main problem with the use of planning phases as reference data: the timing, form, and function of planning phases are unique to different boards. Furthermore, the mode by which confidence accumulates and discussions occur also differ depending on the board members at a given time. This makes the information an inconsistent reference mode by which to test the entire timeframe over which the model runs (which uses eleven years of historical data).

This is a manageable obstacle. The coefficients to the discussion variables and the confidence operator are the calibration variables in the model – the variables that can be adjusted to calibrate the model. They are effectively aggregated attributes for the individuals on the board. Therefore, the variables have to be readjusted for each board and the model behaviour compared to that particular board’s planning periods. As the model is built for the present
board, the planning phases that the model demonstrates during the recent board’s tenure are the initial reference modes.

The results of the model can be seen in Figure 9-14. The model shows the confidence of the board in being able to take on a new house between 0 and 1 (red), the planning phase (green) is triggered by confidence, and the confidence operator (blue) which is as a consequence of the surplus the organisation is deriving.

As can be seen, for the recent board, confidence has peaked once and is on the rise again. This reflects the reference mode for this board. In late 2010 and early 2011 (months 102-114), the board undertook a planning process that reviewed its ability to take on another house. This is reflected in the peak that occurs at month 105. Furthermore, the rise which is currently occurring reflects the continued financial strength of the organisation and a planning process the organisation was undergoing in early 2012 (effectively month 122).
Another reference mode is whether these planning phases did demonstrate that L’Arche could make other expenditures instead. This did follow on from the planning process carried out in 2011, when they decided they had ample funds and surplus income to purchase a new car. This purchase will affect future surpluses and influence their ability to afford a new house in the future, in effect engaging the red arrow in Figure 9-13.

Looking back at the organisation’s boards over the last ten years, the way surpluses and discussions supported or didn’t support their confidence was different. The previous boards, whether through internal instability or through a high level of risk aversion, undertook no planning processes between 2002 and 2010 (months 0 to 96), despite surpluses being generated (see Appendix G).

Another explanation for the lack of planning over that period could have been the spike in staffing costs that occurred between month 36 and 60. Over this period, staffing costs increased by almost a third and are currently mostly offset by non-ongoing fundraising through philanthropy. The pertinence of such an issue could have offset the board’s confidence. Using qualitative information in such a way is not included in the model.

The results of the study were presented at a meeting with the Community Leader and a proxy for the Chair of the Board. Here they were informed of the model and what it did. They confirmed the planning phases used as reference modes.

9.13.4 Reassess scenarios based on learning

*(Step 19, post-workshops: reassess scenarios)*
Process: Reassess scenarios

The scenarios were then reassessed in light of the findings from the system dynamics approach. This was done in two parts. First, it was done with a small group from the board. Second, it was assessed by the whole board after the final presentation was given (section 9.14).

Results and observations

The group of four from the board who reviewed the results of the system dynamics portion of the study and assessed them against the scenarios concluded that there was no learning that motivated a change in the scenarios. However, they did note that there were other lessons to be drawn from observing the system maps and the system dynamics model alongside one another. Such benefits included a more detailed picture of what was preventing the organisation from making its investment and what it could do about it. These comments were made with particular reference to the leverage points and strategies developed in the four workshops (see section 9.11).

The results of the boards’ assessment of the system dynamics model against the scenarios were captured in the surveys. These are discussed in the survey results shown in section 9.15. Generally, however, the board found that the system dynamics model (and only the model, as they did not have the system maps and many were not involved in the process) did not motivate a reassessment of the scenarios (see Table 9-8).
9.14 Study closeout

9.14.1 Delivering results, handover, and closeout

(Step 20, post-workshops: study closeout)

The results of the study were presented at a board meeting. A comment was made that they could see the theory behind the model regarding discussion reflected in specific examples and conversations that the board have had. After the meeting the board members completed a survey (see survey D in Appendix A) that explored the ability of the artefacts from the study – the scenarios and system dynamics model – to change their perceptions and gauge how well fundamental traits were met. The major results of the surveys are shown in the next section.

9.15 Survey results

As discussed in Chapter 4, participants were given surveys before the workshops began, after the third workshop, which focused on system dynamics, after the final workshop, and several months after the study was complete. Unfortunately, the final survey was only completed by the board, only three of whom had been involved in any part of the study. As a consequence, the evaluation that occurred in this survey – the scenario traits, the system dynamics model traits, and the final assessment of understanding – only occurred upon reflection of the artefacts of the process: the scenarios and the dynamic model. As discussed, involvement in the process is paramount to gaining the most out of the process, and too often people focus on the scenarios or on the dynamic model. These results then must be considered with great caution. For the reasons for asking these questions and the responses see Chapter 4 and Appendix A.
### 9.15.1 Scenario traits

The scenario traits were assessed by the board several months after the workshops. Only three board members out of eleven had been involved in the process in any way. The results of this part of the survey can be seen in Table 9-3.

<table>
<thead>
<tr>
<th>Scenario trait question</th>
<th>Positive responses (per cent positive)</th>
</tr>
</thead>
<tbody>
<tr>
<td>The scenarios are simple</td>
<td>71%</td>
</tr>
<tr>
<td>The scenarios are reasonable</td>
<td>71%</td>
</tr>
<tr>
<td>The scenarios are believable (credible)</td>
<td>71%</td>
</tr>
<tr>
<td>The scenarios are realistic</td>
<td>71%</td>
</tr>
<tr>
<td>The scenarios are probable</td>
<td>57%</td>
</tr>
<tr>
<td>The scenarios are relevant</td>
<td>71%</td>
</tr>
<tr>
<td>The scenarios are complete</td>
<td>14%</td>
</tr>
<tr>
<td>The scenarios are evocative</td>
<td>29%</td>
</tr>
<tr>
<td>The scenarios are novel and unique</td>
<td>14%</td>
</tr>
<tr>
<td>The scenarios have a short name</td>
<td>71%</td>
</tr>
<tr>
<td>The scenarios are internally consistent</td>
<td>71%</td>
</tr>
<tr>
<td>The scenarios captured my imagination</td>
<td>29%</td>
</tr>
<tr>
<td>The scenarios capture a number of different uncertainties</td>
<td>86%</td>
</tr>
<tr>
<td>The scenarios encompass both my concerns and the external reality of the organisation</td>
<td>57%</td>
</tr>
<tr>
<td>The scenarios encourage me to consider new possibilities</td>
<td>29%</td>
</tr>
<tr>
<td>The scenarios challenge norms and assumptions</td>
<td>29%</td>
</tr>
<tr>
<td>The scenarios have influenced my understanding</td>
<td>29%</td>
</tr>
<tr>
<td>The scenarios are useful and productive</td>
<td>71%</td>
</tr>
<tr>
<td>Did the scenarios leave out?</td>
<td>33%</td>
</tr>
<tr>
<td>Did the scenarios lead to any action?</td>
<td>67%</td>
</tr>
</tbody>
</table>

Table 9-3: Traits of the scenarios as evaluated by the board

### 9.15.2 System dynamics

The third workshop emphasised the system dynamics part of the process. Table 9-4 (overleaf) focuses on that particular workshop. Despite the incomplete nature of the results from the workshop, the participants appeared to think it was a helpful workshop. Participants believed that the workshop helped them to understand the key variables better, understand feedback better, and understand stocks and flows better (to all of which 88% of respondents gave
positive responses with 12% abstaining). Of all responses, 86% said the workshop helped them to understand accumulation better with 14% abstaining. All respondents also agreed that including system dynamics in the workshop helped them to understand the uncertainties, their causes and their effects. Significant here is that only 50% of respondents agreed that the system dynamics exercises made them reassess the scenarios, with the rest disagreeing with the statement.

<table>
<thead>
<tr>
<th>Attributes of the system dynamics workshop</th>
<th>Positive responses (per cent positive)</th>
</tr>
</thead>
<tbody>
<tr>
<td>This workshop has helped me to understand key variables better.</td>
<td>88%</td>
</tr>
<tr>
<td>This workshop has helped me to understand accumulation better.</td>
<td>86%</td>
</tr>
<tr>
<td>This workshop has helped me to understand feedback better.</td>
<td>88%</td>
</tr>
<tr>
<td>This workshop has helped me to understand stocks and flows better.</td>
<td>88%</td>
</tr>
<tr>
<td>Using system dynamics has helped me to understand what the uncertainties are.</td>
<td>100%</td>
</tr>
<tr>
<td>Using system dynamics has helped me to understand the causes and effects of the uncertainties.</td>
<td>100%</td>
</tr>
<tr>
<td>The system dynamics exercises and results made me reassess the scenarios initially generated.</td>
<td>50%</td>
</tr>
</tbody>
</table>

**Table 9-4: Traits of the system dynamics workshop as evaluated by the workshop participants**

Table 9-5 shows the assessment made by board members of the traits of the system dynamics model. These were the only two traits that literature proposes for a dynamic model (so few perhaps because the literature does not want to focus on the model). Only 29% of respondents thought the model was simple and only 43% believed it reflected the behaviour they observed. No respondents abstained from the voting.

<table>
<thead>
<tr>
<th>System dynamics model trait</th>
<th>Positive responses (per cent positive)</th>
</tr>
</thead>
<tbody>
<tr>
<td>The dynamic model is simple</td>
<td>29%</td>
</tr>
<tr>
<td>The dynamic model reflects the behaviour I observe</td>
<td>43%</td>
</tr>
</tbody>
</table>

**Table 9-5: Traits of the system dynamics model as evaluated by the board**
9.15.3 Decision problem

The evaluation of the process itself occurred immediately after the final workshop and involved almost all the participants that had been involved in the workshop. This evaluation was based on the traits identified in the literature that a process aimed at solving a decision problem requires to be effective. The questions and their responses can be seen in Table 9-6, overleaf.
<table>
<thead>
<tr>
<th>Traits of the adopted process</th>
<th>Positive responses (per cent positive)</th>
</tr>
</thead>
<tbody>
<tr>
<td>The process has simplified the problem</td>
<td>67%</td>
</tr>
<tr>
<td>The process has helped face uncertainty</td>
<td>100%</td>
</tr>
<tr>
<td>The process has taken steps to reduce it uncertainty</td>
<td>78%</td>
</tr>
<tr>
<td>The process has placed emphasis on communication and participation</td>
<td>90%</td>
</tr>
<tr>
<td>The process has encouraged interaction</td>
<td>100%</td>
</tr>
<tr>
<td>The process has facilitated negotiation</td>
<td>78%</td>
</tr>
<tr>
<td>The process has generated ownership</td>
<td>89%</td>
</tr>
<tr>
<td>The process has provided for the consideration of a plurality of facts, values, norms, and alternative courses of action</td>
<td>100%</td>
</tr>
<tr>
<td>The process has assisted in arriving at a unified resolution of the problem based on at least some of the material considered</td>
<td>63%</td>
</tr>
<tr>
<td>The process restricted mathematisation</td>
<td>50%</td>
</tr>
<tr>
<td>The process considered many different factors</td>
<td>100%</td>
</tr>
<tr>
<td>The process unified various areas that naturally conflict to some degree</td>
<td>60%</td>
</tr>
<tr>
<td>The process explicitly modeled cause and effect</td>
<td>90%</td>
</tr>
<tr>
<td>The process iterated and allowed for the inclusion of new information when it came to light</td>
<td>100%</td>
</tr>
<tr>
<td>The process focused on supporting judgement</td>
<td>75%</td>
</tr>
<tr>
<td>The process was transparent</td>
<td>100%</td>
</tr>
<tr>
<td>The process was readily understandable</td>
<td>90%</td>
</tr>
<tr>
<td>The workshops helped me to surface my views</td>
<td>100%</td>
</tr>
<tr>
<td>The workshops helped surface other participants’ views</td>
<td>100%</td>
</tr>
<tr>
<td>The workshops helped to explore the similarities and differences between all views in the group</td>
<td>90%</td>
</tr>
<tr>
<td>The workshops helped me to explore and learn how the different views that affect each other (connections)</td>
<td>90%</td>
</tr>
<tr>
<td>The workshops helped uncover the causes and consequences of issues that prevented building group knowledge</td>
<td>44%</td>
</tr>
<tr>
<td>The workshops helped me to use the knowledge acquired to expand my own understanding of the situation</td>
<td>90%</td>
</tr>
<tr>
<td>The workshops helped me to select a set of actions that could bring about the desired results if implemented</td>
<td>70%</td>
</tr>
<tr>
<td>The process is credible – is it a valid process that can assist to assess L’Arche’s issues and options.</td>
<td>100%</td>
</tr>
<tr>
<td>The process is transferable – it could be transferred to other contexts and even other organisations.</td>
<td>100%</td>
</tr>
<tr>
<td>The process is dependable</td>
<td>80%</td>
</tr>
<tr>
<td>The process is confirmable</td>
<td>78%</td>
</tr>
<tr>
<td>The process is broad enough and flexible enough to apply to a wide range of the organisation’s problems</td>
<td>100%</td>
</tr>
<tr>
<td>The process could be easily introduced into the organisation as a permanent decision making tool. Why?</td>
<td>60% (plus written response)</td>
</tr>
<tr>
<td>The process incorporate appropriate characteristics of existing decision making approaches.</td>
<td>100%</td>
</tr>
<tr>
<td></td>
<td>(plus written response)</td>
</tr>
<tr>
<td>The process uncovered new perspectives I had not previously considered. If so, what?</td>
<td>67%</td>
</tr>
</tbody>
</table>

Table 9-6: Traits of the workshops as evaluated by the workshop participants
The only predominantly negative response in Table 9-6 was that participants did not believe the process uncovered the causes and consequences of issues that prevented building group knowledge. With such overwhelming support, it appears as though the approach adopted is an appropriate process to address decision problems.

