FRAMING USER CONFIDENCE IN A
SYSTEM DYNAMICS MODEL:

THE CASE OF A WORKFORCE PLANNING
PROBLEM IN THE NEW ZEALAND ARMY

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ABSTRACT

Despite unresolved controversy and ongoing debate about user confidence in system dynamics models, there has been limited empirical exploration of the concept of user confidence in system dynamics models. This research elicited the concept of user confidence using a framing method (Russo & Schoemaker, 1989); analyzed the confidence criteria using constant comparative analysis (Cavana, Delahaye & Sekaran, 2001) and organized the confidence criteria into a descriptive framework. This research was conducted as an ethnographic case study of a New Zealand Army workforce planning problem.

The simultaneous objectives of this research were to elicit the concept of user confidence in a system dynamics model and to assess the usefulness of the framing method for ascertaining user confidence criteria.

The findings suggest that users of a system dynamics model had unique views of confidence, and while these views changed during the model-building project, they shared a common perspective of utility. Interestingly, user confidence criteria did not change significantly between the qualitative and quantitative stages of model-building. Output from the system dynamics workforce model supported the dynamic hypothesis that the use of ‘aspirational’ separation forecasts have contributed to New Zealand Army workforce shortfalls during times of high labour demand. Additionally, framing proved to be a useful methodology for eliciting and interpreting the elusive concept of user confidence in this case study.

This case study concludes that although the confidence criteria of model users are diverse, extensive and difficult to elicit; framing can be employed as an interpretive filter to ascertain the elements of user confidence.

Keywords:

framing, military, model validity, system dynamics, user confidence and workforce planning

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TABLE OF CONTENTS

	Page
ACKNOWLEDGEMENTS	iii
TABLE OF CONTENTS	iv
LIST OF FIGURES	vii
LIST OF TABLES	viii
LIST OF APPENDICES	ix
CHAPTER 1 : INTRODUCTION	1
1.1 Overview of Chapter 1	1
1.2 Background	1
1.3 Research Problem	3
1.4 Research Objective	4
1.5 Research Questions	4
1.6 Value of this Study	4
1.7 Terminology	5
1.8 Structure of this Dissertation	6
1.9 Summary of Thesis Introduction	7
CHAPTER 2 : LITERATURE REVIEW	8
2.1 Overview of Chapter 2	8
2.2 Analysis of Organisational Problems	9
2.2.1 Models of Organisational Problems	10
2.2.2 System Dynamics and Military Problems	13
2.2.3 Military Workforce Planning	14
2.2.4 Summary of Organisational Analysis	17
2.3 Confidence in System Dynamics Models	18
2.3.1 A Definition of User Confidence	19
2.3.2 Non-Positivist User Perspectives	21
2.3.3 A Continuum of User Perspectives	24
2.3.4 The Concept of User Confidence	27
2.3.5 Summary of System Dynamics Literature	32
2.4 Framing	32
2.4.1 The Framing Method	34
2.4.2 Empirical Studies in Framing	38
2.4.3 Summary of Framing Literature	38
2.5 Complementary Research Methods	39
2.6 Summary of Literature Reviewed	40

CHAPTER 3 : RESEARCH METHODOLOGY	41
3.1 Overview of Chapter 3	41
3.2 Research Framework	41
3.2.1 Research Objective	41
3.2.2 Research Questions	41
3.2.3 Paradigm of Enquiry	42
3.3 Research Design	43
3.3.1 Case Study	45
3.3.2 System Dynamics	46
3.3.3 Framing Interviews	48
3.3.4 Ethnography	49
3.3.5 Sample Selection	50
3.3.6 Content Analysis	51
3.4 Research Chronology	52
3.4.1 System Dynamics	52
3.4.2 Framing Interviews	54
3.4.3 Framing	55
3.4.4 Analysis	55
3.5 Summary of Research Methodology	58
CHAPTER 4 : CASE STUDY	60
4.1 Overview of Chapter 4	60
4.2 Problem Structuring	61
4.2.1 Background to the Problem	62
4.2.2 Project Definition	65
4.3 Qualitative Model	67
4.3.1 Reference Mode of the Problem	67
4.3.2 Causal Structure	69
4.3.3 Feedback Processes	70
4.4 Quantitative Model	74
4.4.1 Computational Model	76
4.4.2 Workforce Sector	77
4.4.3 Enlistment Planning Sector	82
4.4.4 Other Sectors	84
4.4.5 Model Testing	85
4.4.6 Simulation Results	86
4.4.7 Sensitivity Analysis and Policy Insights	88
4.5 Summary of Case Study	90

CHAPTER 5 : FINDINGS AND DISCUSSION	91
5.1 Overview of Chapter 5	91
5.2 Observations of User Confidence	91
5.2.1 Themes of User Confidence	91
5.2.2 Model User Views and Frames	93
5.2.3 Model User A	94
5.2.4 Model User B	96
5.2.5 Model User C	97
5.2.6 Model User D	99
5.2.7 Model User E	100
5.2.8 Model User F	102
5.2.9 Model User G	104
5.2.10 Comparative Analysis	105
5.2.11 Discussion of Findings	108
5.2.12 Summary of Interpreted Confidence Criteria	112
5.3 Methodological Findings	113
5.3.1 Benefits of Framing	114
5.3.2 Challenges of Framing	115
5.3.3 Boundaries	116
5.3.4 Framing Questions	117
5.3.5 Interviewing	118
5.3.6 Summary of Methodological Findings	119
5.4 Summary of Findings and Discussion	120
CHAPTER 6 : CONCLUSIONS	121
6.1 Overview of Chapter 6	121
6.2 Interpreted Confidence Criteria	121
6.3 Framing Method	124
6.4 System Dynamics	125
6.5 Army Workforce Planning	127
6.6 Research Contribution	127
6.7 Research Limitations	128
6.8 Recommendations	129
REFERENCES	164

LIST OF FIGURES

	Page
<i>Figure 2.2.1-1.</i> Sequence of research activities and dissertation structure.	6
<i>Figure 2.2.3-1.</i> A chronology of workforce planning.	14
<i>Figure 2.3.3-1.</i> Definitions of user confidence.	26
<i>Figure 2.4.1-1.</i> Russo & Schoemaker's 10 Framing Questions.	36
<i>Figure 3.2.3-1.</i> Relational map of research techniques for this study.	44
<i>Figure 3.4.2-1.</i> Sequence of model-building activities.	55
<i>Figure 4.2.1-1.</i> Comparison of recent actual and planned Army RF separation rates.	64
<i>Figure 4.2.2-1.</i> Stakeholder map of the principal model users for the WETA model.	65
<i>Figure 4.2.2-2.</i> Stakeholder map of the principal model users and their stakes.	66
<i>Figure 4.2.2-3.</i> Model and sector boundaries for the RF workforce planning problem.	67
<i>Figure 4.3.1-1.</i> Historic pattern of achievement of the RF workforce target.	68
<i>Figure 4.3.2-1.</i> Major feedback processes of the WETA model	70
<i>Figure 4.3.3-1.</i> Loop 1: Separation.	71
<i>Figure 4.3.3-2.</i> Loop B2: Target Achievement.	73
<i>Figure 4.3.3-3.</i> Loop B3: Training capacity.	74
<i>Figure 4.4.2-1.</i> Diagram view of the WETA model.	78
<i>Figure 4.4.2-2.</i> Seasonal RF separation indices calculated for calendar year 2003.	79
<i>Figure 4.4.2-3.</i> Actual RF separation rate and forecast rate for the period 1992-2006.	79
<i>Figure 4.4.2-4.</i> Average Army RF separation rate and annual trend lines: 1992-2006.	80
<i>Figure 4.4.3-1.</i> Elements of the recruit planning calculation.	82
<i>Figure 4.4.5-1.</i> 'Behaviour reproduction' results for the period July 2000 - July 2006.	86
<i>Figure 4.4.6-1.</i> 'Base case' simulation for the period 2000-2015.	87
<i>Figure 4.4.6-2.</i> Simulation results for a reduction in the desired separation rate	87
<i>Figure A4-1.</i> Diagram for the WETA Model	148

LIST OF TABLES

	Page
Table 2.3.3-1. <i>Theoretical perspectives for evaluation of system dynamics models.</i>	24
Table 2.3.4-1. <i>Forrester's (1973a) confidence criteria for clients and model-builders.</i>	28
Table 3.3.2-1. <i>Stages of the WETA model-building project.</i>	46
Table 3.3.4-1. <i>Participation levels for ethnographic research; highlighting actual levels in this study.</i>	50
Table 3.3.6-1. <i>Content analysis stages.</i>	52
Table 3.4.1-1. <i>Sequence of major model-building and research activities.</i>	53
Table 3.4.4-1. <i>Duration of interview recordings.</i>	56
Table 3.4.4-1. <i>NZ Defence Force and NZ Army workforce on 30 June 2006.</i>	61
Table 4.3.2-1. <i>Key variables for the WETA model.</i>	69
Table 4.4.1-1. <i>Summary of the WETA model input variables.</i>	76
Table 4.4.3-1. <i>Components of the enlistment planning calculation.</i>	83
Table 4.4.5-1. <i>'Confidence-building tests' used for the WETA model.</i>	85
Table 4.4.7-1. <i>Sensitivity analysis for the WETA model base case.</i>	88
Table 5.2.1-1. <i>Comparison of confidence themes with other system dynamics descriptive frameworks.</i>	92
Table 5.2.2-1. <i>Example layout of interpreted confidence criteria from framing interviews.</i>	94
Table 5.2.3-1. <i>Interpreted confidence criteria for model user A.</i>	95
Table 5.2.4-1. <i>Interpreted confidence criteria for model user B.</i>	96
Table 5.2.5-1. <i>Interpreted confidence criteria for model user C.</i>	98
Table 5.2.6-1. <i>Interpreted confidence criteria for model user D.</i>	99
Table 5.2.7-1. <i>Interpreted confidence criteria for model user E.</i>	101
Table 5.2.8-1. <i>Interpreted confidence criteria for model user F.</i>	102
Table 5.2.9-1. <i>Interpreted confidence criteria for model user G.</i>	104
Table 5.2.10-1. <i>The qualities of WETA model user interpreted views.</i>	106
Table 5.2.10-2. <i>The qualities of WETA model user interpreted frames.</i>	107
Table 5.3.6-1. <i>Descriptive framework of user confidence for the WETA model.</i>	122
Table A1.2-1. <i>Examples of model user terminology.</i>	137
Table A1-2. <i>Workforce planning terms.</i>	138
Table A4-1. <i>Equations for the WETA model.</i>	148
Table A5-1. <i>Descriptive Framework of User Confidence.</i>	161

LIST OF APPENDICES

	Page
Appendix 1: Glossary of terminology	132
Appendix 2: Research documentation	141
Appendix 3: Frame analysis worksheet	146
Appendix 4: Documentation for the WETA model	147
Appendix 5: Descriptive framework of user confidence	161

CHAPTER 1 : INTRODUCTION

'Only in the West does Science exist at a stage of development which we recognize today as valid.'