9.15.4 Comparison and Change

Unfortunately, comparison between the first and final surveys was impossible, because only one person completed both surveys and different populations cannot be compared. This discounted the first survey. However, in the second and third surveys, completed at the end of two of the workshops, participants were also asked to assess changes in their own understanding. In these surveys 100% of respondents believed that the inclusion of system dynamics helped them to understand what the uncertainties were and what the causes and effects of the uncertainties were. In terms of influencing point of view, 89% believed the process helped them to see the problems around L’Arche’s growth from other stakeholders’ perspectives. Furthermore, questions about the inclusion of system dynamics in the process received substantial positive responses, as can be seen in Table 9-7 (for the supporting material for this survey, please see Appendix A).
Combining scenario planning and system dynamics

Variable | Question asked                                                                                                                                                                                                 | Positive responses (per cent positive) |
----------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------|
Does it affect peoples’ points of view? Do they begin to see things differently? | The workshops helped me to understand other stakeholder’s points of view?                                                                                                                                     | 89%                                    |
Changed perceptions of the problem (effected how you saw the problem) | The inclusion of the system dynamics modelling changed my perceptions of the problem (effected how I saw the problem)                                                                                       | 100%                                   |
Changed your understanding of how other people saw the problem | The inclusion of the system dynamics modelling changed my understanding of how other people saw the problem                                                                                               | 89%                                    |
Increased confidence in their grasp of the issues | The inclusion of the system dynamics modelling increased my confidence in my grasp of the issues                                                                                                             | 90%                                    |
Increased understanding of the feedbacks and causal strength in the scenarios | The inclusion of the system dynamics modelling increased my understanding of the feedbacks and causal strength in the scenarios                                                                             | 100%                                   |
Made the text comprehension, metaphors and scripts used in the scenarios easier to understand | The inclusion of the system dynamics modelling made the text comprehension, metaphors and scripts used in the scenarios easier to understand                                                                 | 80%                                    |

Table 9-7: The impacts participants of the workshops believed the inclusion of system dynamics had on their understanding

The final survey was completed by board members several months after the process was completed. The respondents to this survey believed that the scenarios reflected their world view (71%), that the process was useful (57%) and that they would engage in the process again (57%). However, not all the results were as promising. The respondents did not believe the process had changed their perceptions (14% said it had), they did not believe the dynamic model added greatly to the scenarios (43%) and only 29% believed the system dynamics model helped them to understand the scenarios (29% responded positively to this). Furthermore, despite the participants believing the model did more to change their perceptions (43% responded positively) than the scenarios did (29% responded positively), these numbers are particularly small. The results of this survey can be seen in Table 9-8 (opposite).
Before all the results are discussed, the context of the final survey requires emphasising. The time since the workshops and the make-up of the board meant that this assessment was mostly based only on the artefacts of the process and the written information that accompanied them (see Featherston & Doolan, 2011). As argued earlier, the artefacts are not the main goal of either process, but rather more is gained from the process itself than from the artefacts. Because of this, the discussion will be more orientated to the responses to the process, rather than the final survey.
9.16 Discussion

9.16.1 General discussion of the scenarios and their assessment

Scenario focus
As the focus of scenario planning was a topic previously discussed and will be discussed at length in the next chapter, a reflection upon the L’Arche study is necessary. An organisation’s environment is classified by literature in two ways. First, it is divided into the external environment and the internal environment (see Hanson et al., 2008). Second, it is divided into the general environment – factors that cannot be influenced by an organisation – and the contextual environment – factors that can be influenced by an organisation (see van der Heijden, 2005).

The scenarios in this study include aspects from all four of these categories. During the study, participants identified trends and drivers that they later identified as leverage points they could employ to influence many of the conditions described by the scenarios. This demonstrates a focus on both the contextual environment and the general environment. This observation means that the participants found the predeterminants and uncertainties of their system were just as much in the way L’Arche operated and its immediate environment (contextual environment) as it was in the setting in which the organisation is situated (the general environment).

Furthermore, the scenarios also consider elements of both the external and internal environments. This contradicts Simpson (1992, p.11) and Schoemaker (1995), whom focus solely on the external environment. However, this contradiction is less significant than it first appears. For example, for the sources of funding, participants included government funding
(external), core member fees, and philanthropy (internal). Participants did not perceive the trends and drivers to be divisible as per the category’s distinction. However, this inclusion, while clearly reflecting internal action, only reflects a basic response the organisation would have to such a situation. It is, in effect, almost an automatic response. To neglect them would have removed much of the complexity behind L’Arche’s operations and some of the reality of the scenarios.

Assessment of the scenarios
As discussed, the scenarios can be evaluated in two ways: direct observation and participant observation. Direct observation of the scenarios is easy, but somewhat less reliable. The two key uncertainties that defined the scenario matrix are important considerations for L’Arche, as demonstrated by the time and effort they have put into discussing them in and out of the workshops. The scenarios themselves also map out a large possible space in which L’Arche’s future could fall and clearly push a space well beyond their current financial structure. The results also encapsulated some of the learning that went on in the workshops, incorporating novel ideas, such as the possibility of a heavy reliance on philanthropy, into the scenarios. However, whether they have stimulated action is difficult to establish as any action that has been taken could have been motivated by the scenarios, the scenario planning process, the normal activity of the organisation, or any combination of these.

Participant observation was caught in two ways: by recording their responses in the workshops and through the surveys. In the workshops participants commented on a number of ‘aha’ moments, a number of novel ideas identified in the workshops, and conversations that occurred that worked on incorporating the new ideas into the existing business idea. These indicate that the process encouraged them to conceive new ideas and reconcile them with their current understand, key goals of scenario planning (Bloom & Menefee, 1994, p.225;
Fahey & Randell, 1998). However, it is evident that these were not reflected by the scenarios, as established by the board.

The assessment of the scenarios by the board (see Table 9-3) mostly confirmed that the scenarios met many of the traits identified by the literature, but there were a few exceptions to this. First, the board did not see the scenarios as complete (14% agreed that they were) and did not generally find them novel and unique (14% agreed that they were). Second, they did not find the scenarios were able to capture their imagination (29% agreed that it did capture their imagination) or help them conceive new possibilities (29% agreed that they did), despite the observations made in the workshop. More alarming is that the board did not believe the scenarios to challenge their assumptions (29% said it did) or influence their understanding (29% said it did), again despite the observations made in the workshops. However, these were the only transgressions against the scenarios with all fourteen other traits having been met according to the majority of respondents.

Again, however, as these were completed by the board, only the scenarios and the presentation were used for their evaluation: which were not a complete reflection of the process and could have been misleading. The narratives could have confused those not in the process, constructing them is difficult (Denning, 2006). Furthermore, presentations can be confusing and not contribute or even thwart understanding. Therefore – the point is reiterated for emphasis – the evaluation based on the final surveys must be taken with vigilance.

One further comment evaluating the scenarios will be made: the names given to the alternatives on the funding axis could have been clearer. Non-government funding was always understood to be predominantly from philanthropy. Core member fees are a significant source
of funding, currently greater than philanthropy, which is small relative to the other two sources. However, it was not considered to be part of Non-government funding because it had a smaller feasible range to move than philanthropy and could not be an alternative to large losses of funding (despite the fees having been increased to help L’Arche through financial hardship several years ago). The Non-government funding alternative could have been named more appropriately to reflect the understanding that it meant predominantly philanthropic sources.

9.16.2 General discussion of the system dynamics aspect of the approach

The utility of the system maps from the workshops

The system maps were only of partially assistance to the approach because of the structure of the activity itself. The structure of the activity meant that the information acquired from it was underdeveloped or not of the right character. The activity attributes that were observed to have potentially hindered the results of the activity were: the understanding participants had of the techniques of system mapping, the emphasis of the activity, and the purpose of taking the approach. The participants were not familiar with system dynamics, so they were educated about the field, its goals, techniques, and their requirements. Furthermore, the emphasis of the activity had to be on developing diagrams that were useful to a system dynamics approach. Finally, the system maps had to be developed with a purpose, as identified in the HVM study. The results of the activity were only partially useful because of a failure to enforce or realise any one or any combination of these reasons requirements. However, one of these was particularly prominent: the purpose of the exercise, as is discussed in the next section.
The Purpose of Modelling

The modelling that occurred between and immediately after the workshops indicate that there was not a specific enough focus for a system dynamics approach at that stage of the study. The focus of ‘growth’ was general and, as the results of the study show, a more specific purpose was needed to complete a system dynamics approach. As stated the results from the workshop exhibit a lack of focus, reducing their utility. But even the modelling that occurred immediately after the workshops, in the form of the non-system dynamics models, was not targeted enough for a system dynamics approach.

It would, however, have been challenging to identify a specific purpose before the workshops. Identifying the aims before the workshops would have required more time, resources, and pre-workshop activity. Furthermore, it was in the interest of the study to begin the workshops in a timely fashion. In the end, the workshops themselves turned out to be a guide for developing a purpose for the system dynamics approach.

If this perspective is taken, then the process system dynamics is not unlike scenario planning. Wack (1985b) and Simpson (1992) propose there are two types of scenarios: those that explore the future – and are of little use to managers – and those that highlight the uncertainties and lessons learnt – and aim to influence managers’ perceptions of the world. Examples of the second category include models such as Forrester’s (1969) Urban Dynamics model and Meadows and her colleagues’ (Meadows et al., 1972) Limits to Growth model. The models developed during this study appear to share common categories: there are those that explored the system, its structure and how it works were the dynamic models, and those that target peoples’ mental models of how the world works and its behaviour was the confidence model.
Furthermore, the different models can also be separated into Schoemaker’s (1995) two categories of scenarios: learning scenarios and decision scenarios. The early system mapping and dynamic modelling that occurred, which resulted in the two ‘traditional’ dynamic models, were the learning steps of the process. The system dynamics model that was developed then reflected the learning that took place and the systems’ behaviour and aimed to change peoples’ perceptions. This bridges the divide between the two sets of definitions and not only brings Wack’s (1985b), Simpson’s (1992), and Schoemaker’s (1995) work closer together, but also demonstrated the close processual nature of scenario planning and system dynamics.

Discussion of the system dynamics results

The model appears to accurately reflect why there is a misalignment between L’Arche’s confidence and ability to grow. However, there are several limitations to the model. Perhaps its greatest drawback is the reference modes to which it can be compared. With only two reference modes for the current board and no previous reference modes, building a large amount of confidence in the model – the only measure of model accuracy – is constrained. However, the consideration of other expenditures, such as a new car, helps somewhat to increase confidence in the model. By correlating both planning phases and other major expenses with the model, confidence in the model is increased.

Matching the model to historical data could be considered a form of confirmation bias – a desire to see the model outputting the behaviour that confirms real data (see Wason, 1960; Wason, 1966; Wason & Shapiro, 1971; Kiesler, 1971). This could be the case, particularly with so few points of data in the reference mode. However, the model demonstrates a testable theory, one that can be tested for falsification over time. By scrutinising its assumptions and testing the theory it expounds, rather than taking its results as truth, the theories are much more flexible than the model on its own would suggest. Furthermore, the model is an
improvement on mental models because its non-linear behaviour can be calculated using a computer and because it is explicit, so assumptions can be scrutinised (the same reasons that reasons that are cited by Meadows et al., 1972).

Participants generally thought the inclusion of system dynamics into the study was useful, as reflected in their responses (discussed in Section 9.15). However, the board generally thought that the system dynamics model was simple (29% said it was simple) and only just under half (43%) believed the system dynamics model reflect the behaviour they observe. However, as stated, towards the end of the study more than half of the board was replaced, creating questions about the longevity of information the new members had to call on to make their assessments. Perhaps then the more telling evaluation is by the specific clients, namely the Community Leader and General Manager, who generally found the model to reflect their observed behaviour.

There are other ways of assessing the results of the system dynamics approach. Homer (1997, p.293) suggests “the models that prove most compelling to clients generally have two things in common: a potent stock and flow structure and a rich fabric of numerical data for calibrating that structure’. The stock of confidence is novel and the clients found it a useful guide for reflecting upon the causes of L’Arche’s planning processes. As for numeric data there was a plethora of information that went into developing the relationships between surpluses and the boards’ response, not to mention the budgeting information included in the model.
9.16.3 The combined approach

With the validity of the system dynamics and scenario planning elements of this study having been established, their effectiveness in combination can be discussed. Central to this area is the differences between the approaches that could have detracted from integrating their results, whether there was any observable change in either approach caused by information from the other, and ultimately if another approach could have been used to achieve the same results.

Differences between the approaches

The results of the study were given to L’Arche over a long time period, despite the study focusing on an integrated approach. The immediate results of the workshop were supplied by a previously chosen deadline. This included much of the information about the scenarios, other the workshop activities, and the redeveloped influence diagrams. But none of the system dynamics models were included; they were not even developed by that stage. The provision of the results over a period, particularly divided as they were, means that L’Arche would be less inclined to use them in conjunction, detracting from some of the potential benefits. The only redeeming feature of the process is that when the dynamic models were finished all results were presented to the board simultaneously.

One difference between the approaches as executed here is that the scenarios and the dynamic model cover systems of different scale. It was argued in the previous chapter that scenario planning and system dynamics can cover similar scales of systems. However, the scenarios and systems dynamics model shown here do not. The scenarios cover a broad system that includes many external agents and factors, such as the government, philanthropists, and economics. The system dynamics model, however, covers only the
planning process, and treats all else as exogenous. While the system dynamics model has value, its contribution to scenario planning appears to be limited by this disconnect.

The final difference observed between the two approaches was the different stakeholders and type of contact required for the different approaches. Most of the information collected for the scenario planning approach occurred in the group workshops, which involved a number of different participants from a variety of backgrounds. However, when the system dynamics approach collected information from the same participants the results were less useful, whether this be because of poor instruction, poor emphasis for the activity, or a poorly defined purpose. Instead, the system dynamics approach benefited much more from one-on-one contact with L’Arche personnel, particularly board members, who slowly built an understanding of the system and of the information required to build the model.

*The utility of their integration*

The generation of influence diagrams and stock and flow diagrams based in the scenarios provided little more than a starting point for the activity. Participants began outlining the major elements of their system in their particular scenario. After this they resorted back to their mental models of the current system to fill in the detail. As a consequence, no new factors, variables or system structures were introduced because of the scenario focus. The lack of scenario focus stemmed from the failure to emphasise thinking of the system in their scenario while generating the diagrams, which was difficult with the number of participants in the workshop. In the end the scenarios provided a perspective or a way to think about the system to begin with, which is positive in such an activity, but it does not necessarily need to be done by scenario planning.
In terms of co-informing each other, one aspect of this study is clear: system dynamics did not motivate a reassessment of the scenarios. The activities and learning that occurred in the system dynamics workshop and the system dynamics model generated did not cause participants to rethink or change the scenarios. Furthermore, the board did not think the system dynamics model changed their view of the scenarios at all (0% believed it did, see Table 9-8). Perhaps this was because of their different scales (level of aggregation) or because their mental models were accurate enough and system dynamics only confirmed their thinking. Either way, the system dynamics approach failed to motivate a reassessment of the scenarios.