Weber, 1887, p. 13

1.1 Overview of Chapter 1

The purpose of this first chapter is to explain the research intention of this thesis within the context of the field of study and the case study organisation.

The structure of this chapter commences with the historical context and origins for this study in section 1.2. It then progresses into the research problem (section 1.3) and the research focus, including the research objective (section 1.4) and research questions (section 1.5). The remaining sections deal with the value of the study (section 1.6), terminology within the report (section 1.7) and structure for the remainder of the report (section 1.8). The chapter concludes with a summary (section 1.9).

1.2 Background

In the first 50 years of the field known as system dynamics, the validity and validation of models has been written about in considerable detail (see for example Forrester, 1961; Richardson & Pugh, 1981, Barlas, 1989; and Ford 1999) and much debate has ensued (such as Ansoff & Slevin, 1968; Forrester, 1968b; Nordhaus, 1973; Forrester & Senge, 1980; and Barlas 1996). Much of the literature about validity has focused on the theory, products and tools of system dynamics while apparently avoiding the social dimension of model-building (Robinson, 1980). Forrester (1973a) has proposed that the validity of system dynamics models is a 'public issue' (p. 1) and so the final judge of a model's validity must be the model user (Coyle & Exelby, 2000). However, the weight of thinking about system dynamics model-building appears to have swung towards the technical quality of models at the expense of their practical value.

While working as a manager within the defence sector for the last 15 years, the author was involved in the design and construction of several system dynamics models. This privileged experience as both an organisational insider and technical expert led to

questioning of the author's perception that Army managers were rarely satisfied with or interested in these models. This led to an interest in the perspectives of the model users concerning the validity of these system dynamics models and how their notions of judgement differed from those of model-builders. At about the same time, the author's peers in workforce planning and analysis within the New Zealand Defence Force began to enquire frequently whether system dynamics models might be a 'valid' tool for their purposes. This study has realized this topical opportunity to explore a subject of immediate interest to model users, as well as providing military workforce planners with a tool for helping them design their model-building projects.

Before proceeding, it is necessary to explain the use of the terms *validity* and *confidence*. It has become common for *validation* to mean *confidence-boosting* (Coyle, 1977) and *validity* has been used widely in the field of system dynamics, although it is not well defined (Barlas, 1996). Forrester (1961) first used the more holistic idea of *user confidence* and this has been carried through in key texts such as Forrester & Senge (1980) and Sterman (2000). Coyle & Exelby (2000) have favoured the term *validity* because it is more concise, although they have also acknowledged *validity* can falsely imply the absolute quality of truth; a view that '(too) many seem to hold' (Forrester & Senge, 1980, p. 211). (Further discussion of the terminology in this report can be found in section 2.3.1.) As demonstrated by Gass & Joel (1981), the term *confidence* was chosen for use throughout this report as a means of drawing attention to the model user's influence over the outcome of a model-building project, and therefore lessen the focus on the concept of *validity*. A more detailed explanation of these differences and implications can be found in section 2.3.1.

Interest in this topic grew first from an undergraduate model-building project for the Australian Army while studying at the Australian Defence Force Academy in Canberra from 1988 to 1992. There has been a belief that computer simulation models can be an aid when tackling organisational problems (Lane, 1998; Sterman, 2000; and Größler, 2004), and therefore they can ultimately lead to improvements in society (Forrester, 1973a). However, it seems unfortunately common that system dynamics model-building projects struggle to realize their intended benefits (Sterman, 1991). While various recent studies have reported the utility of system dynamics models for military workforce planning (such as Blake, Linard & Paterson, 1999; and Wang, 2005) reports of implemented system dynamics models are scarce and some authors have

even suggested that success in this field has been as much due to good timing as it has to user confidence (Bakken, Østbye & Røksund, 2005).

As a military planner, the author has also been involved in analysis and decision-making that would appear to be contrary to the tenets of systems thinking. Some examples include: dealing with the symptoms of a problem rather than its cause; a reluctance to look strategically at internal issues; blaming problems on unforeseeable external influences to the exclusion of the potential impact of internal policies; and holding to an implicit belief that the forces within an organisation are both stronger than the forces outside it and that those forces are in or near a state of equilibrium. Such behaviour is unfortunately common in management (Richmond, 1993). This thesis project attempts to make such ideas explicit in order to explore the way managers deal with the complex problems of organisations.

1.3 Research Problem

Numerous frameworks of model validity and user confidence have been developed for operations research and management science models (See for example Mitroff, 1969; Ansoff & Hayes, 1972; Shannon, 1975; and Gass & Joel, 1981). Although similar work has been reported in the field of system dynamics (see for example Lane, 1995; and Coyle, 1996, chapter 12); the work across both these fields has been primarily theoretical and described mainly in terms of the technical qualities of the model, that is 'validity'; rather than its social context, in the form of 'confidence' (refer to chapter 2). In the same way that system dynamics has been criticized for assuming that model-building has a pre-determined managerial purpose (Flood & Jackson, 1991), the field has also tended to assume the confidence of its model users and has not so far attempted to describe what confidence might be. This is the gap in knowledge the author chose to explore, which Coyle & Exelby (2000) also referred to when acknowledging the need for 'formal criteria for the establishment of confidence in, or the 'validation' of, system dynamics models.' (p. 27)

In their book *Decision Traps*, Russo & Schoemaker (1989) have explained how the framing method can be used by managers to avoid decision traps such as the repeated use of the same thinking frame to solve disparate problems. This research method has been applied, as explained in chapter 3, as a means of understanding user confidence in a system dynamics model. This approach interpreted the views of users as an

alternative to the traditional ‘paradigm of the empirical sciences’ common to model builders (Berends & Romme, 1999, p. 582). The framing method may therefore enable model-builders to avoid the trap of treating all problems and model users as if the confidence criteria are pre-determined by scientific means.

This enquiry into the concept of confidence was situated within an investigation of a contemporary workforce planning problem faced by the New Zealand Army. The problem and the associated system dynamics model, described in chapter 4, were structured as a macro model of the major components of the regular force population and included aspects of enlistment planning, recruit training and expenditure on salaries. The resulting system dynamics model, called ‘workforce enlistment target achievement’ or ‘WETA’, was employed with the purpose of understanding the effect of policy options.

1.4 Research Objective

The objective of this study was to elicit the principal model users’ concept of confidence for a system dynamics model using framing, by interpreting the elements of their view of the model as confidence criteria. The research was based around the case study of a contemporary workforce planning problem for the New Zealand Army.

1.5 Research Questions

Two research questions follow from the research objective:

1. What are the interpreted confidence criteria of system dynamics model users for an Army workforce planning problem?
2. How does framing assist the model-builder to elicit and interpret the concept of user confidence?

1.6 Value of this Study

This report may be regarded as targeted towards the ‘minority (of people) ... comfortable with the rigors of modeling’ (Lane, 1998, p. 944) and particularly those who practice systems enquiry. For this audience, it is anticipated the value of this report to include the application of the framework of user confidence to related projects and the use of framing as a confidence defining technique. Further value

might arise from subsequent research linking user confidence criteria to specific confidence building tests and the decision that often confronts model-builders about whether or not to build a quantitative system dynamics model. This primary audience would also appreciate that by conducting parallel studies of the model users and the organisational problem, this research is a rare example of simultaneous research methods in the fields of framing and system dynamics.

The secondary audience for this report is the New Zealand Army. By seeking to recognise leverage points in the Army workforce planning system, the aim of this project is to cause enduring improvement to the achievement of Army workforce planning targets. However, it is recognised that the potential policy levers identified in this study will require further analysis before any significant benefits can be realized. In addition, the descriptive framework of user confidence can be used the Army for the design of any immediate or future system dynamics model-building projects. Not surprisingly, both these potential benefits satisfy the criteria of utility against which system dynamics models tend to be judged, as reflected in the literature (chapter 2) and the findings of this study (chapter 5).

1.7 Terminology

The term *model* has been used throughout this report to refer to the constructed objects of model-building. In system dynamics, it has been typically ambiguous whether *model* refers to a specific object or the aggregate of numerous objects; such as a sector diagram, a systems/sub-system diagram, a rich picture, a causal loop diagram, an influence diagram, or a quantified computer simulation model. The latter approach has been adopted in this report to reinforce the idea of confidence as the sum of perceptions about a number of model-building tools.

The term *model user* in this report means a person involved in the development or application of the model, while *principal model user* means a stakeholder with ‘a vested interest in the problem situation and its solution’ (Landry, Malouin & Oral, 1983, p. 216). The project role of *model-builder* has also been differentiated in this report, as the convention for the individual constructing the model.

The related terms *operations research* (‘OR’) and *management science* (‘MS’) have been used throughout the text of this report as their usage has become so common that ‘today few people try to differentiate between OR and MS’ (De Greene, 1982, p. 61).

The term *workforce planning* is used to mean the strategic analysis of the structure and behaviour of a defined group of employees for corporate planning purposes. The report also refers to the system dynamics model built for this case study as *WETA*, being the acronym for ‘workforce enlistment target achievement’.

As explained briefly in section 1.2, and again in more detail in section 2.3.1, the report uses the term *user confidence* throughout this report. Where the terms *valid*, validity or validation appear it is mostly to reflect the usage in a literary or empirical source. The terminology and abbreviations used in this report are described in appendix 1.

1.8 Structure of this Dissertation

Figure 2.2.1-1. Sequence of research activities and dissertation structure.

This dissertation is organized into four main chapters; which when added to the obligatory introductory and summative chapters brings the total number of chapters to six. Included at the rear of this report are five appendices, consisting of a glossary, key documents, framing interview worksheet, documentation for the system dynamics model, descriptive framework of user confidence and finally a list of references. The essential parts of this introductory chapter are the key elements of the research

framework and the perceived value of this study, to which have been added an explanation of key terminology and this current section to explain the structure. The concluding chapter summarises the key findings and implications for system dynamics military workforce model-building, followed by the contribution and limitations of this study. The flow of research activities and their place in this dissertation document are shown in *Figure 2.2.1-1* above. (Refer to the glossary in appendix 1 for the definition of specialist terms).

Chapter 2 of this dissertation contains a review of the literature for organisational problem-solving, system dynamics and framing. In this part of the report, the purpose is to identify perceived gaps in knowledge within these fields. Chapter 3 is written as an explanation of the research methodology for this study, including the research framework, research methods and an account of actual research events. The case study in which this research is based, is described in chapter 4 according to the four stages of development in the model-building project. The findings of this dissertation are contained in chapter 5; including summaries of the views and frames of model users, discussion of user confidence themes and an assessment of framing for this application. Chapter 6 concludes this dissertation by addressing implications of this research, the contributions to existing knowledge, caveats for these findings and recommendations for further work.

1.9 Summary of Thesis Introduction

This chapter highlights the key issues behind this study, while also broadly explaining how the research problem, research case and model-building approach fit within this context. It explains how the author came to undertake this research and the purpose of enquiry. This chapter also summarises the research problem and research questions. Finally, this chapter explains the potential value of this thesis project, the terminology used and the structure of this dissertation.

CHAPTER 2 : LITERATURE REVIEW

'There is no absolute proof but only a degree of hope and confidence that a particular measure [of validity] is pertinent in linking together the model, the real system, and the purpose ... when agreement [between the model, system and purpose] is reached, we must remember that it is agreement, not proof.'

Forrester, 1968a, pp. 614-615

2.1 Overview of Chapter 2

The purpose of this chapter is to summarise the literature reviewed for this dissertation and highlight the gaps in knowledge. It first shows that models have often been used to understand organisational problems, as a lead-in to the system dynamics model of an Army workforce planning problem that are presented in chapter 4. The report then explores the debate about confidence in system dynamics models and sort the existing concepts of confidence in a way that complements the empirically based descriptive framework presented in chapter 5. This rounded out this chapter with an introduction to framing in management applications and a brief explanation of multi-methods, as preparation for the chapter on research methodology that immediately follows this one. The remainder of this chapter overview introduces the parts of this chapter in more detail.

Section 2.2 explores the way systems models, including computer simulation models, have been used in the field of operations research and management science to approach organisational problems. Such problems are considered to be 'wicked' and 'messy' (Sterman, 2000) because they consist of social phenomena and the computer models of these problems are developed and used within the social context of the decision-makers of those organisations. The system dynamics method of analysis was developed specifically with a view to improving the management of organisational systems (Forrester, 1965), of which military workforce planning is a refined application. A brief outline of military workforce planning is also contained in section 2.2, highlighting the relatively early stage of development of this field. Computer model-building in defence organisations has recently moved towards explanatory, non-equilibrium representations of their systemic nature, particularly as computing technology has enabled more complex analysis. The knowledge gap concerns the confidence criteria of model users.

Section 2.3 is a review of system dynamics literature, first highlighting the vision of system dynamics to improve management efficacy. Four confidence perspectives and a range of confidence issues are defined from the broad debate about user confidence. System dynamics confidence building tests are also reviewed. The gap in system dynamics knowledge pertinent to this study, like that in military workforce planning, is the judgemental views of model users towards the model.

Section 2.4 concerns framing. The three main elements in this section are a discussion of the definition of framing, an introduction to the framing questions developed by Russo & Schoemaker (1989) and a summary of empirical research using framing. The knowledge gap identified in this field is the utility of framing as a method for obtaining evaluation criteria in operations research and management science.

2.2 Analysis of Organisational Problems

Organisations are social entities and the problems that arise from their social processes are ‘wicked’ (Rittel, 1972; and Mason & Mitroff, 1981) and ‘messy’ (Eden, Jones & Sims, 1983). The socially based problems of organisations are also transient, unstructured, difficult to recognise or define, subjective and dependent on individual interpretation (Checkland, 1981). A major consequence of the ambiguity and ill-defined nature of organisational problems is the potential for different views of the same problematic situation. Whereas with ‘puzzles’ and ‘problems’ it is clear what needs to be done, messes are characterized by ‘situations in which there is considerable disagreement about what needs to be done and why’ (Pidd, 2004, p. 7).

It is into this arena of complex and challenging intellectual work that operations researchers and management scientists have ventured with a range of tools and techniques. The origins of this class of research method lies in operations research, but these two fields are now indistinguishable and are commonly referred to with the joint label ‘OR/MS’ (De Greene, 1982). The tools of operations research and management science are the mathematical and conceptual models that are created as representations of the problems they attempt to address, and it is those tools, which are the subject of this research. The following section identifies the main challenges for the builders of operations research and management science models of organisational problems and explains some ways in which system dynamics models reduce these challenges.

2.2.1 Models of Organisational Problems

The most basic function of an operations research and management science model is to answer a defined question; however, it has been found that the wicked and messy properties of organisational problems do not lend themselves kindly to the application of science, and particularly to the rigour of mathematics. Pidd (2004) has argued that computer models are a ‘tool for thinking’, however the rationalist approach common to operations research and management science has not proved to be effective for the wicked problems of organisations (Simon, 1990). Instead, Pidd (2004) has proposed an alternative approach of ‘procedural rationality’ that means negotiating feasible solutions in an environment of disagreement about what should be done and the gradual accumulation of limited knowledge. The system dynamics method is such an approach. When a research method such as system dynamics is used, the model user is the sole judge of the model’s credibility (Balci, 1987) and their judgment can determine whether insights from the model will be translated into action towards the problem (Pidd, 2004).

While models are intended to answer certain questions, they can also lead to further questions, and so Checkland (1981) has regarded the solution of complex social problems as a ‘structured debate’ (p. 150). Models are best treated as a convention and means of communication rather than an approximation of reality (Espejo & Harnden, 1989). It has been further argued by Bryant (1993) that the aim of models is less to generate a solution than to improve the ‘quality of discourse’ about the problem. Sterman (1991) has argued for system dynamics models to be used as a platform for debate as this can promote learning, insight and discernment.

From the related field of public policy model-building, Greenberger, Crenson & Crissey (1976) have pointed out that the potential uses of models go far beyond the simple scientific function of providing an answer to a question. They describe other uses as ‘developing a political warrant for authoritative decision-making: converting perceived problems into political issues, assembling support for proposed actions, resolving conflicts, legitimating decisions, and securing compliance’ (p. 26). They have also explained that models can be used to focus attention, delay action by slowing down the process of decision-making, or enhancing the credibility of an issue with the ‘dignity of science’ inherent in a model (p. 46). These potential uses can arise in

organisational models due to the political forces present in the social context of organisations.

Simulation is a particular model-building technique of operations research and management science that has proven popular for organisational problems (De Greene, 1982). In its simplest terms, a simulation is 'a virtual model of a process' and a model is 'an approximation of reality that emphasizes some features at the expense of others' (Schrage, 2000, p. 7). Naylor (1972) has described simulation model-building 'as a numerical technique for conducting experiments with certain types of mathematical models which describe the behavior of a complex system on a digital computer over extended periods of time' (p. 205).

Despite the potential benefits of computer models outlined above, the use of computer models has disappointed the expectations of scientists and users (Greenberger et al., 1976). Despite more than 50 years of operations research and management science development and use, it is a 'fact' that many users 'mistrust the analyses based on measurement and mathematical model-building, and prefer to rely on intuition' (Tait, 1988, p. 669). Sterman (1991) has claimed that the effective use of models is not a matter of course and the theoretical benefits of computer models are often not realised due to practical shortcomings.

From an analysis of about 800 management science papers from the ABI/INFORM computerised abstract database between 1980 and 1990, Clark (1992) found that simulation models were the third most cited analytical method for corporate strategic planning (90 papers), a long way well behind forecasting (320) and decision support systems (119). Clark discovered that only one instance of simulation models was reported for the defence sector, while the most common functional areas for simulation were administration and planning (27), followed by human resource planning (16) and finance (11). Clark's research reveals that managers have preferred a predict-and-prepare approach to strategic problems but they have made little use of these tools for military workforce planning problems.

In an empirical survey of members of the Operations Research Society resident in the United Kingdom, Clark & Scott (1995) found that simulation model-building was the second most commonly reported strategic-level operations research and management science tool, after spreadsheets. They also found that simulation models

were most frequently used for the strategic evaluation of alternative strategies (76% of respondents) for production and operations (78%). The reported application to human resource problems was less frequent (48%).

Berends & Romme (1999) conducted a literature review of the '10 major journals' from the field of operations research and management science between 1986 and 1998 and found that few journals published papers concerning simulation research, and the general trend had not changed during this period. They identified that three forces were preventing progress in fields like system dynamics: 'the emphasis on academic specialisation, the complicated rather than complex systems viewpoint and the paradigm of the empirical sciences' (p. 582).

A difficult practical issue for model-builders is the justification of a particular model-building method for a certain application. The broad scope of choice in model-building methods is apparent in the review by Meadows & Robinson (1985) of nine different 'world models'. The choice of the means of solution and action can be one of the analyst's biggest difficulties (Davies & Mabin, 2001a). Some authors encourage a pragmatic approach to this, advising the selection of the most suitable method from those available, taking into account model-builder availability, computing capability and the available data (Laublé, 2005).

A major factor in selecting a model-building method is the nature of the problematic situation. Hard operations research approaches have been taught and used as if all problems are easy to define, which they often are not (Davies & Mabin, 2001a). The system dynamics approach assumes that real world problems can be agreeably resolved into distinct, causally linked entities (Flood & Jackson, 1991) and yet wicked problems cannot be 'exhaustively formulated' (McLucas, 2003a). Carrier & Wallace (1994) have also suggested that inappropriate solutions can arise from the use of model-building methods that do not suit the decision-maker's root metaphor. The challenge of matching a problem-solving method to a problem is exacerbated by the lack of ways to categorize problems, the sensitivity of each method to the model-builder's skill and the natural bias of model-builders towards their own methods (Laublé, 2005). Taken together, this means it is difficult to judge the suitability of a model-building method and consequence is that pragmatism plays a significant part in the selection of a model-building method.

Barlas & Carpenter (1990) have differentiated between computer models as either empirical or holistic, the latter being more suitable for social or complex organisational problems because of their descriptive and explanatory power. Sterman (1991) has presented the choice as optimization or simulation, concluding that the former is unsuitable for complex problems especially those involving human behaviour. In this way, system dynamics authors have generally agreed that system dynamics is a suitable method for models of social systems (see for example, Forrester, 1975; and Sterman, 2000). This report uses the term 'social system' to mean organisations of people where the defining characteristic is that choice and free will is a characteristic of both the individual and the organisation as a whole (Ackoff, 2001).

2.2.2 System Dynamics and Military Problems

Coyle, Exelby & Holt (1999) have described defence problem-solving using system dynamics as having a 'strong track record of successful applications, where success is judged by the enthusiasm of clients for the practical results of studies' (p. 381). In addition to the numerous published system dynamics studies of military problems, there have also been 'an endless list of applications to classified problems.' (Coyle & Powell, 2005, p. 790) These models have been concentrated within the North Atlantic Treaty Organization (NATO), the US Department of Defense and defence organisations in Norway and Australia (McLucas, 2000). The type of problems suited to system dynamics are mainly operational (Coyle & Powell, 2005) as a means of providing preliminary insights prior to detailed analysis (Wolstenholme, 1998). Recent examples include command and control systems (such as Coyle, 1987; and Bakken & Giljam, 2003); conflict scenarios (Moffat, 1996); national security scenarios (Burke & Hummel, 2005; and Weaver, 2005) and submarine operations (Coyle & Gardiner, 1991). McLucas (2002) has identified several reasons why system dynamics has not been more successful in this area, including: the scarcity of aggregated data, a user expectation of a high level of analytical detail, the reluctance of military decision-makers to accept the use of estimated parameters in lieu of data, and a tendency for military users to interpret results as predictive.