Despite this, the use of system dynamics did provide a richer account of the decision problem. The system dynamics approach solved a problem that scenario planning did not. As a consequence more information was provided about the decision problem than would otherwise have been the case. However, to addressing the thesis of this dissertation more comprehensively means assessing if this information could not have been achieved by other approaches. Accounting models, for example, also provided more information regarding the decision problem. But it appears that system dynamics provided information about the decision problem that other techniques, such as accounting might not have, because of its systemic structure focus, endogenous perspective, and aim of understanding the cause of behaviour. These benefits were specific to system dynamics and contributed specific understanding about the decision problem.

9.16.4 A key methodological limitation

One of the key limitations of this study was the number of people involved in the process. The investment of the participants’ time in the study was appreciated from both the study’s and the Community Leaders’ perspective. However, the involvement of fifteen people in the
process and the feedback of the extra eight people from the two boards that sat during the project limited the validation that could occur. Increasing the number of perspectives against which the process and its artefacts could be exposed would have increased the validity of the conclusions drawn. However, L’Arche’s community was small and the number of perspectives that could have been used was already reaching capacity. The alternative then was to use people to validate the results that came from even further afield, but this could have led to other complications in the validation process that would have had to be mediated.

9.17 Chapter conclusions

9.17.1 Conclusions specific to scenario planning

A scenario planning process was successfully applied in a real application to a not-for-profit organisation. The approach used a number of workshops, which included a number of structured activities, and involved participants from a variety of backgrounds to collect information and develop the scenarios. Several activities were then executed to use the scenarios to understand L’Arche and its operating environment and to develop strategies and action agendas that it could use.

Generally, direct observation and participant observation supported the scenarios developed in the study. There was some discrepancy between the final survey and all other forms of observation collection, which could be explained by the detachment many of the board members who completed this surveys had from the rest of the process. The general quality and acceptance of the scenarios is interesting because they included elements that contrasted
somewhat with the literature, such as the inclusion of a basic level of strategic reaction to the scenarios.

9.17.2 Conclusions specific to System dynamics

A system dynamics exercise was also successfully applied to a real situation, the first applied system dynamics approach to be completed in this work. The system dynamics activities executed in the workshops yielded only context and guidance for the modeller. However, further work with specific individuals meant that learning could occur and a system dynamics model around that learning developed.

The confidence model presented demonstrates why there is a misalignment between L’Arche’s perceived ability to grow and its actual ability to grow. More specifically the model reflects the impact budget surpluses have on the confidence of the board, despite no long-term or structural change occurring to L’Arche’s finances. The model highlights the fact that unless there is a shift the in the organisation’s funding structure, L’Arche will not be able to occupy a new house. The combination of the model and an understanding of L’Arche’s funding structure led to this conclusion. This information can be used by the board to understand their behaviour when confidence around occupying a house builds, instead of instigating a long and costly planning process.

Furthermore, the findings of the model can be used to inform government personnel about L’Arche’s impasse. As stated, the government has offered L’Arche a house, for which the expenses would not be the purchase of the house but its leasing and maintenance. If the
government understands why L’Arche rejected the offer, and why this behaviour could repeat, then it could be an important part of changing the system that is restricting L’Arche’s growth.

Despite the system maps that were generated in the workshops being less useful than desired, many of the participants found the system dynamics workshop very useful. Furthermore, the participants’ assessment of the scenarios captures the influence of system dynamics on the scenarios and therefore could reflect a level of perceived benefit even though it is deferred. The full value of the approach was not realised by the new board, whose only reflection on it was the final system maps, the ‘traditional’ dynamic models, and the system dynamics model. Furthermore, the inexperience of the new board possibly made these of less valuable because of the unfamiliarity with the issues faced by L’Arche. This could be rendered after time, whereby they would understand the context of L’Arche and its issues and use these to understand and reflect upon the artefacts of the process.

9.17.3 Study conclusions

Despite the obvious indicators suggesting the integration of the approaches was not useful, there is evidence to suggest that the approaches did inform one another. The obvious indicators were if the system dynamics process motivated a reassessment or changed the scenarios and whether the scenarios assisted in the systems mapping portion of the study. In this study system dynamics did not assist scenario planning as there were no changes to the scenarios when the system dynamics portion of the study was completed. Furthermore, the scenarios did little but provide a starting point for the system mapping.
However, such broad observations exclude the learning and reflecting that could have occurred between the two approaches during the workshops and after. For example, the use of the system maps developed to select leverage points or the supplementary nature of information provided by the confidence model. Furthermore, there were other non-tangible benefits from the process. As Ritchey (2006, p.800) put it ‘one of the implicit outcomes of such an approach is a shared terminology and problem concept among participants, and a better understanding of wider contexts’. As observed in the discussion sessions, participants began to use language from both fields to describe their ideas, demonstrating the learning and language developing from the process. These benefits demonstrate the strength of co-executing scenario planning and system dynamics approaches.
Chapter 10  Discussion

The primary goal of this work was to assess if system dynamics could be used to address scenario planning’s subjective nature and the role of possibly ill-informed mental models in the development of scenarios (see Chapter 2). However, Chapter 2 and Chapter 3 also identified several other criticisms of scenario planning and system dynamics that combining the approaches may have assisted to overcome. This chapter draws on the case studies to demonstrate how scenario planning was used to inform system dynamics and visa-versa. In addition, several other benefits of integrating the approaches were also realised. This chapter will evaluate those benefits against the fields from whence these approaches originate.
Unfortunately, the problem of induction (Hume, T 1.3.4.1 SBN83-84; Taleb, 2005; 2007) does not allow generalisations to be drawn from the studies. Instead, this chapter looks at the specific benefits observed in the studies and discusses how, in that study, that benefit helped scenario planning, system dynamics, or both. These then form unfalsified theories that further testing should endeavour to falsify (see Popper, 1934: 1959).

This chapter begins with a brief summary of the major conclusions drawn from each of the studies. It then contrasts scenario planning and system dynamics based on the experience and knowledge collected during the studies. The chapter touches on an alternative of developing scenarios through system dynamics, before looking at if and how combining the approaches addressed the criticisms of scenario planning and addressed the criticisms of system dynamics in the workshops. Along with these sections general comment will also be given to how the approaches addressed each other’s requirements. For example, how system dynamics helped participants to suspend disbelief, an important feature of and for scenario planning (Schwartz, 1996; Frittaion et al., 2010; 2011). Further comment will also be given to other benefits observed from their integration. The chapter will wrap up by commenting on the fields more generally, the method used to address the thesis, and the limitations of the work.

10.1 Major conclusions from the studies in brief

Each study contributed to developing an integrated approach of scenario planning and system dynamics, gave evidence to support or deride the claim that one of these approaches can be used to inform the other, or both. The first two studies were mostly scenario planning focused, with endeavours into using system dynamics with them. The FDF study established a scenario planning approach. It also provided a brief look into the mechanics and benefits of developing influence diagrams in a scenario planning process, which failed to be of any assistance. The
HVM study explored a different way of generating scenarios, one that on the whole did not appear to work. From a system dynamics perspective, the system maps were more useful to system dynamics, but were not taken any further.

The other next two studies explored more comprehensive integrations of scenario planning and system dynamics. The China Futures study explored integrating system maps from different scenarios and found that scenario planning and system dynamics explore relationships at different levels (scopes), an obstacle that needs to be overcome in their integration. The Grass-Rabbits-Foxes study gave an example of how system dynamics models can be used to reflect back on scenarios and how the reverse can be done too. The study also demonstrated that integrating system maps and even a system dynamics model based on the different scenarios, is indeed possible.

Finally, the L’Arche study demonstrated a real world application of the approaches integration. The scenarios and dynamic model developed were generally supported by the client, board, and workshop participants with some small exceptions. There were some differences between the approaches in terms of their results, their scale and stakeholders. The study resulted in the confidence model not motivating a reassessment of the scenarios and the scenarios providing only a starting point for mapping the system. Despite this, the two approaches provided complementary insights into the decision problem. There was also evidence to suggest that the learning from one approach was taken into the other, as was evident by the use of the influence diagrams to identify leverage points and linking these leverage points to strategies aimed at shifting L’Arche from one scenario to another. Furthermore, participants found the language from both fields useful for discussing their ideas in the discussion sessions.
10.2 Contrasting and comparing scenario planning and system dynamics

During the studies several differences between scenario planning and system dynamics were discerned that can affect how they are integrated, both theoretically and practically. These differences arise from the theoretical background of the approaches. These differences were identified either through the synthesis of the literature on the two approaches or were highlighted by the studies. In some cases, conceptual links that bridged these differences were identified.

10.2.1 Different scope

One of the differences between scenario planning and system dynamics discerned during the study was their different scope or foci (not scale). The focus of the approaches was given in Chapter 4, when the benchmark approaches were outlined. The literature there made it appear that the focuses of the approaches were different. The focus of system dynamics was on particular behaviour observed within a system (Forrester, 1961; Sterman, 2000; Meadows, 2008). This systemic behaviour delineates ‘the’ focus problem in an attempt to address the problems it creates. Alternatively, scenario planning was given a much broader focus, specifically focusing on ‘what keeps the operating managers [or client] up at night’ (Simpson, 1992, p.12). Van der Heijden (2005, p.17) lists a range of reasons to employ a scenario planning approach, including to address a specific problem, to ‘open up minds’, and to ‘make sense of a puzzling situation’. Schoemaker (1995) suggests creating two different sets of scenarios, one set of ‘learning’ scenarios and a second set of ‘decision’ scenarios, making it appear that scenario planning can be used when the problem itself is not clear or evident. These accounts emphasise a vast scope within which scenario planning could be employed. Furthermore, scenarios generated can be used to motivate strategic conversations among
decision makers on more than one outcome or future development, further widening its potential scope or focus.

These differences in scope were observed in the China Futures study. In the study, the diagrams generated were of little use for further development in system dynamics. It was apparent that the information that participants collected from the scenarios was different to the information required for system dynamics: a more specific focus was needed for a system dynamics approach. Furthermore, the vague and unaligned nature of the influence diagrams emphasised the need for system dynamics to address a problem rather than map a system.

In contrast to the generality of the Four Futures for China Inc. scenarios (see Randall & Goldhammer, 2006) used in the China Futures study, the Royal Dutch/Shell planning group’s 1972 scenarios about the supply of oil (see Wack, 1985a), were quite specific. This supports the above claim that the range of situations to which scenario planning can be applied is quite broad, supporting the breadth of focus expounded by Simpson’s (1992) vagueness and van der Heijden (2005) more specific list demonstrating breadth of purpose.

The consequences of scenario planning’s generality in focus and system dynamics’ specificity are simple: an integrated approach needs to accommodate the differences in focus to be successful. For example, in the L’Arche study, the scenarios were not developed around a specific problem or observed behaviour, but rather around an ill-defined ‘why can’t we expand?’ The system dynamics approach was then employed to focus on specific systemic behaviour that was being observed: the misalignment between perceived and actual ability to grow. The focus of the scenario planning phase of the study was broad and included the specific problem addressed by system dynamics.
The resulting conclusion is that the definitions of purpose given in Chapter 4 are not quite complete. Scenario planning can be applied very broadly and very specifically, as shown by the *Four Futures for China Inc.* scenarios (very general), the L’Arche study (general), and Wack’s (1985a) 1972 scenarios of the oil industry (specific). System dynamics, however, has a very specific, ‘behaviour problem’ focus, which is emphasised by many of the approaches proponents (for example, Sterman, 2000; Meadows, 2008).

### 10.2.2 Differences in timeframe

Another observed difference between the approaches is their focal timeframes. Scenario planning looks at the future, usually between 5-25 years away (Wack, 1985a; Schwartz, 1996; van der Heijden, 2005). System dynamics explores the structure of the present system, using past data and peoples’ present understanding (Forrester, 1961; Sterman, 2000; Meadows, 2008). In the L’Arche study the scenarios were set in 2025, but the specifics of the confidence model only applies to the present board, as demonstrated by the inaccurate reflection of planning phases for the previous board (see Section 9.13 and discussion in Section 9.16). However, the goals of scenario planning and system dynamics are not as grounded in the timeframes of their artefacts as one might think.

System dynamics is not all about the present. It explores and clarifies a system’s structure, providing information about the reasons for its behaviour and by doing so gives indication about its possible future behaviour. Furthermore, its learning focus (Forrester, 1985; de Geus, 1992; Morecroft, 1992; Lane, 1992; Saeed, 1993) encourages understanding about the system’s structure that should be taken forward and used to develop policy and strategy. System dynamics can be also be used as a method of generating a technological prediction
about the future (see Chapter 3). Although it should be noted that these predictions become tenuous when looking at the timeframe over which scenarios are cast. \(^{30}\)

Scenario planning is also not grounded solely in the future. Scenario planning requires an understanding of the present in order to define the predeterminants and uncertainties that are used to generate scenarios (even the ‘science’ of astrology admits it needs an understanding of the present to know where the planets will be in the future). This is the reason for the learning focus of scenario planning.

Like system dynamics, scenario planning also focuses on exploration – rather than forecasting – further mitigating how problematic the timeframe gap may appear. Scenarios map out the limits of a space that the future is likely to be in (if constructed well), helping people to understand what is possible (Schwartz, 1996). An example of this is Kahn’s (1960) work during the cold war, which helped develop understanding about the consequences of thermonuclear war. Because it focuses on mapping, scenario planning is as divisive as system dynamics when used for prediction. Indeed, Kahn’s (1960) book, *On Thermonuclear War* was not a prediction, but an exploration into what was possible. Kahn’s (1962) follow-up book, *Thinking About the Unthinkable*, suggests (even in the title) that the purpose of such an approach is not to predict the future, but to explore it. By moving away from forecasting and towards exploration scenario planning aligns itself more with system dynamics, which explores a system to understand the causes of a problem.