Two system dynamics models of the Norwegian Defence Force personnel system have examined the consequences of feedback loops linked to budget compliance constraints that result in unexpected and sub-optimal outcomes. Bakken's (2000) first

model of the whole organisation was followed by the work of Bakken et al. (2005) to investigate changing recruitment and career management policy. In the second application, the authors explained that ‘the model-supported intervention significantly reduced the probable risk of failure in policy design and implementation’. The reasons they give for the success of this ‘model intervention’ were that a detailed model was included which ‘crucially enhanced the analysis’ face validity’ and that ‘the results fell within the comfort zone of most key stakeholders’ but yet ‘challenged intuitions enough so that the model was considered invaluable’.

2.2.3 Military Workforce Planning

Figure 2.2.3-1. A chronology of workforce planning.

Adapted from Bramham (1995)

The field of workforce planning has emerged recently from a number of similar disciplines, as illustrated in Figure 2.2.3-1 above. The forerunner of this field, called *personnel planning* took shape in the 1950s, following after ‘the Military who first developed a systematic and strategically-oriented way of analysing future Manpower needs’ (Achi & Mott, 1982). *Manpower planning* arrived in the 1970s, introducing a more disciplined and precise approach to the management of staff numbers (Bramham, 1995). This is reflected in UK titles such as *A Guide to Manpower Planning* (Bowey,

1974), *Practical Manpower Planning* (Bramham, 1978) and *The Manpower Management Handbook* (Bennison & Casson, 1984). Bowey (1974) defines *manpower planning* as ‘the activity of management which is aimed at coordinating the requirements for, and the availability of, different types of employee’ (p. 1), which implicitly overlooks soft variables and qualitative factors of employee management. The terms *manpower planning* and *personnel planning* have remained in use in the UK (see for example Bakken et al., 2005).

The reborn field of *human resource planning* came about in the 1980s, although it took a decade of use to be accepted by authors such as Bramham as the ‘new label’ for personnel planning (Bramham, 1995). With this acceptance came acknowledgement of the human aspect of managing personnel, and attention to qualitative management issues such as work motivation, job satisfaction and employee commitment. Nevertheless, Bramham (1995) has expressed doubt as to whether the label of human resource management implies a shift towards valuing the employee or simply a change in label. The use of the term *workforce planning* is now in common usage for large public sector organisations in the USA, including US, Australian and New Zealand (NZ) military organisations (see for example IPMA, 2002; and Emmerichs, Marcum & Robbert, 2004; Blake et al., 1999; and the NZ Ministry of Defence, 2004). *Workforce planning* has been defined as ‘a systematic process for identifying the human capital required to meet organisational goals and for developing the strategies to meet these requirements’ (National Academy of Public Administration, 2000, p. 1).

Bennison & Casson (1984) have provided a range of insights into the mechanisms and policies for managing the workforce in large organisations, although like most texts in this field their prescriptions and advice are based primarily on experience rather than published research. They have recommended a pragmatic replacement policy for the reason that historical flows may not be a reliable indicator of future policy and they have also noted the preference of ‘established large organisations’ for initial recruitment policies. Early workforce planning approaches grew from the use of actuarial life tables, which treat populations as stable and flows as an average based on historical rates (Vajda, 1970). These origins account for the treatment in early models of the workforce as an inventory of goods, structured as systems of stocks and flows (Bramham, 1974). This focus has remained to the present day (see for example Emmerichs, Marcum & Robbert, 2004). The most common type

of workforce model is aggregate, deterministic and simulatory (Bennison & Casson, 1984).

Initial interest in manpower planning resulted from computerization (Bramham, 1974). However, a lack of success initially turned managers against the use of computers (Bennison & Casson, 1984). Military workforce planners have been presenting their models and methods since the early 1970s, (for example; Smith, 1971). The increased availability of computing power, the computerization of personnel management records and the increasing complexity of the workforce has since improved the appeal of computer based workforce planning. Despite the field of workforce planning entering its fifth decade, it is still not practiced universally by large organisations. Despite significant public sector downsizing in the USA in the 1990s, many large public sector organisations there have not developed a workforce planning capability (IPMA, 2002, p. 1).

Ashton & Ashton (1988) surveyed the use of management science models for workforce planning in 101 US and Canadian industrial firms, where they found very little use compared with the 50% of companies using management science models in other functional areas of business areas. The reason for this lack of use appeared to be perceived complexity and cost-effectiveness. Encouragingly, they reported the least common factor was any behavioural resistance of management.

Gass has summarised the basic concepts of 'analysing extended planning horizon military manpower problems' (1991, p. 65), identifying Markov rate models as suitable for forecasting the movement of the workforce through a hierarchical structure of graded positions. Parker & Caine have demonstrated the relative advantages of system dynamics models over Markov models because the former 'proves easier to build and provides a richer picture for the decision maker' (1996, p. 44). In an unpublished inter-departmental paper, Wang (2005) has identified the suitability of system dynamics models for studying problems where feedback and non-linear behaviour are influential elements of the system, and he has reiterated Coyle's (1996) advice that system dynamics is better suited to strategic problems at a policy level.

Only in the last decade have system dynamics model-builders begun to report their models of workforce planning problems. Although some early system dynamics models of military workforce systems were developed at the Massachusetts Institute of

Technology ('MIT') (see Andersen & Emmerichs, 1975), this work has not been published. Blake et al. (1999) have presented their model of the optimum workforce structure for the Australian Army to address the problem of unstable 'boom-bust' recruitment cycles and more recently, Cavana (2004) has described the dynamics at work for the retention technicians in the New Zealand Army.

Some system dynamics model-builders have included workforce sectors in their models of non-military organisational problems, such as knowledge management (MacDonald, Potter & Jensen, 2003). Most recently, Bakken et al. (2005) tested a transformational personnel policy for the Norwegian Armed Forces using a system dynamics model. In the non-military context, Holström & Elf (2005) modeled the problem of staff retention and job satisfaction in a healthcare workforce. The common characteristic of system dynamics workforce planning models, including those cited above, is a hierarchical structure of stocks and flows.

2.2.4 Summary of Organisational Analysis

In summary, it is necessary for client and model-builder to choose which problems to model and which methods to use for each problem. Model-builders can expect organisational problems to be wicked and messy. Simulation models have emerged as a common management science and operations research method for solving organisational problems; however, their application to the field of strategic human resource management has been limited. This research attempts to redress the apparent bias of system dynamics research towards 'academic specialisation' and the 'paradigm of the empirical sciences' (Berends & Romme, 1999) by lending legitimacy to the model user's view.

A common use for models is to inform structured debate (Sterman, 1991). There are a number of possible model-building approaches for any situation but some models are more suitable than others and selecting a suitable method is an imprecise process. The choice of a method inevitably involves a degree of pragmatism (Laublé, 2005). The use of models for debate and their pragmatic need reinforces the need to define and explore the concept of user confidence. System dynamics has been proposed as a suitable model-building method for the problems of social systems (Forrester, 1973a), although little has been reported about their application to workforce planning

problems. The next section of this chapter takes a more in-depth look at this field of application.

While the use of operations research and management science models in this field dates back to the 1970s, these models appear to have been less prevalent in workforce planning than other areas of organisational analysis. System dynamics models have been used to simulate the hierarchical structure of labour pools, however reports of the application of this method to military workforce analysis have been so far limited to Norway and Australia. Overall, the success of system dynamics models in the sphere of military workforce problem-solving has been equivocal.

The subsequent section provides a summary of the debates about system dynamics confidence and model testing.

2.3 Confidence in System Dynamics Models

This section explores current theoretical and empirical knowledge about user confidence in system dynamics models and highlights the need for an empirically based framework of user confidence; which integrates a broad range of perspectives and criteria. A short summary of system dynamics models of defence problems has also been included. There is no better place to begin this section than the actual state of confidence amongst system dynamics model users.

System dynamics has attracted a noticeable degree of adverse public and academic attention over its 50 year history (see for example Wagner, 1963; Ansoff & Slevin, 1968; Nordhaus, 1973; Sahin, 1980 and Flood & Jackson, 1991), with one author suggesting that Jay Forrester, the founder of system dynamics has been controversial in defining the scope and purpose of system dynamics (Greenberger et al., 1976). This controversy is no more evident than in the broad range of irresolvable disputes that have been raised about Forrester's flagship system dynamics *World Model* (Myrtveit, 2005). These controversies overshadow all system dynamics models, and have been the source of much recent discussion within the system dynamics field. This debate is not limited to system dynamics models, as a similar controversy has arisen concerning all management science models (Barlas & Carpenter, 1990). To illustrate the wider challenge for operations research and management science models using the words of Déry, Landry & Banville (1993): 'there is no agreement ... on what is a valid model or on what is *the* way to validate models' (pp. 168-169, italics in original).

Alternatively, as Coyle & Exelby (2000) have stated in a milder fashion, the treatment of system dynamics user confidence in literature has been ‘by no means consistent’ (p. 35). To place this debate about confidence in system dynamics models it is helpful to understand the extent of system dynamics’ practical impact.

Forrester (1973a) himself has admitted that, ‘in spite of the vast time and effort expended on formal models in the social sciences, formal model-building for social phenomenon has had negligible impact on practical policy design’ (p. 3). Although there are fundamental differences between model-building methods, the confidence in computer model-building method in general has suffered due to the widespread failure of econometric models to predict accurately (Sterman, 1991). Critics have explicitly asserted that system dynamics method is inaccessible (Ansoff & Slevin, 1968) and that the data required for models is scarce (Mohapatra, Mandal & Bora, 1994). System dynamics model validation techniques have also been criticized for being unscientific and subjective (Wagner, 1963; Ansoff & Slevin, 1968; and Legasto & Maciariello, 1980). The equivocal success of system dynamics models in some fields points towards a weakness in the understanding of user confidence issues.

2.3.1 A Definition of User Confidence

Section 1.2 briefly explained that the use of *confidence* and *validity* terminology in system dynamics has been inconsistent (Barlas, 1996) and therefore potentially confusing however, the descriptive aim of this study requires precise meanings. Following the example of Gass & Joel (1981), this report uses the term *confidence* as the ultimate judgement of a model’s creation, subordinating the concepts of *validity*, *validation* and *verification*. The choice of *confidence* attributes evaluation of the model to its user, and therefore diminishes the notion that a model has objective qualities that are independent of its users. An extensive account of user confidence statements by management science authors is included in sub-section 2.3.3. The following section explains the reasoning for the choice and provides precision definitions of the terms for this study.