---

\(^{30}\) Technological predictions require the numerous assumptions made to remain unaltered (Popper, 1957; 1966a; 1966b). As time progresses, particularly in unstable environments, predetermined elements become fewer (van der Heijden, 2005). Therefore, the information on which the assumptions are based is also likely to change, requiring extreme vigilance with any prediction made.
The Grass-Rabbits-Foxes and L’Arche studies both exemplify many of these common elements of scenario planning and system dynamics and demonstrate how the timeframe gap is less important than it originally appears. In the Grass-Rabbits-Foxes study, the scenarios provided novel information for the system maps and dynamic models, exemplifying the exploratory and learning nature of the approaches. Furthermore, both the Grass-Rabbits-Foxes and the L’Arche studies exemplified how important it was to develop an understanding of the present system in order to build the scenarios.

System evolution (change)
The discussion of the approaches’ timeframes is incomplete without considering the evolution of systems. Meadows’ (2008) leverage points (see Chapter 4) not only describe how decision makers can affect systems, but also delineate the ways in which systems change. This notion of evolution has consequences for the integration of scenario planning and system dynamics.

Systems evolution can make technological predictions in system dynamics tenuous. A technological prediction relies on the assumptions of a system remaining the same (Popper, 1957; 1966a; 1966b). If the system changes or evolves, many assumptions may become invalid. The risk is that such predictions become increasingly tenuous when systems change (evolve) along the dimensions of the ‘higher’ leverage points. Especially when changes in the lower echelons of Meadows’ (2008) leverage points, however minor, could make assumptions, or even groups of assumptions, completely redundant (for the full list see Chapter 4 or Meadows, 2008).

System change was evident in the Grass-Rabbits-Foxes study. The base case reflected the system’s behaviour in Australia. By moving the rabbits and foxes to Easter Island the context
affected the internal structure of the system. One of the evolutionary changes was at Meadow’s (20008) ‘numbers’ leverage point level when the nutritional value of grass was changed to simulate a decrease in the amount of grass rabbits ate per month. A ‘higher’ leverage point change was also simulated, with the introduction of birds as fodder for foxes. Both of these changes were identified using scenario planning and are step changes in a system’s structure that demonstrate the ability of system dynamics to consider them.

Scenario planning and system dynamics can consider both discontinuity and gradual change and as a consequence so can an integrated process of the two approaches. As shown, system dynamics can consider step changes (or discontinuities) in the system. Scenario planning can similarly consider discontinuities (see Schoemaker & van der Heijden, 1992). The ability of system dynamics to consider gradual (continuous) change has been demonstrated many times. This is observable in systems that oscillate, such as Morecroft’s (2007) Fisheries model. This behaviour is triggered by the dominance of loops rising and falling because of inherent delays within the system, consequently dictating the system’s behaviour. Such behaviour could be seen between the rabbits and foxes in the initial run of the base model (reproduced as Figure 10-2 below). Scenario planning considers continuous change by using trends to dictate much of the structure of its scenarios.
While scenario planning addresses both types of change, system dynamics addresses both only when they are considered internal to the system. Through exchanging loop dominance, system dynamics can consider change, as shown by Morecroft (2007) and the Grass-Rabbits-Foxes study. However, these loops must be included in the modelling. If a discontinuous change is needed, it can be included in system dynamics, as shown by the planning cycle in the L’Arche study. If these considerations are not included, then the assumptions, learning, and any technological predications made using a system dynamics model could be misleading. Modelling the evolution of systems is possible, but it adds an extra-layer of complexity to modelling. Whether it should be considered depends on its relevance, necessity, and the motivation of the client and modellers to include it.

From the studies it appears as though the differences in timeframe can be bridged by certain activities. As shown in the Grass-Rabbits-Foxes study, the process of backcasting can help link the two approaches and understand the evolutions in the present system, drawing out some detail of the changes that may occur to the system. When combined with a model-casting
exercise, these actives were able to co-inform each other, creating a richer picture of the system. As is typical with any such approach, such links could be wrong because in essence they are prediction, but their exploratory nature helps to develop an understanding of what might happen to the system, and how, and assists to generate memories of the future (see Ingvar, 1985).

The consideration of timeframe thus far has taken a very static view of the combination of these two approaches. However, both tools are iterative, not only in their approach, but in terms of their employment. Royal Dutch/ Shell, an early adopter of scenario planning, continually employs the approach, sometimes on different problems, but many times on the same problem31 (Schwartz, 1996; Schoemaker & van der Heijden, 1992). As the system evolves employing scenario planning again encourages learning about how the system has evolved and why it has evolved. The same logic applies to system dynamics; reemploying the approach could help understand the cause of observed systemic behaviour in the evolved system. The consideration of timeframes of the two approaches is very similar: learning about the present system and their ability to consider change. The iterating nature of the appropriate application of these two approaches further reduces the importance of the timeframe gap between their artefacts.

10.2.3 Strong versus weak signals

The treatment of strong and weak signals also appears to differ between scenario planning and system dynamics. Schoemaker & Day (2009) argue that scenario planning can be used to detect and explore weak signals. System dynamics on the other hand appears to focus on

---

31 Compare, for example, Wack (1985), de Geus (1988), Schoemaker and van der Heijden (1992), and Morecroft (2007) and their recounts of various scenario planning exercises at Royal Dutch/ Shell.
Combining scenario planning and system dynamics

strong signals, as is indicated by its focus on the present system structure and dominant influences that drive behaviour. However, scenario planning also considers strong signals. Schoemaker & Day (2009) propose scenario planning as a way to detect and explore weak signals, not that it does this exclusively. Strong signals feature quite readily in scenario planning. A number of the studies demonstrated this, including the FDF (Chapter 4), HVM (Chapter 5), Grass-rabbits-foxes (Chapter 8), and L’Arche (Chapter 9) studies, who all had scenarios that included a number of the key elements that were present in their system maps. For example, the role of government regulation in the food and drink industry was included in the scenarios developed in the FDF study (Chapter 4).

The benefit of integrating scenario planning and system dynamics was that scenario planning could pick up on weak signals that could be explored using system dynamics. An example of this is the change in nutritional value of grass in the Grass-Rabbits-Foxes study. System dynamics was then used, along with scenario planning, to explore the implications of this weak signal and the effects it might have on the system.

10.2.4 Qualitative versus quantitative

Another apparent difference between the two approaches is the qualitative nature of scenario planning and quantitative nature of system dynamics. While functionally the two approaches appear to be divided by these different classes of information, such a conclusion would be misled. Scenario planning ‘simplifies the avalanche of data into a limited number of possible states’ (Schoemaker, 1995, p.26). In a way it integrates various types of future orientated data (Postma & Liebl, 2005, p.165). This data is both qualitative and quantitative. Furthermore, system dynamics also considers qualitative data, this is part of Meadows’ (2008, p.170) suggestion to understand and ‘get the beat of the system’.
The approaches’ adherence to qualitative and quantitative principles is also apparent in their results or ‘artefacts’. Scenarios are typically qualitative, whilst the dynamic models generated by system dynamics are quantitative. However, the main outcome of the approaches, which has been continually touted, is learning, which occurs both on qualitative and quantitative levels. Furthermore, scenarios are not unknown to include quantitative elements such as dates (see for example le Roux & Maphai, 1992) and the description of the cause of systemic behaviour in system dynamics is often found qualitatively (see for example Sawin et al., 2003; Soo et al., 2013). These arguments demonstrate that while the approaches appear to follow qualitative and quantitative principles separately, this conformity is apparent, rather than actual.

10.2.5 Different requirements from stakeholders

What is required from stakeholders appears to vary between the two approaches. In the L’Arche study the stakeholder group used in the workshops proved to be suitable for the development of scenarios and provided information during the system mapping exercises that increased the modeller’s breadth of knowledge of the organisation. However, this group did not provide the information needed to address the core problem of the workshops using system dynamics because a more specific problem had not yet been defined. Furthermore, even if it had been defined, the post-workshop meetings and interview sought specific data and information which would have been difficult to capture in a larger group workshop, such as the timing of planning phases. The workshops did provide much of the structural information for the ‘traditional’ dynamic models, but not for the system dynamics model. This and the specific information needed for both forms of modelling had to be acquired from the interviews and meetings with board personnel after the workshops.
This calls into question the types of stakeholders needed for an integrated approach of scenario planning and system dynamics. In the L’Arche study few board members were involved in the workshops. However, it was these board members who were able to provide the specific information about system structure, decision structures, and data that was needed for the dynamic model. Engaging stakeholders that can provide both the specific information needed for system dynamics and the context and perspective needed for both approaches is an essential consideration when employing an integrated approach of scenario planning and system dynamics.

Another consideration is also the number of stakeholders used in the different studies. The FDF study was a large scale workshop involving almost thirty stakeholders, the Grass-Rabbits-Foxes study involved eight people, and the L’Arche workshops involved twelve stakeholders. Work has been on small group model building processes (Richardson et al., 1989, p.345) and on the use of larger groups for model building (Vennix, 1990; Vennix et al., 1990; Vennix; 1996). Ultimately however, the knowledge needed to be elicited for a project dictates the number of people that need to be involved (Richardson et al., 1989). The different scopes and scales of the studies required different processes and different numbers of stakeholders. Thus a comparison of the number of stakeholders in each study would be infeasible and unwise.

10.3 Developing scenarios through system dynamics: an exclusion

Within system dynamics, there is a way to generate ‘scenarios’ without the use of scenario planning, these are essentially runs of models with varied parameters and are sometimes known as ‘what-if’ scenarios (for example, see Zagonel et al., 2011). Studies that use this parametric variation to create ‘scenarios’ include: Urban Dynamics (Forrester, 1969), Zagonel et al.’s (2011) theory of the prevalence of cigarette smoking, and Limits to Growth (Donella et
al., 1972) and its follow up books: Beyond the Limits (Meadows et al., 1992), Limits to Growth: The 30 Year Update (Meadows et al., 2004), and 2052: A Global Forecast for the Next Forty Years (Randers, 2012). Bean et al. (1992) also appear to discuss generating scenarios from a system dynamics model and, while their exact methodology is unclear, allude to simple variation change to generate their scenarios.

Calling these parameter variation runs scenarios is sensible, but these scenarios should not be confused with those from scenario planning. Scenario planning begins with the ‘extremes’ and uses these to define the space the scenarios map out. To create its scenarios (hereon parameter variation scenarios), system dynamics varies individual parameters within a range. This range does not explicitly aim to suspend disbelief, but simply demonstrates the impact of varied parameters. Scenario planning also goes a step further, rather than varying one parameter between scenarios, it allows ‘patterns and clusters’ to be identified that give rise to very different scenarios (Schoemaker, 1995, p.27). Finally, scenario planning also makes explicit the uncertainties in the system, demonstrating yet more possible variations in future situations. The Grass-Rabbits-Foxes study demonstrated that system dynamics can make people perceive that these uncertainties are rigid. In general, it is the process of scenario planning that separates its scenarios from the parameter variation scenarios observed in system dynamics. These reasons explain why scenario planning through parameter variation, unless stipulated by scenarios generated using scenario planning was excluded from the studies.

10.4 How system dynamics informed scenario planning

From the studies it was evident that system dynamics did help scenario planning to, at some level, overcome the criticisms levelled against it in Chapter 2. The criticisms highlighted in
Chapter 2 were scenario planning’s subjective nature and the role of possibly ill-informed mental models in the approach, the need to develop its theoretical foundations, the need to involve decision makers in the approach despite its time and resource intensity, and the lack of an evaluation method for the approach. Also identified in the chapter were a range of implementation issues, in particular a focus on the scenarios, rather than on scenario planning. In this section each of these criticisms is assessed based on evidence from the studies and from literature.

10.4.1 Subjective nature

As argued in Chapter 2, one of the criticisms of scenario planning is its subjective nature. One of the main reasons for employing system dynamics was to see if it could be used to help increase the objectivity of scenario planning. Only the Grass-Rabbits-Foxes and L’Arche studies provided evidence to support or confute this hypothesis. The Grass-Rabbits-Foxes study demonstrated how a model of system dynamics could inform people’s structure of the system. More specifically, it helped the participants to conceive the feedback and delay driven, non-linear structure and complex relationships between the populations. Mapping the system out in system dynamics helped to solidify the inferences and quantify the relationships within the system.

The L’Arche study also demonstrated how system dynamics could be used to understand a question that went unanswered and untested during the scenario planning workshops: why L’Arche’s desire, perceived ability, and actual ability to grow continually remained at odds with each other. Using the structured approach to explore the systemic behaviour helped to understand the reasons for this misalignment and generate a model that reflected the observed behaviour. Both the Grass-Rabbits-Foxes study and the L’Arche study exemplified
how system dynamics objectively assisted mental model development during a scenario planning process.

Formalising and Engaging System 2
System dynamics also helped the subjective nature of scenario planning by formalising people’s thinking and encouraging them to think more deeply about their inferences. Mental models are notoriously ‘slippery’ (Meadows, 2008, p.172). Mapping out systems and generating system dynamics models encouraged people to surface their mental models, making them explicit and testable by themselves and others, an important way of informing mental models (Senge, 1992). This formal approach to mental model development is much less vague than scenario planning’s, which mostly suggests a process of information collection, emersion, and inquiry (Wack, 1985a; Schwartz, 1996), with minimal systems mapping (see van der Heijden, 2005) to test mental models.

Furthermore, the process of system dynamics requires explicit identification of relationships, which encouraged people to think about their assumptions and system inferences. In the early scenario planning studies, for example the FDF and HVM studies, people used their informal, even intuitive, thinking of the system, which can be poorly informed (Kahneman, 2011), to map a system out. System dynamics, however, encouraged people to shift from intuitive thinking, what Kahneman (2011) calls System 1, and to the more deliberate and calculating System 2 – laborious, but generally more considered thinking – to consider the system and its relationships.

Mental models
Decreasing subjectivity, increasing formalisation, and encouraging participants to think more deeply about their inferences are all related to participants’ mental models. As outlined in
Chapter 2, scenario planning is a process of sensemaking and mental model development. The system dynamics approach got participants to make their conclusions from sensemaking and mental models explicit. The two benefits of doing this are the act of parsing them through conscious thought, which allows some level of assumption sense-checking, and the act of ‘crowd checking’ or using multiple people to check if the assumption or inference is shared – a sort of peer-review.