The most common of the evaluative terms used in the literature is *validation*. The report has adopted Forrester & Senge’s (1980) definition of *validation*, as the ‘process of establishing confidence in soundness and usefulness of a model.’ (p. 210) Validation of system dynamics model is conducted informally and qualitatively (Meadows, 1980) and

has come to mean ‘confidence-boosting’ (Coyle, 1996). *Validation* is an error-seeking exercise, designed ‘more at invalidating than validating the model’ (Greenberger et al., 1975, p. 71) whereas *confidence* is the situation that results from this process. A related term is *verification*, which McLucas has defined as ‘the process of determining whether or not the products of a given phase of the system dynamics development cycle fulfil the requirements established during the previous phase.’ (2002, p. 151) Therefore, while *validation* concerns the overall process and assessment of the model from an external perspective, *verification* refers to the linkages between elements of the process and their internal consistency. Therefore, *validation* and *verification* are the elements of the process used to generate *validity*.

Although the term *validity* has not been well defined (Barlas, 1996), it has gained common usage in system dynamics. For instance, Coyle & Exelby (2000) have favoured the use of *validity* because it is more concise than other terms, while they have also acknowledged that *validity* can falsely imply absolute truth. The report has adopted the definition of *validity* used by the system dynamics group at MIT; which states ‘(*validity* is the) judgment of a model’s suitability for a particular purpose. A model is valid when it accomplishes what is expected of it.’ (Zhu et al. 1995) The elements of this definition are that: *valid* models are purposive; *validity* is a judgment of the suitability of the model; the judgment of *validity* is subjective and relative to the model user’s expectations; and *validity* is utilitarian, because it alludes to an outcome or intervention from the model-building project. So what then does *confidence* mean?

The term *confidence* has not been defined in system dynamics literature, suggesting that its meaning is common or assumed. Forrester (1961) has stated that *confidence* is an ‘interim’ measure of the success of a model, pending judgement of the model-based intervention, while Vennix has explained that *confidence* is necessary because validity can ‘never be established’ (1996, p. 89). *Confidence* has also been described as ‘central’ to *validity* (Wolstenholme, 1990); a recognition of the trade-off between satisfaction and effort (Forrester, 1994); something which accumulates gradually (Maani & Cavana, 2000); the threshold for a consultant to use the model to provide practical advice to a fee-paying client (Coyle & Exelby, 2000); and the end or outcome of model-building (Forrester, 1961, chapter 13; Forrester & Senge, 1980; and Sterman, 2000). Given this broad range of usage, the common meaning of *confidence* was chosen for this study; as ‘firm trust; a feeling of reliance or certainty; a sense of self-reliance, boldness.’ (Concise

Oxford Dictionary, 1990, p. 239) In this sense of the word, judgement is a feeling about the quality of an object, rather than a measure of that quality.

To summarise, the following reasons support the use of the term *confidence* in this study, with its common meaning; rather than *validity*, *validation* or *verification*:

- *Confidence* is subjective and relative to the user (Zhu et al., 1995); rather than an absolute meaning suggested by the term *validity* (Forrester & Senge, 1980).
- *Confidence* reflects the perspective that users experience model-building as a social process (Robinson, 1980; and Checkland, 1981).
- *Validity*, although it is a commonly used term in system dynamics, is poorly defined (Barlas, 1996) and therefore ambiguous and potentially confusing.
- *Validation* is a social process (Barlas & Carpenter, 1990) and an impossible outcome in any absolute sense (Stermann, 2000); and thus it has taken on a practical meaning as a process for gaining relative improvements in *confidence* (Forrester & Senge, 1980; and Coyle, 1996).

2.3.2 Non-Positivist User Perspectives

A potential weakness of system dynamics model-building, already discussed in section 2.2.1 is the prevalence of a positivist paradigm. The persistence of this paradigm appears to run contrary to the utilitarian perspective, which has been a defining theme throughout the history of system dynamics. Forrester commenced the first recorded exposition of system dynamics validity with the issue of utility when he stated, ‘the significance of a model depends on how well it serves its purpose’ (1961, p. 115). Various authors have reinforced the importance of a specific purpose (Stermann, 1991; Vennix, 1996; and Coyle, 1996), and not just any generic purpose (Roberts, 1978a). This need for purpose has also been stated explicitly in various definitions of system dynamics user confidence (for example Forrester, 1961; Coyle, 1977; Richardson & Pugh, 1981; Zhu et al., 1995; and Stermann, 2000). To reinforce the importance of purpose, Forrester & Senge (1980) have formally defined a ‘boundary-adequacy test’, which confirms the included variables are adequate for the model’s purpose. Usefulness has also been identified as a central aspect of confidence in operations research and management science models (Legasto & Maciarello, 1980). ‘Operational utility’ has been identified as the ultimate measure of confidence in a

system dynamics model (Forrester, 1975, p. 29) which bears out the prevalence of purpose and usefulness as confidence criteria for system dynamics models.

Nevertheless, some authors have also expressed caution about the role of purpose in model-building. For instance, Ansoff & Hayes (1972) have suggested that a view of confidence based on the purpose of a model is subjective and equivocal because clients and model-builders assess model-building from different perspectives with uneven emphasis on model-building purpose. This issue has been indirectly addressed within system dynamics method by the practice of group model-building, which seeks to align the subjective mental models of stakeholders (Vennix, 1996). However, at the method level, Flood & Jackson have asserted that the assumption of a unitary purpose for a model is a theoretical flaw of system dynamics because the unchallenged purpose of system dynamics ‘ultimately relates back to the particular prejudices of the modeller’ (1991, p. 80). They have portrayed system dynamics models as a disguised representation of the world that is not fully explained to the client and, most importantly in their view, is not open to a process of social negotiation. In summary, it is clear that a utilitarian perspective has been a key element of confidence in system dynamics models, with the exception of a few authors who have questioned the appropriateness of system dynamics.

In addition to user confidence being ascribed utilitarian meaning, Randers has suggested the utility of a model comes down to the relative importance ascribed to it by the model user (Randers, 1980). A common caveat of management science models has been that objective, scientific and definitive criteria for user confidence do not exist (Déry et al., 1993) and that absolute confidence in a system dynamics model is impossible (Forrester, 1968; Vennix, 1996; Coyle, 1997; and Sterman, 2000). Rather than objective criteria, the user must rely on ‘faith’ or ‘judgement’ (Forrester, 1961) and ‘hope’ or ‘confidence’ (Forrester, 1968) recognising that there are ‘no value-free models’ (Sterman, 2000, p. 851). In the field of system dynamics there has been an ‘increasing acceptance of the relativistic notion that “usefulness” implies a specific social context (and) that “confidence” depends on the interpretation of, and social relationships between, the builders of a model’ (Lane, 1998, p. 938). The social context of building computer models has been seen as a major reason for models to be assessed from a relativist perspective (Eden & Sims, 1979; Barlas & Carpenter, 1990; and Sterman, 2000). In this vein, Forrester has stated that ‘model validity is a relative

matter' (1968, p. 3) and adopted the relativist viewpoint of validity as an 'acceptable level of confidence' (Forrester, 1973a, p. 25).

The natural conclusion of these relativist notions is that any one of the potential users, critics or audience for a model can be regarded as the model 'evaluator' (Forrester & Senge, 1980) or 'arbiter' (Coyle & Exelby, 2000). For example, Mitroff (1969), and the United States Department of Defence (1994) have specified the model user as the model's ultimate judge. In Mitroff's (1969) view, a judgement about the model emerges in the evaluator's mind as a mentally constructed reality. Reality from a relativist perspective has been explained as a scientific-like attempt to give meaning to the chaos of life by constructing a personal interpretation of social experience (Eden et al., 1983). Therefore, in judging confidence in a computer model, each user can be viewed as an evaluator who holds their own relativist 'mirror' (Rorty, 1979) to the model and in so doing they construct and observe their own reality.

Barlas & Carpenter (1990) have concluded that because the system dynamics method has been framed within a relativist perspective, it is therefore difficult to reconcile with the conventional positivist perspective of most operations research and management science methods, providing an explanation for the rejection of system dynamics by the community of formalistic scientists. Furthermore, Déry et al. (1993) have argued that a relativistic perspective of scientific knowledge is unavoidable due to what they have described as the 'social impregnation' of that knowledge by each scientist in that field. In summary, key authors have adopted elements of a relativist perspective towards user confidence in system dynamics models.

A *theoretical perspective*, in its simplest sense, is a broad category of knowledge based on a fundamentally unique way of treating that knowledge. The concept of *theoretical perspective* is essentially the same as *theory of knowledge*, which can be found in some system dynamics literature (see for example Barlas & Carpenter, 1990). The definitions for the four theoretical perspectives used in this research are shown in Table 2.3.3-1 below. These perspectives correspond to the four viewpoints of confidence developed by Pala et al. (1999) drawing from operations research and management science literature: process and types of validation (rationality); accuracy of representation (empiricism); usefulness (utility); and process and confidence (relativism).

2.3.3 A Continuum of User Perspectives

Table 2.3.3-1. *Theoretical perspectives for evaluation of system dynamics models.*

<i>Theoretical Perspective</i>	<i>Definition</i>
<i>Rationalist</i>	‘a model or theory is simply a system of logical deductions from a series of synthetic premises of unquestionable truth’ (Naylor & Finger, 1967, p. B-93), and ‘the theory that reason is the foundation of certainty in knowledge’ (Concise Oxford Dictionary, 1990, p. 995)
<i>Empiricist</i>	‘a model will be seen as valid only if it originates from factual observations, of which the model is an objective reflection, and if the observation terms used to reflect it are translated into logico-mathematical terms.’ (Déry et al., 1993, pp. 170-171), and ‘relying solely on experiment’ (Concise Oxford Dictionary, 1990, p. 383)
<i>Utilitarianist</i>	‘Knowledge is genuinely scientific only if it leads to effective actions, if it is a useful instrument. ... useful theories are not to be rejected.’ (Déry et al., 1993, p. 173)
<i>Relativist</i>	‘the doctrine that knowledge is relative, not absolute’ (Concise Oxford Dictionary, 1990, p. 1014)

The order of perspectives in Table 2.3.3-1 above has been adopted from Barlas & Carpenter (1990), although shown in reverse order, as this represents a continuum stretching between positivist and relativist views at its opposite ends. Lane (1995) has identified a progressive shift in system dynamics confidence perspectives from predictive falsificationism to utilitarianism. While early operations research and management science authors have concentrated on the empirical representativeness of models (Churchman et al., 1957), their focus has more recently turned to usefulness (Landry & Oral, 1993). A similar ‘validation trajectory’ has been identified by researchers working with agent based simulation models at Stanford University (Levitt, 2004), which has originated in the perspective of reasoning (cf. rationalism) and moved through representation (cf. empiricism) to usefulness (cf. utility). A limitation of this foundationalist-relativist continuum is that it reinforces foundationalist thinking and therefore does not consider the implications of more contemporary philosophical perspectives (Barlas & Carpenter, 1990).

Key statements of user confidence are presented in their historical context and location on the continuum of perspectives in Table 2.3.3-1 above. This diagram

includes the major literary sources from the field of system dynamics and paraphrases their meaning of the concept of confidence into a concise expression of less than ten words and not more than two distinct ideas. This map of user confidence ideas suggests a diversity of theoretical perspectives and the centrality of that utilitarian perspective.

The originating schools of theoretical knowledge for computer models have also been included at the top of *Figure 2.3.3-1* below (shown in black with white font). Déry et al. (1993) have identified three philosophical roots for the schools of thought about the validity of computer models: logical empiricism, falsification theory and instrumentalism. The logical empiricist school has treated observations as objective and the observer as a mirror reflecting and representing the facts, from which theories are induced; tested and eventually accepted as law. The falsification school has rejected the idea of validity but accepts validation as a continual process; which abandons a model or theory if it is found to be unsound. The instrumentalism school, which has been closely associated with the field of system dynamics, has tended to put aside the verification, or correctness, of models and instead judged models in terms of their practical effect, despite contrary empirical evidence.

2.3.4 The Concept of User Confidence

Despite the wealth of literature about model validity and user confidence, there are few detailed frameworks of the issues that model users are concerned about. Instead, many system dynamics authors have chosen to prescribe aspects of model-building practice and in doing this they have assumed that the typical model-builder will seek to develop the ‘soundness and usefulness’ of a model (Forrester & Senge, 1980, p. 210). To dispel this common assumption of model-builder self-efficacy, Eberlein & Peterson have stated explicitly during all stages of model-building prior to testing, a system dynamics model-builder’s ‘confidence in the results exceeds the objective merits of the situation’ (1994, p. 160). Sterman has also identified that model-builders tend to work defensively rather than reflectively (2000, p. 858). Of further concern is that model-builders can be biased towards their discipline (Laubl, 2005) and therefore unlikely to admit incompetence. In conclusion, there is no empirical support for the literary and theoretical assumption that model-builders are better model evaluators than other model users. The traditional approach to evaluating the quality of system dynamics models has been to use the expert judgement of a model-builder, however alternatives to this approach have recently begun to emerge (see for example Luna-Reyes, Diker & Andersen, 2005). Differences in the concepts of user confidence in system dynamics model users are significant because they underpin disputes about confidence in the model (Legasto & Maciarello, 1980). A framework of user confidence would therefore be a useful start point for developing empirically based ways to improve user confidence. What then would make up a framework of user confidence?

A plethora of terms have been used to describe the evaluative qualities of system dynamics models, illustrating the breadth and diversity of thinking about this issue: *significance* (Forrester, 1961); *usefulness* (Forrester, 1968a); *operational utility* (Forrester, 1975); *adequacy* (Roberts, 1978a); *accuracy* (Roberts, 1978b); *compelling* (Homer, 1997); *credibility* (Balci, 1987 and Sterman, 2000); and *suitability* (Zhu et al., 1995). This range of ideas illustrates the broad scope of issues associated with the concept of user confidence. It is relevant to now consider why this diversity of views has arisen and summarise the existing frameworks of user confidence.

Table 2.3.4-1. *Forrester's (1973a) confidence criteria for clients and model-builders.*

<i>Role-based views of confidence in system dynamics models</i>	<i>Theoretical perspective</i>
<i>Client ('operator') perspective:</i> <i>'practical and pragmatic', 'does what is intended'; 'effective' and 'applicable to the matter at hand'</i> <i>'reveals ... critical relationships'</i> <i>'a degree of confidence'</i>	<i>Utilitarianist</i> <i>Rationalist</i> <i>Relativist</i>
<i>Model-builder ('observer') perspective:</i> <i>'measure of skill to be judged by (the model builder's) peers'; 'correct derivation from premises'; 'the logical system to which the inference belongs'; 'to display individual effort, diligence, and virtuosity' and 'a basis for competitive debate'</i> <i>'certain statistical tests are met'</i>	<i>Rationalist</i> <i>Empiricist</i>

In his unpublished paper *Confidence in models of social behavior—With emphasis on system dynamics models*, Forrester identified a gulf between the concept of user confidence for clients and model-builders by stating that users ‘can arrive at entirely different opinions about the validity of a specific model’ (1973a, p. 32). He described the two groups as the *operators*, with utilitarian views, and the *observers*, with ‘formal logic’ views. Forrester’s summary of confidence criteria are listed in Table 2.3.4-1 above. Forrester has been clear that both logical correctness and appropriateness to model purpose are essential for user confidence, and he has specifically criticized model-builders for ignoring the relevance of the model. In this paper, Forrester (1973a) has emphasized the perspectives of utility and rationalism.

Forrester is one of several management science authors who have identified differences between model-builder and client views of confidence. Ansoff & Hayes (1972) have claimed that operations research and management science model-builders and their clients possess disparate views of the purpose of model-building, the former appreciating quality while the latter seek value. They have suggested that model-builders prefer a model to be ‘*non-trivial, powerful, and elegant*’ whereas managers look for it to be ‘*relevant, valid, usable, and cost-effective*’ (Ansoff & Hayes, 1972, p. 252, italics in original text). Yewlett (1984) has identified differences in evaluation perspectives within the field of operations research and management science model-builders, explaining that scientists generally seek to extend knowledge while model-building professionals seek to make decisions. Hodgkinson & Johnson (1994) have found that variations in evaluation perspectives are related to the functional roles of managers.

Finally, within the field of operations research and management science, Gass & Joel have argued that ‘the level of confidence can vary from user to user because of ... subjective judgmental preferences’ (1981, p. 342). Within system dynamics model-building, Forrester & Senge (1980) have identified role-based differences in the views of system dynamics model users, stating that model-builders search for structural insights and ‘correct predictions’ while clients look for causal explanations to ‘important problems’ and ways that policy changes can solve those problems. Together these works suggest that differentiation in user confidence can arise from the individual roles and interests of model users.

The most common style of framework for system dynamics user confidence is a summative one, such as Pidd’s expression of confidence as ‘the way (the model) is built ... the way that the people who built it seem to act and ... the insights that it produces’ (2004, p. 13). Randers (1980) has identified seven characteristics of a system dynamics model, which have been commonly found to be desirable: insight generating capacity, descriptive realism, mode reproduction ability, transparency, relevance, ease of enrichment, fertility, formal correspondence with data and point predictive ability. Coyle (1996) has listed some of the criteria used for reviewing system dynamics models as: purpose, suitability, basis, credibility, creativity, simplicity, redundancy, transparency, flexibility, generality, sensitivity, soundness, productivity, cost and promotion. The similarities and differences between these lists lend weight to the suggestion that a detailed framework of system dynamics user confidence would be extensive and diverse.

One of the most comprehensive frameworks of system dynamics user confidence has been presented by Lane (1995), for which he has borrowed the operations research and management science metaphor of model-building as a tetrahedron. The top vertex of this slender pyramid is the perceived problem in relationship with the closely spaced vertices of the base which represent the qualitative model, quantitative model and policy insights of the ‘theoretical system dynamics’ activities. The six edges of the tetrahedron represent the types of validity. The stages of model-building are represented by each vertex. Following after previous authors (Hollinghurst, 1995; and Oral & Kettani, 1993), Lane has unfolded the upright sides of the tetrahedron to arrive at a three-pointed star whose centre is theoretical system dynamics. The purpose of Lane’s star is to ‘help readers to embrace a better framed view of system dynamics

validation’ and to ‘return practitioners to the fold of rigorous simulation’ (1995, p. 129). A key implication of Lane’s conceptual framework is that a model-building project must involve at least one of the non-theoretical types of system dynamics model-building to form a bridge back to the client’s problem, and this choice of activity will determine which validity criteria become pertinent to the users’ confidence. Lane has equated user confidence in a model with the types of validity ‘desired’ by the client for that project. A further implication of Lane’s framework is that user confidence might be dependent on the nature of the problematic situation.

However, it is unwise to assume that all managers accept the need for system dynamics models or the systemic, rationalist type of analytical planning these models represent. Behn has stated that rather than pursue strategic planning, ‘public managers do and should grope along’ (1988, p. 643) because the principles of management are imprecise and contradictory. Additionally, Lindblom’s (1979) pragmatic claim that policy making can only occur through ‘disjointed incrementalism’—where managers solve policy problems by ‘muddling through’—has been widely cited in strategic management literature. Schmidtchen has also observed that incrementalism is the root metaphor of strategic management in western military organisations, because ‘defence is a pragmatic culture which fosters leaders who believe that order can come from chaos through their efforts. ... pragmatists are also incrementalists’ (2006, p. 78). An incrementalist approach to organisational strategy equates to what Ackoff has called ‘problem resolution’ and therefore it sees a managers’ ‘qualitative judgments and common sense’ (2001, p. 343) as more appropriate than the models of strategic planners. This literature suggests that defence managers may emphasise qualitative aspects of user confidence, or at worst, they may be ambivalent towards a model-building project because they prefer a less rationalist approach to organisational problems. Either way, the only way to find out is to ask those managers.

It is evident from the numerous descriptions of user confidence that system dynamics model-builders have been filling this knowledge gap using their personal observations of model-building projects. That no empirical answer to this research question has yet been published means only that the accuracy of those observations are yet to be proven. An example of a study of this nature is that conducted by Mitroff (1969) into the decision behaviour of a design engineer, although that study dealt with a single person, rather than an organisation.

In summary, the field of system dynamics has not yet seen an empirically based framework of user confidence. From the literature of operations research, management science and system dynamics there appears to be a wide diversity of user confidence criteria, due partly to the roles and interests of model users. This breadth and extent of issues has been demonstrated by the confidence criteria put forward by Randers (1980) and Coyle (1996). The most comprehensive descriptive framework of system dynamics user confidence is a process-based view adapted by Lane (1995) from Oral & Kettani (1993). Qualitative aspects of confidence in planning techniques can be expected within military organisations due to the prevalence of incrementalist thinking, and yet there have been no published empirical studies of the concept of user confidence in system dynamics model users.

Forrester has warned that no ‘objective quantitative methods exist for determining the validity of models from the viewpoint of the (client)’ (1973a, p. 35). The problem with validation tests is that when a model passes a particular test, that does not suggest it will also pass any other test. This is De Bono’s second law at work: ‘Proof is often no more than lack of imagination in providing an alternative explanation’ (1971, p. 113), a rule he stated after observing the explanations that 1,000 people gave for the mysterious toppling behaviour of a black cylinder on a bare and unmoving table top. From this experiment, De Bono deduced two general rules of ‘everyday thinking’ (1971, p. 182): ‘(1) Everyone is always right. (2) No one is ever right. These (rules) are not contradictory.’ The observers of De Bono’s toppling cylinder had only their everyday thinking to understand its mysterious and invisibly caused behaviour. Likewise, each system dynamics model user when they act as an evaluator must judge the behaviour of a computer model according to their own everyday understanding. Therefore, computer model users accept that no person will ever know the absolute validity of a model: because no one is ever right. Instead, it is legitimate to accept that different evaluations of a model will arise and each user’s evaluation will be legitimate for them. This notion of evaluative legitimacy is a foundation for the use of framing, which the following section will explain in detail.