However, the ability for system dynamics to assist mental model development is still limited, just as it is with any other problem structuring or foresight process. Groupthink (Whyte, 1952; Janis, 1971; Janis, 1972; ‘t Hart, 1990) is one situation that would make the surfacing of one’s ideas less useful as potentially erroneous concepts that are shared by the whole group pass peer-review. Furthermore, system evolution can still introduce unforeseen events and structures that render any mental models developed less useful. For example, Morecroft and van der Heijden (1992) and Morecroft (2007) discuss the development of a model about the world oil production system. However, even with the scenarios (see Cornelius et al., 2005) and with the model (Morecroft & van der Heijden, 1992; Morecroft, 2007), they still did not see the collapse of the Soviet Union in the early 1990’s (Morecroft, 2007, p.277). This is a prime example of Taleb’s (2005; 2007) Black Swan – an unpredictable event that can have enormous consequences on the system.

While Black Swan events exemplify the problems with prediction, as an example of system evolution they highlight the time dependent relevance of having ‘informed’ mental models. As time progresses mental models can become out-dated and misinformed. This is why scenario planning and system dynamics focus on learning rather than prediction (Wack, 1985; Lane, 1992; Morecroft & van der Heijden, 1992; Saeed, 1993; Schoemaker, 1995; Morecroft, 2007;
Featherston & Doolan, 2012). By continually learning about the system, new information is considered and mental models are updated.

*Reassessing scenarios*
The argument that system dynamics informed scenario planning is supported if system dynamics encouraged a reassessment of the scenarios themselves. While it has been demonstrated through the studies that system dynamics did help people question their assumptions and change people’s thinking about the system, there is mixed evidence in this work to suggest that it can motivate changes in the scenarios themselves. In the FDF study, the influence diagrams proved little help to developing the scenarios. In the L’Arche study, the system dynamics approach motivated no change in the scenarios, perhaps caused by the misalignment in scale of the results (see Chapter 1). The only evidence to the contrary is from the Grass-Rabbits-Foxes study. Despite the system diagrams and dynamic model having partially defined participants’ understanding of the system, exploration of the system using system dynamics did encourage a re-draft of the scenarios. This redraft was in the form of introducing the concept of birds as fodder for the foxes to the scenarios.

Using the scenarios as a guide for the influence the system dynamics approach had on scenario planning might, however, be a little misled. In the Grass-Rabbits-Foxes study, the scenarios outlined the preliminary conditions of the situation that could arise, but the modelling executed redefined what people thought the impact of such changes would be on the populations. This shows that the strength of the combination of these two approaches is more than just introducing more robust mental models for scenario development.
10.4.2 Implementation

Several implementation issues were identified in Chapter 2, including an excessive focus on scenarios rather than scenario planning and the necessity for scenario developers to be reputable, credible, and trusted. The integrated approach appeared to move focus somewhat away from the scenarios, but only because there were other results accompanying the study (see for example the L’Arche study). However, focusing on the models rather than the process is also an issue in system dynamics, as discussed in Chapter 3. Perhaps a more significant indicator for its evaluation was the ability of the L’Arche process to satisfy the processual requirements, as shown in the previous chapter (also see Appendix A). By satisfying all but one of these in the L’Arche study, the integrated process emphasised other achievements, such as surfacing views, facilitating negotiation, and generating ownership, rather than focusing only on the production of scenarios.

In Chapter 2 it was identified that a scenario developers’ reputability, credibility, and trust were important in scenario planning (Frittation et al., 2011). In the L’Arche study, all three of these traits were noted to increase. As the participants went through the four workshops, the board appeared to have greater trust in the results. Furthermore, the board’s confidence in their reputability and credibility also increased. However, whether this development is due to the integrated approach or because of the time spent on the problem is unclear. Trust, like many relationship qualities, takes time to build (Hackman & Morris, 1975). Therefore, the causation is unclear. The traits could have developed because of the time spent working on the decision problem and could have arisen with the employment of any approach addressing such a decision problem, rather than specifically because of the integration of system dynamics and scenario planning.
### 10.4.3 The evaluation of scenarios

System dynamics did not help to develop an evaluation process for scenario planning or scenarios. Chermack et al. (2001) identified the lack of evaluation process as the most critical aspect to the development of scenario planning as a field. Unfortunately, the application of system dynamics did not assist to render this deficiency.

A process to evaluate scenarios and then indirectly evaluate scenario planning was developed during this work. As far as is known, it is a novel method for the evaluation of scenarios and scenario planning. The process also evaluates a system dynamics process and its artefacts, but as system dynamics did not help establish the evaluation process, it did not help to overcome this criticism of scenario planning. It should be noted that more work on this evaluation process is needed. Further comment on the evaluation process is made later in this chapter (section 10.8.1).

### 10.4.4 Theoretical foundations and resource intensity

The final two major criticisms of scenario planning outlined in Chapter 2 were its underdeveloped theoretical foundations and the resources required for the approach. This work did not contribute much in the way of theoretical grounding for scenario planning, except in highlighting many of its founding tenants and comparing them to system dynamics. It also did not address scenario planning’s resource intensity, except to say that when a system dynamics model was developed (in the Grass-Rabbits-Foxes and L’Arche studies) it required more resources than scenario planning.
Combining scenario planning and system dynamics

It was argued in Chapter 3 that scenario planning is resource intensive. The same can be argued for system dynamics. Bean et al. (1992, p.70) argue that building accurate models that are useful take resources that people are ‘unable or unwilling to allocate’. Combining the approaches did not help with this issue. However, it was observed in the studies that the time required to instruct people about scenario planning, at least what was required from them for a scenario planning approach, was vastly less than for system dynamics. This was particularly the case in the HVM study, where it was highlighted that more training was needed to acquire the information needed from people for a system dynamics approach.

10.5 How scenario planning informed system dynamics

10.5.1 Communication: Misunderstanding and misapplication

The conclusion from Chapter 3 was that the key criticism present in system dynamics is the field’s failure to communicate the approaches’ goals and how it achieves them, which has led to many misplaced criticisms of the field, many poor examples of its application, and its poor rate of adoption. Unfortunately, there is very little evidence from this work that combining system dynamics with scenario planning addresses this criticism. The combination of scenario planning did little to communicate system dynamics’ goals or requirements, at least not in any way that could not have been achieved otherwise.

Scenario planning maintains an open and dynamic focus

One exception to this is the misled criticism that system dynamics is not open and dynamic enough to address social systems. It was demonstrated in Chapter 3 that this was not the case and evidence from the studies supports system dynamics’ capabilities to be open and dynamic. Scenario planning has an ability to exhibit a plurality of different trends and drivers and their
different variations. Where the scales of the system dynamics and scenario planning aligned, system dynamics appeared just as open and dynamic. For example, the Grass-Rabbits-Foxes study did not have key uncertainties that could not be incorporated into the system dynamics approach. This does not mean that the model is able to simulate all trends and drivers, but it provides an instance that demonstrates the ability of the approach to consider the same factors as scenario planning in similar ways. This does not disprove the criticism, which was done in Chapter 3, but it does act to pacify those who assert it.

10.5.2 Other unaddressed criticisms

The prime conclusion aside, Chapter 3 also identified several at least partially unaddressed criticisms of system dynamics that are still pertinent. Such criticisms include the role of historical data in building confidence, the field's reductionist perspective, and how it addresses pluralism, and hierarchy. Out of these four criticisms, the integrated approach of scenario planning and system dynamics used in the L’Arche study only motivates a review of pluralism.

Pluralism

The combined approach assisted system dynamics to consider a plurality of different perspectives of the system and how it operated. In the L’Arche study, the workshops collected a number of different stakeholders together who provided their different perspectives on the different structure of the system in the initial systems mapping exercise. The influence and stock and flow diagrams that came out of the workshop reflected these different views and informed the modeller about the structure of the system. However, it was not necessarily the scenario planning portion of the workshops that allowed this to occur, but it was the way in which the system dynamics approach was applied. Similar group model building exercises, like
that of Richardson et al. (1989) and Vennix and his colleagues (Vennix, 1990; Vennix et al., 1990; Vennix; 1996) can help system dynamics to achieve such a pluralistic orientation.

10.6 Mutual assistance

It was observed during the studies that scenario planning and system dynamics provided each other with mutual assistance in a number of different areas. These areas include framing and exclusion, learning, and communication.

10.6.1 Framing and exclusion

There is evidence from the studies that suggests combining scenario planning and system dynamics can encourage people to consider new factors by framing problems differently and reducing the exclusion of potentially important information from the process. Framing is the context that one uses to observe a situation (Schön & Rein, 1994). Reframing is the process of using a different context to view a problem (Bolman & Deal, 2003). By examining frames, reframing, and reflecting people can discover and understand reasons, purposes, and goals that were previously veiled (Schön & Rein, 1994; Bolman & Deal, 2003).

Finding information by approaching the problem from a different angle and reframing the context from which it is perceived can help to reduce important excluded information.

Exclusion of information can happen for any number of reasons; bounded rationality – the limitations of time, information and cognitive capacity – is often cited as a reason for excluding information and options in decision making (Simon, 1957; 1979; 1982). Morecroft (2007, p.210) provides Figure 10-3, (which is strongly grounded in previous work: Morecroft, 1983) which outlines five filters that can be responsible for ensuring information is not used in a
decision (see Morecroft, 2007, p. 210-2). The five filters in this figure outline the five reasons why information may not make it to the point where it is used to develop policy (or strategy).

![Five filters diagram]

Figure 10-3: The policy function, information filters and bounded rationality (Morecroft, 2007, p.210)

These filters apply to any problem solving process the result of which is a policy. Reframing can alter the information that passes through the filters. The filters themselves change based on the frame, just like the perspective someone has of a decision problem. By changing the perspective one takes when viewing a problem, the filters themselves change. For example, Schön & Rein (1994) explain that people have different goals based on their frame of the problem and that by viewing the situation using someone else’s frame they can understand what motivates their behaviour. The shift in frame is responsible for them taking in information that was previously filtered because of their perspective (Schön & Rein, 1994). This information not only assists to develop their understanding of the decision problem, but also informs the strategies or policies developed.

There is evidence from the studies to suggest that scenario planning and system dynamics provided different contexts from which to observe the system, thus uncovering information
not previously considered. Perhaps the most potent example of this was the Grass-Rabbits-Foxes study. In this study, scenario planning illustrated how the base model could be applied to the island by helping to uncover variations that might occur to the model as a consequence of the island. An example of this is the change in the nutritional value of grass. In the same study, taking a system dynamics approach also uncovered information not previously considered in the scenario planning approach, such as birds being fodder for the foxes. The L’Arche study also contributes to this argument: in the study the scenario planning process was not able to identify why the difference between desire and ability to grow persisted, despite there being proof to the contrary, but a system dynamics approach was able to address this issue.

However, the evidence supporting the ability of scenario planning and system dynamics to reframe each other’s problem was not forthcoming in all the studies. The FDF study, for example, found that the influence diagrams did not help develop or reassess the scenarios. It is possible that the limitations of the systems mapping approach adopted in this study meant that this did not work, but it is still not supportive evidence.

10.6.2 Learning

The two approaches also provided instances where they assisted the learning expounded by the other. Introducing new information is the first step in Daft and Weick’s (1984) learning process (Figure 10-4). Framing, reframing, and reflecting contribute to the collection of new information. However, the introduction of new information does not necessarily mean that learning occurs. As outlined in Chapter 2, learning does not actually occur until action is taken to correct errors in knowledge (Argyris, 1976, p.365). When new information is made sense of and gives rise to new theories, these new theories must be communicated and usurp or be
combined with existing mental models (known as interpretation in Figure 10-4). These actions constitute corrections in errors of knowledge. However, replacing and freezing new mental models is difficult (Senge, 1992). Furthermore, establishing if learning has occurred can be difficult, particularly if the ‘action’ is a cognitive correction and is not readily evident. One way to establish if it has occurred is whether new action reflects the learning.

![Figure 10-4: Daft & Weick’s (1984, p.286) learning process](image)

The studies provide mixed evidence of learning having occurred. In the FDF study, despite the influence diagrams being inappropriate for a system dynamics approach, it does not exclude them from having provided some information for the scenario planning approach. The fact that participants said they were of little use for a scenario planning process also does not exclude them from having assisted learning. The information on the diagrams could have been assimilated quickly, making the diagrams themselves of little value but creating new conceptualisations that were easy to take forward into the scenario planning process. Unfortunately, the study offers no conclusive evidence to support or deride this possibility, so no conclusion can be drawn about learning from system maps in this study.

The HVM and China Futures studies also do not provide any evidence of an integrated approach supporting learning any more than scenario planning and system dynamics would have done individually. This is perhaps partly because they were incomplete. The HVM study demonstrated several times the importance and value of learning and group learning: in several different workshops participants were observed having the same discussions, making sense of their mental models and forming similar conclusions. However, there was little
evidence of that learning being carried forward into the system dynamics approach. The China Futures study also provided little evidence of learning. Participants did not create system maps that reflected the information from the scenarios. As the system dynamics approach was not completed in either study, no evidence was produced for the reverse. This again provides inconclusive evidence.

However, the Grass-Rabbits-Foxes study did provide evidence that learning during the execution of one approach did inform the other. When the scenarios demonstrated that there were gaps in the base model, participants took action to redesign the model to rectify these gaps. Furthermore, the desire to redraft the scenarios when the dynamic model demonstrated they were incomplete – and did not include birds as fodder for foxes – shows that learning from system dynamics informed scenario planning. Taking these actions to render the model and the scenarios consistent with one another is evidence of learning. These actions are examples of Argyris’ (1976, p.365) definition of learning: ‘the detection and correction of errors, and error as any feature of knowledge or of knowing that makes action ineffective’. This ability to co-inform each other and evidence of learning were key benefits of integrating scenario planning and system dynamics in this study.