2.3.5 Summary of System Dynamics Literature

The following is a summary of the literature of confidence in system dynamics models reviewed for this study. This review has identified a gap in knowledge for an empirically based framework of user confidence in system dynamics models.

There has been a public controversy about the confidence in system dynamics models since the field's emergence in the 1960s and a lack of understanding of the concept of user confidence may be contributing to this problem. User confidence in system dynamics models has been eroded through debate and criticism of the method and a few high profile models (Myrtveit, 2005). A range of theoretical perspectives have been identified in the literature of confidence in system dynamics models, spanning across the positivist-relativist spectrum of theoretical perspectives. The utilitarian perspective of confidence has been the most common theme in operations research, management science and system dynamics literature, although some authors have expressed concern about the overall purpose of system dynamics. A relativist perspective has also come through in much of the system dynamics literature, suggesting that each model user acts as an evaluator of the model.

The absence of an empirically based framework of system dynamics user confidence is a current gap in the body of system dynamics knowledge. A wide range of concepts of user confidence have been described by various system dynamics authors, which some authors have suggested is due to the diversity of user roles and interests, as well as the unique characteristics of each organizational problem. It has also been suggested that some managers do not accept the value of systems analysis of military problems. However, for any user presented with a system dynamics model, their evaluation of the model will be legitimate for them and therefore it is important to understand their concept of confidence in the models that they use. It is in this context that framing can offer utility.

2.4 Framing

Illustrations of the utility of framing for management decision-making are all around us, as Goodwin & Wright (2004) have shown. For example, when disembarking airline passengers at a particular airport complained about the waiting time at the baggage claim area, the airport authority could identify no feasible way to get passenger baggage into the terminal before the passengers. There simply were no

technical solutions. When the distance between the aircraft gate and the baggage claim area was increased, the bags arrived before the passengers, the problem was solved and there were no complaints. Goodwin & Wright's point is that 'it is often tempting to view decision problems through a technical frame' and to become so absorbed in the complexity of this approach that simple solutions go unnoticed.' (2004, p. 359) Transferring their thinking to this particular study, the problem in this case has been the challenge of building confidence in system dynamics models, the 'technical frame' has been formal tests of the model, and the simple solutions may yet be the ideas that emerge from the frames of the model users. This following section explains framing in detail and summarises previous framing research.

To derive an explanation of the framing method from its literary origins is difficult because the concept lacks development (Gamson, 1974) and its definition has been described as 'casual' and 'vague' (Scheff, 2005). The author therefore developed a definition specifically for this study, by applying framing literature to the particular application of operations research, management science and system dynamics. Framing is a term from the field of sociology and has been attributed to Goffman's book *Frame Analysis* (1974, revised 1986). Goffman used framing to describe a 'schemata of interpretation' at an individual level (1974), which in effect means that frames can be legitimate alternative views for the same experience or situation. Framing has consequently been understood as an 'unavoidably social' activity (Scheff, 2005), and in these terms it can be seen as an appropriate tool for exploring the multiple views of system dynamics model users within the social context of a model-building project.

Framing has been used in a wide range of fields. In behavioural science, framing can mean the expression of a decision-making choice under uncertainty (Kahneman & Tversky, 1981 and 2000); in political science, framing refers to the way a political message is structured and conveyed (Dion, 2000); and in social science, it means an 'assumptional structure' (Schön & Rein, 1994, p. viii). In the field of operations research and management science, framing has been used to mean a particular problem-solving method (see Davies & Mabin, 2001a), and is linked to the metaphor of alternative window frames which provide different views of the same object (for example Pidd, 1996). These concepts provide a context for the specific definition of framing for this study, which is explained in the following section.

The following definition of framing was developed for this study, based on literature from the fields of management science, social science and organisational studies.

A frame is a cognitive structure for an experience, embedded within a particular social context.

As this definition illustrates, frames are based on the experiential view of an individual, and so it excludes collectively formed ideas and concepts originating from thought alone. The element of context in this definition provides a strong link to qualitative methods of research because the exclusion of context is a fundamental characteristic of quantitative research methods (Scheff, 2005).

When a frame is used it provides meaning for a particular view and it is this property which makes frames suitable in qualitative research method. A view is a particular perspective about an experience within the social setting of an organisation. In the context of this research, a view will usually identify a problem or debate within an organisational setting. It should be noted that a frame need not be distinct or distinguishable from another frame, as the concept of framing does not depend on any specific quality of any particular frame, including its uniqueness. Frames are primarily a means of understanding views; although they can also be used comparatively in an approach known as meta-framing.

Framing is the use of a frame to understand a particular view.

2.4.1 The Framing Method

Russo & Schoemaker's management book *Decision Traps* (1989) is the origin text for the use of framing as a problem-structuring method in management decision-making, followed in 2002 by their book *Winning Decisions*. Both their books have put forward a method for improved management thinking which uses framing as the first of four problem-solving steps. They have stated that it is the responsibility of senior management to frame problems appropriately, or in their words to develop 'winning frames'. Although some authors have agreed that frames should be 'directed' or selected (for example Evans, 1991), still others have suggested that frame selection does not add significant benefit (see Davies & Mabin, 2001a). The paradox of framing lies in its strength: that a single frame can be both illuminating and revealing while also limiting (Davies & Mabin, 2001a).

Russo & Schoemaker (1989) have identified 10 barriers to effective decision-making. The two barriers pertinent to this research are *frame blindness* and *lack of frame control*. *Frame blindness* results from inadequate consideration of the way a problem is viewed, which causes the decision-maker to neglect suitable options or ignore key goals. *Lack of frame control* means only viewing the problem in one way, thus being influenced by inappropriate frames. Their premise is that frames are used instinctively and unavoidably to simplify problems as a basis for rational decision-making. Russo & Schoemaker have admitted that ‘no one can completely avoid the dangers of framing’ (1989, p. 18). They say that everyone ‘frames’ decisions and some do it better than others, however there are no objective criteria for assessing in advance which frames are better than others. They only advise that managers can and should, but do not naturally, improve the way problems are framed. They have not provided any specific advice for judging the suitability of a frame. Therefore, although Russo & Schoemaker’s (1989) method is aimed at improving management decision-making it can only do this through the interpretation of frames because ideal or optimum frames do not exist. It is the *process* of framing that leads to improved decisions, rather than the *content* of the frames themselves.

Fisher (1998) has reviewed framing literature with a particular focus on its employment in the social sciences. He has cited the use of frame analysis in the study of institutions, political activism and social grievance. Fisher has approached framing from the linguistically oriented methods of discourse analysis, which focuses on the process of communication rather than its content, particularly the text and texture of conversation (Fairclough, 1995). The framing method used in this study is not similar to this sociological approach and therefore the linguistic aspects of user confidence have not been explored. The author’s decision to narrow the scope of framing to managerial and cognitive science was principally driven by the factor of economy.

In the same way that thinking frames can dominate thinking about different problems (Russo & Shoemaker, 1989), it is common for problem-solving techniques to be developed using progressively more detail within the same frame. Rarely will the assumptions, values and beliefs of the frame be questioned, yet challenging the foundations of a frame is potentially more useful and efficient than further development of the method (Davies & Mabin, 2001a). Thinking frames can limit

decision-making and prevent decision-makers from seeing equally useful or legitimate views of a situation.

FRAME ANALYSIS WORKSHEET

1. What issue or issues does the frame address?
2. What boundaries do I (we/they) put on the question?
In other words, what aspects of the situation are left out of consideration?
3. What yardsticks/performance criteria do I (we/they) use to measure success?
4. What reference points do I (we/they) use to measure success?
5. What metaphors—if any—do I (we/they) use in thinking about this issue?
6. Why do I (we/they) think about this question the way I (we/they) do?
7. What does the frame emphasize or highlight?
8. What does the frame minimize or shadow?
9. Do other people in the industry think about this question differently from the way I (we/they) do?
10. Can I (we/they) summarize my (our/their) frame in a slogan?

Figure 2.4.1-1. Russo & Schoemaker's 10 Framing Questions.

Source: Davies & Mabin, 2001a; adapted from Russo & Schoemaker, 1989

The frame analysis worksheet developed by Russo & Schoemaker (1989) consists of 10 framing questions, which Davies & Mabin (2001a) have modified slightly and are reproduced in Figure 2.4.1-1. Russo & Schoemaker have suggested that framing is a learnable art and they have therefore presented the framing questions as a self-applied tool. This study applies that tool to the field of management research. These 10 framing questions can be used to assist managers to overcome two common barriers to effective decision-making; frame blindness and lack of frame control.

A dominant and discernible theme of Russo & Schoemaker's (1989) framing questions in Figure 2.4.1-1 is the use of symbolic cues, namely: *boundaries*, *yardsticks*, *reference points*, *metaphors*, *highlight*, and *shadow*. These symbolic notions suggest a view of management based around concepts of purpose, influence and control. *Boundaries* are the first and most blunt cue that a frame may be limiting or inappropriate for the aims of the manager or the organisation in which she may work. *Yardsticks* and *reference points* explore the frame from a perspective of performance or achievement, where *yardsticks*

are akin to performance measurement scales and *reference points* represent their related success or failure thresholds with respect to assumed goals. Together these symbols allude to the existence of goals, values, and preferred action options. Meanwhile, the frame analysis notions of *highlight* and *shadow* suggest meanings that derive from a textured and dimensional image of the situation, such as contrast, perspective and relief.

The symbolic element of metaphor in the fifth framing question has a substantial foundation in operations research and management science literature. Metaphors are believed to pervade human thinking, or as Lackoff & Johnson have argued: ‘truth is always relative to a conceptual system that is defined in large part by metaphor’ (2003, p. 159). These metaphors are used because, as Immanuel Kant has argued, human knowledge is limited by the ‘manner in which our faculties of perception and thinking organise the raw data of experience’. (Stumpf, 1996) We develop vivid metaphorical images to ‘fulfil a psychological or rhetorical need’ (Jackson, 1999). Jackson & Flood (1991) have emphasized the quality of likeness as an aspect of metaphor that enables managers to understand and learn about complex problems. Metaphorical usage has been encouraged by Pondy (1983) and Morgan (1986) as a means of understanding organisations. An example of metaphorical frames has been presented by Davies & Mabin (2001a) in the form of operations research and management science methods for understanding decision problem options. Some commonly used metaphors in operations research and management science are military, familial, structural/construction, orchestral, theatrical and sporting scenarios.