The L’Arche study exhibited learning in many different areas, but evidence that the approaches supported learning in one another is mixed. Participants did take information they had established in the scenario planning exercises into the system dynamics exercises. For example, the system dynamics exercises began with participants selecting key uncertainties from scenario planning as central factors for the systems mapping exercise. Many of the drivers and implications identified in the scenario planning exercises were included into the influence diagrams and subsequent system maps.
Furthermore, participants also took information from the system dynamics exercises and used it in conjunction with the scenarios to generate novel strategies. For example, they used the leverage points identified in the system dynamics workshop in the windtunnelling exercise and developed strategies to help move L’Arche from one scenario to another. The later of these points is also an example of using the results of the approaches together, which will be discussed later in this section. However, there is also evidence that information was not assimilated and used in the other approach. For example, participants failed to identify the organisation of fundraising events as a leverage point, despite its prominence in the scenario planning activities. While the evidence of learning is mixed, overall the studies demonstrate that some level of additional learning occurred when scenario planning and system dynamics were integrated.

10.6.3 Communication

Another example of learning and of the benefits of using the two approaches together is the enriched language that was being used by the participants in the studies. This was particularly apparent in the Grass-Rabbits-Foxes and L’Arche studies. In the studies during the discussion sessions participants used the language of both approaches to discuss their issues and ideas about the decision problem. For example, in the L’Arche case study, the participants were discussing and comparing the effectiveness of leverage points in different scenarios. The combination of the two different approaches gave participants a richer language than either of the approaches could individually to describe their issues and ideas. They gave participants common expressional domains, such as leverage points and scenarios, from which to understand the abstract concepts (from the metaphorical domain) that they were discussing (see Lakoff & Johnson, 2003).
10.6.4 Mechanics of workshop activities

Executing the two approaches together also provides assistance by allowing more flexibility in the design of workshop activities. The focus in this section is on the mechanics of the activities themselves and how they are executed. For example, in the workshops participants chose a key uncertainty to be the central factor in their influence diagrams, rather than selecting one at random. This not only provided focus, but when combined with the instruction to select a measureable noun guided participants towards selecting the important factors of the organisation. These assisted the diagrams to be more conducive to development into stock and flow diagrams and provided key information about the organisation and the system itself for the modeller.

10.6.5 Results

Finally, using the two approaches in tandem also meant that their results can be used in tandem. An example of this was given when the participants in the L’Arche study used the leverage points and the scenarios to develop strategies. This is also exemplified by the greater detail L’Arche’s scenarios and the Confidence model provide about the issues surrounding their desire to grow, inability to do so, and how this might evolve in the future.

10.7 Integration

The work conducted in this study has uncovered three general key requirements for successful integration: activity execution, quality results, and method of integration. First, because of the workshop approach adopted for this work, the individual activity that aimed to capture the information must be executed. The HVM and China Futures studies yielded little benefit, except methodologically, from the system dynamics approaches because they were not fully
executed. Second, the results of the activity must be useful. The FDF study demonstrated that participants found the diagrams of little use for the scenario planning approach (unless in this case, as hypothetically observed, they internalised the results quickly). Finally, the method of integrating the information from one approach to the other must be congruent with the type of information and its context. Again, the reader is referred to the use of the key uncertainties as central factors in the Grass-Rabbits-Foxes and the L’Arche studies and to the use of leverage points to develop strategies in the scenarios in the L’Arche study. If these three requirements are met then the integration of these approaches is feasible, as shown in the Grass-Rabbits-Foxes and L’Arche studies.

10.8 A comment on methodology

The methodology adopted in this work was considered and structured in nature. It began with establishing a working scenario planning method, albeit including some techniques used in system dynamics (which had already been included by other researchers, for example see van der Heijden, 2005). It then attempted greater integration of the two approaches and tested different methods of doing so. This method concluded in the integrated approach used in the L’Arche study.

Perhaps the methodology’s greatest drawback was that it was not a strictly scientific method. Because it was a process based subject and the topic was its application, the work could not establish a control, very little could be isolated for testing (or applying), and the researcher (facilitator, and modeller) was directly involved in the studies. This led to the studies being isolated examples of integration, rather than being able to draw definitive comparisons between the studies. Such difficulties are common with applied approaches (see, for example, Platts, 1993). Drawing specific conclusions that are widely applicable from examples would be
errorneous because of the problem of induction (Hume, T 1.3.4.1 SBN83-84; Taleb, 2005; 2007), but drawing these conclusions with the appropriate caveats and warrants under post-positivism is acceptable (see Popper, 1966a; 1966b). The methodology perhaps would have been more robust if a single methodology had been tested on multiple situations or a single methodology on one situation with multiple groups. This would have provided a greater same size and validation group to make the theories suitable to be generalised. Furthermore, such an approach would have reduced the differences between the studies, providing a more scientific approach to testing specific theories.

These issues, however, do not detract from the work. The dissertation set out to understand how system dynamics can inform scenario planning and how scenario planning can inform system dynamics. The studies are a very wide set of possible situations where such co-informing behaviour could be observed. Their results exhibit examples of the benefits that were present in integrating the two approaches and that could be present in future applications. The work still provides observations of the benefits observed when the two approaches were integrated.

### 10.8.1 A comment on evaluation

As stated earlier, a method of evaluation is perhaps the most essential development needed for the field of scenario planning to develop (Chermack et al., 2001). Furthermore, despite work being done on the presentation of system dynamics, a method of evaluating a system dynamics approach is also needed. A method of evaluating an integrated approach was developed to gather evidence for this argument. To establish a more comprehensive evaluation method, it integrated a number of different methods, including direct observation and participant observation. Direct observation was collected as notes during the workshops,
particularly based on observations during the activities and discussion sessions. Participant observation was collected as comments from participants, informal feedback, unstructured interviews, and surveys.

The surveys constituted a significant effort during the work. They looked at a number of different perspectives, including the artefacts, by looking at scenario traits, dynamic model traits, processual traits, the presence of systems thinking in the process, and comparisons of and changes in understanding. Questions regarding these areas were gathered from problem structuring methods, scenario planning, system dynamics, organisational change, psychology, and group dynamics. The criteria included aims and goals, benefits, attributes that previous research has identified as necessary, problems, and features that could vitiate the results (and should be avoided) from all these areas.

The aim of this methodology was to test the process before testing its outcomes. That is, testing the process was the priority and testing the outcome was an auxiliary aim. It can, at times, be difficult to distinguish between the two; often it is believed that an effective process would lead to improved performance. However, as argued by Platts (1993), performance has a number of extraneous effects that dilute the effect of a process on end performance. The limitations of the process of evaluation, and of the methodology, are covered in the next, and final, section.

10.9 Limitations of the work

All of the conclusions drawn in this work are with respect to the limitations already outlined in the individual studies, but there are also limitations of the work as a whole. Chief among these
are the limitations in the ability to evaluate the combined approach. However, more general limitations of the study are also present.

10.9.1 Limitations of the method of evaluation

The evaluation method, while novel, has several limitations. These limitations need to be developed further before its potential as a comprehensive evaluation tool of interventions can be realised. One of the evaluation method’s limitations was that the observer was also the researcher. As stated, this departs from a strictly scientific approach as observations were possibly threatened by subjectivity and the researcher could have had an interest in obtaining supportive results, particularly as it was work pursuing a degree. Knowledge of this potential problem, the traps of the confirmation bias (Wason, 1960), and consciously trying to keep an objective perspective were employed to deal with this trapping. However, this was not deemed as a particular threat to the work as the use of the researcher as an observer is quite common, particularly in management and other applied research (see, for example, Mintzberg, 1973; Platts, 1993; Phaal et al., 2010; Stigliani & Ravasi, 2012).

Another limitation for the work was the taking of participant observations in the form of informal feedback. Much of the feedback from the studies was provided informally, where participants made comments that were recorded, either during the process to each other, directly to the facilitator in person or in writing, or during the discussion sessions. Such informal sources of feedback have considerations that need to be made such as their context, timing, and the manner of their delivery. Furthermore, these were recorded through written notes, which have difficulty capturing these contextually rich elements of communication. Perhaps, however, this was a positive element of the method as participants were able to
provide feedback more freely and over longer periods of time, giving them time to consider their thoughts.

The final limitation to be discussed is with regard to the number of people involved in the surveys completed in the studies. One element of the surveys was the change in peoples’ understanding, which required understanding to be gauged before and after the study. However, in the studies where the surveys were used (the Grass-Rabbits-Foxes and the L’Arche study) this capacity was reduced by the limited number of people who completed the first and final surveys.

### 10.9.2 General limitations

One of the limitations of this work is that there were only two studies with appropriate considerations of a system dynamics approach. It is arguable that a system dynamics approach is never complete. However, two studies, the Grass-Rabbits-Foxes and L’Arche studies were pursued until a system dynamics model was created. As there were only two studies this limits the number of different instances evidence could be drawn to support the argument in this dissertation.

However, during this work, generating influence diagrams was seen as a step in the system dynamics approach. While this was done in all of the studies, it was these diagrams that proved to be a bane of the work. Influence diagrams proved to be a difficult tool to develop effectively, which appears to be a consequence of their flexibility. Their ability to take on many forms meant that they did take many different forms, making them at times unconducive to take forward in a system dynamics approach, or even in the case of the FDF study, in a
scenario planning, approach. Even when developers experienced in system dynamics developed influence diagrams, a vague task and focus still detracted from the value of the diagrams generated.

Three lessons can be drawn from the experience during this work with influence diagrams. First, the influence diagrams needed to be very explicit in their purpose: to support a system dynamics process. Influence diagrams are very flexible in their structure and by not being explicit about their purpose the diagrams often did take on very different structures. Second, the diagrams need to have a clear focus to be conducive to assisting a system dynamics approach. The China Futures study demonstrated how people experienced in system dynamics could not develop diagrams that supported a system dynamics approach. The more targeted diagrams observed in the Grass-Rabbits-Foxes study and in the L’Arche exercise were more amiable. Finally, people need to be educated in influence diagrams and supplied ample time to rethinking and redraft them. In many of the studies feedback was limited and the factors that were vague, convoluted, or both, making them unconducive to assisting a system dynamics process. Furthermore, they often appeared unfinished. Educating people and allowing them the time to redraft their diagrams might have helped to overcome the observed shortcomings of the diagrams, especially as peoples understanding of a problem deepens as they work on it (Mintzberg et al., 1976).

Influence diagrams were used, however, because of their many benefits. Coyle (1983a) identifies three such benefits: the method for their development is easy to communicate, they are quick to develop and redraft, and that if their elements and structure are suitable they can be transferred directly to a model without intermediary processing. These three benefits made them the first choice for system mapping tools.
Another limitation of the work was that the skill level of the researcher and facilitator changed throughout the exercise. This was the reason for some of the mistakes made in early studies; lessons that were taken forward into subsequent studies.

The final limitation of the work is that the studies conducted were a non-exhaustive test of the various combinations of elements of system dynamics and scenario planning. Further benefits and more effective means of integration could be found if further tests on alternative combinations were conducted.
Chapter 11   Conclusion

‘Theories are nets: only he who casts will catch’
Novalis

This work has demonstrated that, despite their differences, system dynamics can be used to inform scenario planning and scenario planning can be used to inform system dynamics. However, they only assist each other in specific areas. In this chapter the conclusions drawn from the individual studies will be drawn out first. The conclusions from the work as a whole will then be discussed. This short chapter will conclude with further work that needs to be done in this area.

The main contributions of this work are manifold. The work developed an understanding of areas in which scenario planning can inform system dynamics and system dynamics can inform scenario planning. It has also developed examples of how these occur and discusses why they occurred (sections 11.2 and 11.3). The work also drew out many specific conclusions about the application of system dynamics and scenario planning (these are discussed in along with the specific studies in section 11.1) and conclusions about the specific case studies themselves, for example L’Arche and its decision making processes, which are novel contributions to their respective fields. Further auxiliary contributions are the collection, development, and summary of the critiques of scenario planning and system dynamics (Chapter 2 and Chapter 3 respectively). As these were auxiliary conclusions, these are not included in this chapter.
11.1 Conclusions from the studies

The FDF study established a scenario planning process that developed scenarios that were well received. It built on participants’ knowledge and appeared to build consensus about the major issues facing the UK’s food and drink industry. The study also examined a simple integration of system mapping, which turned out to be a failure. While the original method used to develop the influence diagrams was not successful, it was reworked during the activity and the final process devised was successful. Despite this, the influence diagrams were not used again in the scenario planning process. The study identified that the results from a process need to be relevant and valuable for them to be useful in another approach.

The HVM study trialled an alternative approach to scenario planning. It collated information from many different groups of stakeholders through a number of different workshops. This approach produced trends and drivers that were comparable to the clients’ view. However, it did not allow the process of discussion and group sensemaking to occur with all participants and lacked ownership, which are possible explanations for the study being prematurely terminated. A brief exploration into system dynamics had some promising results, but these were not taken far before the study was terminated. The study emphasised the importance of group sensemaking, in particular consensus building, in a group based scenario planning process.

Together the FDF and HVM studies established a group scenario planning process. They also demonstrated the difficulties behind applying a system dynamics approach. Facilitators of such approaches need to place greater focus on the requirements and structure of system mapping tools to get diagrams that are useful and conducive for a system dynamics approach.
Furthermore, these studies emphasise the need for a significant level of education about system dynamics to ensure the right information is captured for the approach.

The China Futures study used established scenarios and attempted to map the system found in each of the resulting scenarios. The study found that scenario planning and system dynamics have different scopes and have different perspectives of causal relationships. The study found that while scenario planning can focus on either a system or a problem, a system dynamics approach needs to focus on a specific problem. Furthermore, scenario planning considers causal relationships at a broad level, which need to be revised down to more specific relationships for a system dynamics approach. These two related differences between scenario planning and system dynamics are not explicitly present in current literature, but the conclusions drawn about the approaches individually are evident in the literature.

Aspects of the China Futures study meant that other conclusions were limited. The integration of different system maps based on the systems observed in different scenarios did not occur. However, there were other conclusions that were drawn from the study. Firstly, participants did not have enough knowledge of the situation to develop adequate diagrams. This is because they were not involved in the scenario planning approach and because they were not domain experts. Second, the diagrams appeared unfinished; more time was needed to be provided for their completion. Finally, the study highlighted the importance of using a suitably designed activity for generating results in an integrated approach of scenario planning and system dynamics. These were important considerations for future integration attempts.

The Grass-Rabbits-Foxes study explored using an integrated approach of scenario planning and system dynamics on a predator-prey system. The study demonstrated how system maps and a
Dynamic model of a system can inform a scenario planning approach. The systems maps and dynamic model defined relationships that otherwise would have been vague and malleable in a scenario planning approach. Furthermore, it educated the participants on the structure of the system. Finally, it encouraged the consideration of information that had not been previously considered in the scenarios. However, this particular form of integration also had a disadvantage. Some of the assumptions made in developing the dynamic model appeared to become indisputable for participants during the scenario planning process and subsequent work continued within these boundaries.

The study also showed how scenario planning could inform a system dynamics approach. The scenarios introduced elements participants were reluctant to include in the dynamic model. Scenario planning also introduced considerations that had not been included in the dynamic model, such as birds as prey for foxes.

This study also demonstrated a system dynamics model could reflect multiple scenarios. A dynamic model that included the different outcomes and relationships in the different scenarios was developed. Furthermore, this ‘integrated’ model’s simulations pointed to further shortcomings of both itself and the scenarios that were not previously considered, further reducing exclusion.

The L’Arche study took the learning that occurred in the other studies and applied it to a decision problem in the real world. L’Arche wished to identify why it could not expand its operations. The study used a series of four workshops to develop scenarios and map out L’Arche’s system. The inclusion of system dynamics through brief ‘lessons’ and the system mapping exercises was valuable for participants and they produced detailed diagrams of
L’Arche’s system that reflected systems thinking. However, the decision problem was still not specific enough for system dynamics.

After the process meetings, unstructured interviews, and data searches were carried out to further specify the problems and develop a system dynamics model. To assist problem specification, two more ‘traditional’ dynamics models were created of L’Arche: a discrete event model that used a user interface to include feedback in the model, and a continuous model that had feedback built in. These were built from the system maps that were generated in the workshops and more specific information collected after them.

The workshop results and dynamic models shifted the focus from what was stopping L’Arche from growing to why L’Arche’s board had the confidence to grow, when financial models continually said it could not. From the learning that occurred in this space the confidence model was developed. This model reflected how the board’s confidence changed given the monthly financial reports. This model accurately reflected the behaviour of the organisation’s board at the time of the exercise.

Surveys of this applied approach found that the participants generally found the inclusion of system dynamics in the workshops useful and that the approach met almost all of the traits that literature suggests should be in a process that addresses decision problems. The surveys also found that the board generally thought the scenarios met the traits the literature argues they should have. However, while the board would engage in the process again, its members generally did not think the process changed their perceptions of the problem (14% said it did, see Table 9-8) which differs dramatically to those who participated in the workshops (of which 100% said it changed their perceptions, see Table 9-7). While this could be explained by the
dominantly short and recent tenure of many of the board members, it strongly asserts the need to be involved in the integrated approach to reap its benefits.

There were several other conclusions that can be drawn from the L’Arche study. In the study the system dynamics model failed to inform the scenarios. However, the scenarios played a large role in specifying the problem and clarifying the system structure for the modeller. These are key tasks in a system dynamics approach (Meadows, 2008). Furthermore, system dynamics answered a question that scenario planning did not. The L’Arche study also demonstrated that it was essential to understand how the results from one of the approaches could be used in the other, and that these transitions needed to be done smoothly.

11.2 How the approaches informed one-another

11.2.1 System dynamics informing scenario planning

It has been demonstrated that system dynamics can inform scenario planning, as exemplified in the studies. The Grass-Rabbits-Foxes and L’Arche studies were both examples of using system dynamics to inform the mental models of participants. In the Grass-Rabbits-Foxes study it was done by mapping and quantifying the relationships in the system. In the L’Arche study, system dynamics addressed a question unanswered by scenario planning, providing a richer description of the issues faced by the organisation.

There were other criticisms levelled at scenario planning that system dynamics did not assist with. System dynamics did not help to evaluate or develop scenario planning theoretically. Executing a system dynamics approach did, however, put the resource requirements of
scenario planning into perspective. While scenario planning could always consume more resources, scenario planning as adopted in the studies consumed fewer resources than the system dynamics approach. This generates two further conclusions for the dissertation. First, this criticism is somewhat over emphasised in the scenario planning literature when compared to system dynamics. Second, the inclusion of system dynamics considerably increases the resource requirements of an integrated approach. The cost of these resources would have to be weighed against the benefits to assess if this is acceptable.

11.2.2 Scenario planning informing system dynamics

Scenario planning was much less helpful in informing system dynamics. Aside from helping to abate the disproved criticism that system dynamics is not open or dynamic enough for social systems and increasing its ability to consideration plurality, scenario planning did little to address system dynamics’ criticisms. There was no evidence to suggest it helped to improve the communication of its goals and how it achieves them.

11.2.3 Co-informing

Integrating scenario planning and system dynamics had many benefits other than the alleviation of the approaches’ criticisms. Such benefits included framing, reducing exclusion, learning and communication. The two approaches demonstrated many times how they changed the framing of the system, problem, or both and reduced exclusion. In the Grass-Rabbits-Foxes study, both scenario planning and system dynamics encouraged participants to consider information not included in the other. By considering this information they helped include information that otherwise was neglected. Furthermore, their integration developed learning by encouraging participants to render the artefacts of the system dynamics approach
Combining scenario planning and system dynamics (system maps and system dynamics model) and the scenarios consistent with each other.

Finally, the more complete integration of the two approaches observed in the Grass-Rabbits-Foxes and L’Arche studies enriched the language participants used to discuss aspects of the system and decision problem, as observed in the activities and discussion session. These benefits helped improve the overall impact of the intervention or approach taken.

11.3 A note on integration

The studies also highlighted the difficulties of integrating the two different fields. The differences of the fields created different perspectives that needed to be reconciled. Generally there were three barriers to integration identified. The first barrier was activity execution. Using workshops required a combined approach to be made up of many different activities. These activities had to be designed well and involve the right participants in order for them to be completed. The method of scenario development in the HVM study exemplifies this problem.

The second barrier, and related with the first, was the requirement that the results of the activities be accurate and useful. If they were not, people would tend not to carry the results forward into the next exercise. This was apparent in the systems mapping activity adopted in the FDF study.

The third barrier was the method of integration. An appropriate method of integrating the results from activities in one approach into the other had to be designed. If this was not done participants tended to generate their own input for the activities, rather than use the intended information already available. This is where overcoming or reconciling the differences between
the approaches was paramount. This problem was observed in the China Futures study. The use of the scenarios to inform the system dynamics model and visa-versa in the Grass-Rabbits-Foxes study exemplifies an appropriately designed method of integration.

11.3.1 Differences to obviate

In the discussion, several differences between the approaches that were noted in the literature and in the studies were considered and were either reconciled or identified as requiring caution when using a combined approach. The integration of scenario planning and system dynamics, as trialled in this dissertation, is a classic clash of two worlds; two different paradigms coming together and starkly highlighting their differences. However, their differences are fewer than would be thought. The studies demonstrated differences between their specificity of focus (scope), the specificity of the way they treat causality, and their different demands from stakeholders. These differences need to be obviated when attempting to integrate the two approaches. They were shown here to be obstacles to the success of integration if not considered in process design.

Other differences between he approaches were reconciled. The differences between the approaches’ focal timeframe generates precautions rather than limits their ability to be integrated, especially because of their focus on learning. Other differences, such as strong versus weak signals and quantitative versus qualitative foci, have been discussed, but have been shown to be either not present or of no concern when integrating the approaches.
11.4 A precautionary note about these results

There is an important precautionary note to go with this work. Popper (1974b, p.978) argues scientists should not only search for confirming evidence, stating:

‘these are men of bold ideas, but highly critical of their own ideas; they try to find whether their ideas are right by trying first to find whether they are not perhaps wrong. They work with bold conjectures and severe attempts at refuting their own conjectures.’

Popper, 1974b, p.978

This dissertation had a very broad, ambitious aim that would take much more than one project to cover. It endeavoured to understand whether system dynamics could inform scenario planning and whether the reciprocal could also occur. Evidence was found to support the first, but there was little to support the later. The dissertation did not try to establish general theories of integration. Instead, it aimed to observe some benefits of integration, which must now be explored to ‘find whether they are not perhaps wrong’ (Popper, 1974b, p.978).

The generality and applicability of the work had some methodological difficulties as noted in section 10.8. However, novel observations of the integration of scenario planning and system dynamics have been made. Novalis’ quote at the beginning of the chapter defines the motivation for such a broad aim: without developing such a hypothesis, no information regarding it could be collected. The dissertation has uncovered areas in which further work can occur to develop more effective means of integration, some of which are discussed in the next and final section.
11.5 Future work

This dissertation has only scratched the surface of the possibilities of this area of research, but has highlighted many areas in which further work could be conducted. First, more specific tests of the integration of scenario planning and system dynamics could be conducted. The same method of integrating scenario planning and system dynamics could be applied to a number of situations, creating multiple examples from which more robust theories about their integration could be developed. The same process could also be run on the same topic but with different participants to further reduce the variation between studies. Conducting further work in this manner is a more scientific exploration into the details of integrating scenario planning and system dynamics and their potential benefits and hindrances.

Second, further work could be done on the practical applications of the integration of scenario planning and system dynamics. This dissertation has tested only a few of their many possible combinations. Furthermore, the results of this work are bounded by the activities employed, the particular decision problems to which they were applied, and the participants involved in the studies. By exploring alternative workshop structures, activity structures, and decision problems a greater understanding of the possible benefits and drawbacks of integrating these approaches can be developed.

A third area of pertinent further work is to explore the impact of a combined approach on the development of policy and strategy. This work looked only briefly at the implications of the combined approach on strategy and policy development (covered very briefly in the L’Arche study, Chapter 9). Instead this work focused on how the two processes informed each other’s outcomes and how it impacted upon mental models. Going further and looking at subsequent
policy and strategy developments from integrated processes would greatly complement this work.

This work developed a means of assessing the process used in the workshops directly through the desired traits of such an intervention, and indirectly through the scenarios, system maps, and dynamic models that were developed. Further work can also be done to develop this method of assessment further. Furthermore, work could be done to develop a means of assessing an integrated approach’s ability to facilitate organisational change is one such area. This is best done over a long period of time and hence falls outside the work done here. Mantere et al. (2012) offer groundwork for such an endeavour.

Another area of further work which is also related to application, is the possibility of using scenarios to generate values that can be used as the inputs to a system dynamics model to understand the effects of a scenario. A system dynamics model that could reflect scenarios could assist learning. Furthermore, the comparison of the scenarios and the model outputs could act as a method of co-validation.

Further work can also be done to explore using scenario planning to inform system dynamics’ sensitivity analysis. By using the distinctions between uncertainties and predeterminants, the sensitivity analysis could potentially be simplified and draw out the more important assumptions that need testing. This can have consequences on strategy and policy development (for more information see Appendix H).

This work also began to understand, explore and compare the theoretical grounding of the two approaches: their paradigms. Understanding their associated paradigms in more detail and
contrasting them would help uncover how compatible the two approaches are and potentially reveal new conceptual areas where the two approaches could be integrated. Furthermore, overtly linking developments in this area to application would help realise the potential benefits such work could produce.

Finally, further work can also be done in the area of applying the approaches through workshops. The training of participants in workshop based processes is one area that was highlighted in this work. Another area is in understanding how workshops can be prone to groupthink and how they might be able to overcome it.

This study has shown that system dynamics can be used to inform scenario planning, but further work is needed to establish the finer details of their integration and just how the differences of the two paradigms can be navigated to reap the benefits from greater integration. A better understanding of how the two approaches can inform each other will help outline when it is beneficial to employ an integrated approach or employ them individually. Furthermore, it will help design processes that use the approaches to inform each other more efficiently and improve their outcomes, helping to inform decision makers.

11.6 Preparing for change

Addressing decision problems is important for any organisation or government. These are issues that can create symptomatic problems and cause organisations to fail to recognise or misdiagnose threats and miss opportunities.
Perhaps what is most profound from this dissertation is the change in classification of scenario planning it encourages. As stated earlier as a concept that should not be lost, system dynamics is one technique among many that assists exploring and solving decision problems. What is suggested by this dissertation is that scenario planning, the form employed here, with the help of some systems tools, can also be considered one of these decision problem solving approaches. Like system dynamics it does not answer the problem, but structures it, frames it, and provides information so people can imagine, synthesise and develop ideas, and solutions to help construct strategies and policies.

This work focused on using scenario planning to inform and system dynamics and using system dynamics to inform scenario planning. This work demonstrated that using these two approaches together (integrating them) is feasible and has generated examples of the benefits of doing so. By integrating these approaches and improving them it is hoped that more robust means of understanding the present system and developing an understanding of how it could evolve can be developed. This understanding could assist governments to develop more informed policies and organisations to develop more informed strategies and to prepare for the future. With more robust approaches, organisations and governments can address decision problems and better position themselves in their ever turbulent environment, and be prepared for the future.
References


Barlas, Yaman (2007), Leverage points to march "upward from the aimless plateau", *System Dynamics Review*, Vol. 23, No. 4, pp. 469-473.


Braybrooke, David (1964), The Mystery of Executive Success Re-Examined, Administrative Science Quarterly, Vol. 8, No. 4, pp. 533-560


Christopher, Martin (2005), Logistics and Supply Chain Management (3rd ed.), Prentice Hall Inc.: Sydney, New South Wales, Australia.


Cosmides, Leda (1985), Deduction or Darwinian algorithms? An explanation of the "elusive" content effect on the Wason selection task, Doctoral dissertation, Department of Psychology, Harvard University.


Cumming, Graeme S.; Alcamo, Joseph; Sala, Osvaldo; Swart, Robert; Bennett, Elena M. & Zurek, Monika (2005), Are Existing Global Scenarios Consistent with Ecological Feedbacks?, *Ecosystems*, Vol. 8, No. 2, pp. 143-152.


Featherston, Charles & Doolan, Matthew (2011), L'Arche Scenario Analysis: The results of a scenario development project with L'Arche Genesaret ACT, a report commissioned by L'Arche Genesaret ACT.


Featherston, Charles & Doolan, Matthew (forthcoming), Integrating Scenario Planning and System Dynamics: A Study.


Hanson, Dallas; Dowling, Peter J.; Hitt, Michael A.; Ireland, R. Duane & Hoskisson, Robert E. (2008), Strategic Management: Competitiveness & Globalisation, Thomson Publishing: South Melbourne, Victoria, Australia.


Karau, Steven J. & Williams, Kipling D. (1993),


Combining scenario planning and system dynamics


Livesey, Thomas Finbarr; Frau, Ilaria; Oughton, Dominic & Featherston, Charles (2010), *Future Scenarios for the UK Food & Drink Industry*, A report to the Food and Drink Federation produced by the Institute for Manufacturing (IfM), University of Cambridge.


---

\(^{32}\) This was published after the date of submission, but was pertinent enough that it was included while making the final changes to the dissertation.


References


Combining scenario planning and system dynamics

Neilson, Robert E. & Wagner, Christopher J. (2000), Strategic Scenario Planning at CA International, Unknown, Iss. 12, January/February.

New South Wales (NSW) National Parks and Wildlife Service (1999), Fact Sheet: Fox Control in Wildlife Habitat, Conservation Management Note 4, Supplied by the Conservation Partners Program.


Newell, Barry; Proust, Katrina; Wiltshire, Gabrielle & Newell, David (2008), Taking a systems approach to estuary management, 17th New South Wales Coastal Conference: Wollongong, New South Wales, Australia.


Osgood, Nathaniel (2009), Lightening the performance burden of individual-based models through dimensional analysis and scale modeling, System Dynamics Review, Vol. 25, No. 2, pp. 101-134.


Porac, Joseph F. & Thomas, Howard (1990), Taxonomical mental models in competitor
Porter, Michael E. (1980), *Competitive Strategy: Techniques for Analysing Industries and
Porter, Michael E. (1987), Managing value-from competitive advantage to corporate strategy,
Postma, Theo J.B.M. & Liebl, Franz (2005), How to improve scenario analysis as a strategic
management tool?, *Technological Forecasting & Social Change*, Vol. 75, No. 2, pp. 161-
173.
Productivity Commission, Australia (2011a), *Disability Care and Support: Productivity
Commission Inquiry Report (Volume 1)*, Productivity Commission: Melbourne, Victoria,
Australia
Productivity Commission, Australia (2011b), *Disability Care and Support: Productivity
Commission Inquiry Report (Volume 2)*, Productivity Commission: Melbourne, Victoria,
Australia
Radzicki, Michael J. & Tauheed, Linwood (2007), In Defense of System Dynamics: A Response
to Professor Hayden, *Conference Proceedings of the 2007 International Conference of
the System Dynamics Society and 50th Anniversary Celebration*, July 29 - August 2, 2007:
Boston, Massachusetts, The United States of America.
Radzicki, Michael J. (2004), Expectation Formation and Parameter Estimation in Uncertain
Dynamical Systems: The System Dynamics Approach to Post Keynesian-Institutional
Economics, *The 22nd International Conference of the System Dynamics Society*, July 25-
Randall, Doug & Goldhammer, Jesse (2006), Four Futures for China Inc., *Business 3.0:
Randers, Jørgen (2012), 2052: *A Global Forecast for the Next Forty Years*, Chelsea Green
Raskin, Paul D. (2005), Global Scenarios: Background Review for the Millennium Ecosystem
Ratcliffe, John (2000), Scenario building: a suitable method for strategic property planning,


Combining scenario planning and system dynamics

Sawin, Beth; Hamilton, Hal; Jone, Andrew; Rice, Phil; Seville, Don; Sweitzer, Susan & Wright, Diana (2003), Commodity System Challenge: Moving Sustainability into the Mainstream of Natural Resource Economics, A Sustainability Institute Report: Hartland, Vermont, The United States of America.

Schermernhorn Jr, John R.; Campling, John; Poole, David; & Wiesner, Retha (2004), Management: An Asia-Pacific Perspective, John Wiley & Sons Inc.: Milton, Queensland, Australia.


Senge, Peter M. (1992), Mental Models, Planning Review, Vol. 20, No. 2, pp. 4-10 & 44.


References


van der Heijden, Kees A.J.M.; Bradfield, Ron; Burt, George; Cairns, George & Wright, George (2002), *The Sixth Sense: Accelerating Organizational Learning with Scenarios*, John Wiley & Sons, Ltd, Chichester, The United Kingdom.


Williams, Kent; Parer, Ian; Coman, Brian; Burley, John and Braysher, Mike (1995), Managing Vertebrate Pests: Rabbits, Australian Government Publishing Service: Canberra, Australia.


Wulf, Torsten; Meissner, Philip & Stubner, Stephan (2010), A Scenario-based Approach to Strategic Planning: Integrating Planning and Process Perspectives of Strategy, Working paper: Centre for Scenario Planning, Leipzig Graduate School of Management.


Glossary

Anticipatory memory

Anticipatory memory refers to thoughts and ideas that are generated through an activity of a change (Schwartz, 1991; 1996; Chermack, 2004). They are referred to as memories because they are accessed like memories, but have not occurred. They are referred to as anticipatory because they have not occurred but may be triggered to be recalled by signals that indicate the change might occur.

Approach

An approach is a class of prescriptive actions or activities that take a particular perspective to deal with a situation or address a decision problem.

Blind-spots

Blind spots are opportunities, threats, or elements of an organisation’s environment that are hidden from view by a lack of information, perception, or cognition (Chermack, 2004; Wulf et al., 2010).

Business environment (operational environment)

This is the regulatory, economic, political, social, competitive, and technological forces an organisation experiences and conditions in which it operates.
Business idea

The business idea is the activities an organisation does and the way that it executes them in a particular context and situation (van der Heijden, 1997; 2005).

Carrouselling

Carrouselling is an activity where workshop participants either in groups or individually move around a set of stations, often set up around posters, and address each station in turn. Usually there is a group at each station and all groups will move onto another station simultaneously.

Causal loop diagrams

A causal loop diagram is an influence diagram (see influence diagram) that applies a direction to the influence and focuses on feedback loops. Often give the direction of influence around a loop they will be labelled reinforcing – loops where an increase in one variable will follow the chain of causality and it will be influenced to increase further (zero or even number of negative influences in a loop) – or balancing – where an increase in one variable will follow the chain of causality around and force that variable to decrease (odd number of influences in a loop).

Complex decision problem

A complex decision problem is a difficult and complex problem that deals with open societal systems (Radford, 1977, p.xiii). They are often set in what are known as wicked environments (Hogarth, 2001) and are also called decision problems or wicked problems (Churchman, 1967).
Core members

Also known as core community members, L’Arche’s core members are the people whom L’Arche was created to care for. The unique philosophy at L’Arche means the core members are given a social network to enable them to be more independent, rather than have staff on which they rely for support.

Decision option

A decision option is one of a number of possible courses of action which the decision makers wish to assess in terms of their goals (see Montibeller & Belton, 2006, p.779).

Decision problem

See complex decision problem.

Detail complexity

Detail complexity is where a number of variables act to make it difficult to draw conclusions (Mintzberg & Quinn, 1996).

‘Disruptive events’

These are events that particularly disruptive to an organisation’s or government’s usual modus operandi (von Reibnitz, 1988).

Drift

Drift is when ‘realised strategies ... differ from intended [strategies]’ (Mintzberg, 1990b, p.186)
**Driver**

This is an event, trend, or characteristic that could or will influence behaviour in the future. The driver could be a trend or characteristic that is already happening or that may or will occur in the future.

**Dynamic complexity**

Dynamic complexity is where the cause and effect are separated by space, time or both, so the direct cause can be difficult to identify (Mintzberg & Quinn, 1996; Sterman, 2000).

**Endogenous**

Endogenous behaviour is behaviour that arises internally. Often used in the context of system dynamics it describes the behaviour that arises as a result of the system, its structure, hierarchy and interaction, rather than because of factors outside the system (exogenous).

**Endstate**

An endstate is the result or 'situation' of any variable, trend, or driver, particularly uncertainties, in a target year or the end of the period being investigated (for example, in 2025).

**Environment**

See Business environment.
Exogenous

Exogenous behaviour is behaviour that arises because of factors external to a system.

Flows

Flows, known in dynamical systems theory as state change variables, are the modelling elements that increase or decrease a key value in the model (stock).

Future memory

See anticipatory memory.

Future myopia

This is the phenomenon where recent and current issues dominate people's thinking when they think about the future (O'Brien, 2004). Schoemaker (1995, p.25) also referred to 'myopic statements' about how things might unfold in the future.

Group moderation

Group moderation is the use of a group to check and moderate the ideas of an individual or a smaller sub-set of that group.

Heuristics

Heuristics are a set of behaviours that people develop when doing an activity. They are shortcuts or a particular way of doing things that arise directly from their engagement in the task.
**Influence diagrams**

A causal loop diagram is a diagram of system elements that shows which of the elements in the system interact by way of placing an arrow between two points that influence each other, pointing in the direction of influence.

**Intervention**

An intervention is the name given for adopting and applying an approach whose goal is to supply information on a decision problem, addresses a decision problem, or both.

**'History-less' events**

These are events that have no precedent (Schnaars, 1987).

**Key uncertainties**

These are the drivers with the highest cross-product of impact and uncertainty. They are so called because they are relatively high in both impact and uncertainty. Often there are 12 of them, but this can vary based on the number of trends and drivers identified.

**Law of the instrument**

Expounded first by Kaplan (1964), Maslow’s (1966, p.15) puts the law as: ‘if the only tool you have is a hammer, [you tend] to treat everything as if it were a nail’.

**Leading indicators**

See signposts.
**Long term community members**

These are people who have been part of the L’Arche community for a long time. They are ex-L’Arche staff, founders of L’Arche ACT, or both.

**Measurable nouns**

These are noun phrases that stipulate what about the noun is to be measured. Sterman (2000, p.152) says that variables ‘should be nouns or noun phrases’. If they are measurable (quantifiable), however, they are more easily included in dynamic models, so these noun phrases should stipulate what of the noun in particular should be measured.

**Paradigm**

A paradigm is a set of concepts, beliefs, and language that are based on pre-established theories (Kuhn, 1996). Paradigms, different sets of concepts and theories, are based on a set of foundational experiments that defines a particular form of science. Paradigms define the approach taken, the perspectives used, and the method of conducting scientific experiments and ‘cause their practitioners to define different problems, follow difference procedures, and use different criteria to evaluate their results’ (Meadows, 1980, p.24). Scientific paradigms change when a critical mass of evidence that is outside of the current paradigms builds and triggers a scientific revolution (for more information see Kuhn, 1996).

**Parameter variation scenarios (system dynamics scenarios)**

Parameter variation scenarios that are generated in a system dynamics exercise by varying parameters within a model that give rise to different system behaviours. These refer
Combining scenario planning and system dynamics

specifically to those that do not use scenario planning to identify which parameters should be varied, why, and by how much.

Policy

A policy is a deliberate attempt to coordinate action or affect something to realise a desired behaviour or outcome.

The problem

This is the term used to describe the decision, issue, or concern for which the scenario planning process is being used to address.

Problem structuring methods

Problem structuring methods (PSMs) are a broad group of problem-handling approaches whose purpose is to assist in structuring problems rather than directly with solving them (Rosenhead, 1996, p. 117). Examples include GMA, QFD and SODA.

Process

Processes or procedures are the sets of activities used to apply an approach. Processes or procedures, in the case of this dissertation, are made up of activities that a person or people take to search for, extract, and collect information, motivate thinking and synthesis, and generate discussion.
**Remarkable people**

These are people with particular expertise, insight, or ability that have the potential to add value to the scenario planning approach by providing a unique insight into the topic of the scenarios (Schwartz, 1996; van der Heijden, 2005).

**Reperceiving (reperception)**

Reperception is reviewing and changing the way someone views the world, often leading to fresh insights about the causes and consequences of events (Wack, 1985b; Schwartz, 1996, p.36-7).

**Signposts**

Signposts are events or changes that indicate an environmental or organisational change might occur (Schwartz, 1991; 1996). Philips (1996) also developed this idea but from the perspective of future mapping and looking back to see what the significant milestones and turning points leading up to the desired future were.

**Slippage**

Slippage is a term used ‘to mean that strategic intentions get distorted on their way to implementation’ (Mintzberg, 1990b, p.186).

**Stocks**

Stocks, known in dynamical systems theory as state variables, are key values within a system. It is often a number that represents an amount of something real and has a unit attached to it.
Stock and flow diagrams

Stock and flow diagrams are centred on one or more stocks and identify the factors (variables) in the system that are influenced by the stocks and that influence the flows. When used in system dynamics these stock and flow diagrams tend focus on feedback through the stocks and its flows.

Strategic decision

A strategic decision is a decision that either aids in or makes apparent the selection of a strategy or strategies, their implementation or both.

Strategic conversation

The strategic conversation is a name for the ongoing formal and informal talks, meetings, strategy development initiatives, and thoughts and conceptions of plans that occur in an organisation or government about the way that organisation should operate or the policies the government should adopt (van der Heijden, 1997; 2005).

Strategic options development analysis

Strategic options development analysis is a process that uses interviewing and unstructured discussions to formulate mind maps and begin to structure a problem formally (for further information see Eden & Simpson, 1989).
Strategy

A strategy is an integrated and coordinated set of commitments and action designed to exploit core competencies and gain a competitive advantage (Hanson et al., 2008, p.4). Note that this definition is the same as the definition of a policy.

Suspending disbelief

This is where people suspend their disbelief in order to be able to imagine a future state (Schwartz, 1991; Schwartz, 1996; Frittaion et al., 2010; Frittaion et al., 2011). This is particularly important when people perceive the future as improbable or unlikely.

Think the unthinkable

This refers to the idea that scenario planning should help people think about things that they previously did not think or thought were impossible (Bloom & Menefee, 1994; Mietzner & Reger, 2005).

Traceability (also known as an audit trail)

The ability to follow where the information came from in a workshop process and why it was put there (Mercer, 1995).

Trend

A trend is a force that is occurring now and is likely to continue or change as time progresses.
Windtunnelling is the testing of strategies within some set conditions and opening them to checking and criticism by other people (van der Heijden, 1997; 2005).