The remaining three framing questions posed by Russo & Schoemaker (1989) explore the other fundamental element in the definition of *framing* for this study: social context. The question of ‘why this frame?’ (question 6) draws attention to personal bias within the context of motivation and intention, neither of which can exist without a social setting. The ninth framing question ‘what do others think?’ turns attention to other views within the particular social context. The final framing question, which seeks a slogan for the frame, recognizes that communication is an essential function within a social context.

2.4.2 Empirical Studies in Framing

A much recognised study based on the framing method is the investigation of management decision-making under uncertainty by Kahneman & Tversky (1981), who have claimed that risk taking is influenced by the framing of decision choices or outcomes. Positive framing, they have claimed, leads to a risk-averse response and negative framing to a risk-taking response. Their research concerned quantitative topics framed using a small set of discrete options. In contrast, studies in the social sciences tend to involve qualitative problems with an infinite range of potential solutions. Some examples are described below, noting that they are all unpublished theses.

In a political science study, Dion (2000) used framing to explain the conflicting agendas of political elites in the 1993 debate about homosexuals serving in the US military. In a management study, Borden (1993) applied framing in a study to improve the efficacy of CEO-board relationships. Dzbor (2002) employed framing within a conceptual model of the process of creative design. The broad span of these subjects illustrates the adaptability of framing as a research method and the latter studies by Borden (1993) and Dzbor (2002) demonstrate its utility with respect to evaluative topics. Nevertheless, a knowledge gap exists for the application of framing to evaluative research.

2.4.3 Summary of Framing Literature

This section of the literature review has traced the origin of the framing method to the sociologist Goffman (1986), who portrayed framing as reflecting the personal meaning each individual gives to a particular situation in a social context. In the field of management, Russo & Schoemaker (1989) have introduced framing methodology as a tool to assist managers to avoid 'decision traps', such as frame blindness and lack of frame control. Despite their implication that frames should be selected to 'fit' a particular problem situation, the real value of framing lies in the act of framing (and reframing) and thus its employment as an interpretive filter. In addition, framing can also be used in research (and management) by giving legitimacy to other views of a problem and drawing attention to the limitations of each frame.

This study uses the frame analysis worksheet adapted from Russo & Schoemaker (1989) by Davies & Mabin (2001a). The majority of the framing questions explore a

frame's conceptual structure using symbolic language. The key elements of framing are boundaries, performance criteria and metaphors.

A number of empirical studies in social science and management have already demonstrated the adaptability of framing. However, there is a gap in understanding how framing can be applied to evaluative research, such as the criteria on which a user's confidence in a model are based. The combined use of complementary research methods has been shown to 'improve the understanding of problematic situations by providing a means of developing and synthesising multiple perspectives that lead to enhanced perception, insight and knowledge'. (Davies & Mabin, 2001b)

2.5 Complementary Research Methods

The combination of framing and system dynamics model-building employed in this study is an example of complementary research methods. Multi-disciplinary scientific work was once more common in the 'early days' of operations research, when scientists were more open to the views of their peers (Mingers, 1997 and Davies & Mabin, 2001a). Nevertheless, Mingers & Brocklesby (1997) have recommended complementarist approaches, noting that single paradigm practice is common in management science and suggested that multiple methods are actually being practiced, although it may not be recognised as such. Davies & Mabin have encouraged the use of multiple frames, called reframing (2001a); and have demonstrated various combinations of hard and soft methods (2001a and 2001b) including narratives, flow charts, tables, mathematical models, spreadsheets, graphs and various techniques from the theory of constraints method.

The calls for an increase in complementarist methodological approaches have been increasing in the field of systems model-building (see for example, Jackson & Keys, 1984; Mingers & Gill, 1997; and Pidd, 2004). Sterman (2000) has also encouraged the integration of system dynamics with other methods. However, there has also been some resistance towards the use of multiple methods, including criticism in favour of the tension of reframing (Davies & Mabin, 2001a) and the preference for critical rather than complementary methods (see for example Zhu, 1999). On balance, there has been growing impetus for the combined use of complementary methods in operations research and management science.

2.6 Summary of Literature Reviewed

The literature reviewed for this study reveals that building models of organisational problems entails pragmatic choices (Forrester, 1973a) that are embedded within the social setting of the organisation (Vennix, 1996). This study explores the implications of that social setting, especially the use of framing to give legitimacy to the views of model users, in contrast to the current bias of systems model-building towards academic specialisation and the positivist paradigm of science (Berends & Romme, 1999).

Although system dynamics models have been used to investigate a number of military workforce planning problems, it has been suggested that the pragmatist culture of defence does not favour systems analysis (Schmidtchen, 2006). In addition, despite system dynamics being the subject of a public controversy throughout its 50 years of existence, there have been no reports of empirically based frameworks of user confidence. The two non-positivist perspectives of utility and relativity are evident throughout the literature of system dynamics and are therefore expected to appear in the empirical results in chapter 5. Those descriptions of perspectives and themes of user confidence, detailed in appendix 5, satisfies the knowledge gap in the first research question (refer to section 1.5).

A framework of user confidence that includes the perspectives of utility and relativity, gives legitimacy to the views of model users by treating them, appropriately, as evaluators of the model (Forrester & Senge, 1980). Framing is suited to this purpose because it recognizes the legitimacy of individual views. The 10 questions of framing developed by Russo & Schoemaker (1989) and refined by Davies & Mabin (2001a) explore the frames of managers with emphasis on their conceptual structure. The utility of framing is a further knowledge gap, which the second research question addresses (see section 1.5 and chapter 5). The following chapter concerns the various aspects of research for this study, building on the key issues from the literature of system dynamics and framing.

CHAPTER 3 : RESEARCH METHODOLOGY

‘Questions are necessarily prior to answers, and no answers are conceivable that are not answers to questions. A “purely factual” study—observation of a segment of social reality with no preconceptions—is not possible; it could only lead to a chaotic accumulation of meaningless impressions. Even the savage has his selective preconceptions by which he can organize, interpret, and give meaning to his experiences.’

Myrdal, 1968, p. 24 cited in Meadows, 1980, p. 23

3.1 Overview of Chapter 3

This chapter describes the research framework and methodology of enquiry used in this study. The leading sections of this chapter describe the origin and foundations of this study, while the latter sections detail the design factors and actual research activities.

3.2 Research Framework

This section covers the framework of research concepts encompassed by this study, specifically the research objective, research questions and the paradigm of enquiry.

3.2.1 Research Objective

The objective of this study was to elicit the principal model users’ concept of confidence for a system dynamics model using framing, by interpreting them as confidence criteria. The research was based around the case study of a contemporary workforce planning problem for the New Zealand Army.

3.2.2 Research Questions

Two research questions follow from the research objective:

1. What are the interpreted confidence criteria of system dynamics model users for an Army workforce planning problem?
2. How does framing assist the model-builder to elicit and interpret the concept of user confidence?

3.2.3 Paradigm of Enquiry

The paradigm of this inquiry follows the paradigm of system dynamics which, as Meadows has explained, reflects a well-educated Western perspective influenced by ‘a rational, logical, scientific mode of thought’ (1980, p. 25), and that has tended to generate a positivist perspective of knowledge. For the sake of clarity, this report uses the definition of positivism as an approach based on ‘precise, objective measures and is usually associated with quantitative data (Cavana et al., 2001, p. 8). However, the matter does not end there, because it has also been shown that system dynamics has a relativist character (Barlas & Carpenter, 1990). Therefore, as a base for comparison, the system dynamics method and its practitioners represent a combination of positivist and relativist paradigms.

An interpretivist element has been woven into the paradigm of this study in response to the author’s experience that managers tend to be cautious about the application of scientific and analytical aids to decision-making. One model user in this study summed up this sentiment when they stated that ‘HR (human resources) is not scientific’. The author preference was to conduct research that featured aspects of a non-positivist paradigm; which Remenyi, Williams, Money & Swartz (1998) have said is characterized by research techniques such as observing small groups in depth over time, using induction to build theory, keeping the context in mind and seeing the world as an artifact of social construction. Their description has been true of the author’s experience.

This research has combined the paradigmatically dissimilar methods of framing and system dynamics. Numerous theorists have asserted, like Kuhn (1962), that disparate paradigms should not be combined because they are ‘incommensurable’. System dynamics, for example, treats the model as the one correct, managerial view of the situation, whereas framing lends legitimacy to all views. As Flood & Jackson (1991) and Pidd (2004) have suggested, the combination of ‘hard’ and ‘soft’ approaches is both appropriate and useful in this context. Mingers has also called for ‘strong methodological pluralism’ on the basis that problems ‘would be dealt with more effectively with a blend of methodologies from different paradigms’ (1997, p. 9). The author recognizes however that such a pluralist paradigm reifies the co-existence of disparate paradigms, and therefore assumes that user confidence can be simultaneously

objective and subjective in character. The following section explains in detail how particular research methods and techniques are applied in this study.

3.3 Research Design

The first part of this section lays in a logical fashion the grounds for the particular research design used in this study. The subsequent part of this section then explains the design of each research method used within that overall design.

The research design for this study consisted essentially of four methods: system dynamics, framing, interviews and case study. The latter three methods were all driven by the choice of the first method and its combination with issue of user confidence and the context of the problem being investigated. The system dynamics method was selected for the problem of workforce planning in the NZ Army because of disagreement about what should be done (refer section 2.2.1) and the already frequent application of system dynamics to the problems of military organizations (refer section 2.2.2).

Since user confidence in system dynamics models is a relative matter, rather than an absolute perspective (Forrester, 1961), validity and validation of system dynamics models is a 'matter of social conversation' (Barlas & Carpenter, 1990, p.157) and this justifies a qualitative method of enquiry. Since understanding and meaning are based in language, leaders must use language to frame organizational events and objects (Fairhurst & Sarr, 1996) and so framing can be employed to explore management meanings because it gives legitimacy to each leader's expressed view (refer section 2.4.1). Yet because leaders often use language unconsciously, (Fairhurst & Sarr, 1996) it is necessary to elicit their views participatively, using interviews. In addition, the New Zealand (NZ) population is generally distrustful of science (MoRST, 2002 and 2005) so managers can be expected to use familiar concepts to understand unfamiliar scientific ideas (Lackoff & Johnson, 2003) and make sense of their experiences with science (Riesback & Schank, 1989). The framing method provided by Russo & Schoemaker (1989) suits this situation because it draws on metaphors and related linguistic devices.

The fourth component of the research design, the case study method, was selected for several related reasons. Since models are simplifications of reality they must be designed for a specific purpose (Forrester, 1961), which means that each case of a model is relevant only to its given problem context. For this reason, it was

necessary to conduct a bespoke model project as a case study, rather than study a collection of models built by third party model builders. Since any user's view of the model can change during the model building project (Mitroff, 1969) and the model also changes iteratively (Homer, 1996) it was necessary to study the concept of user confidence over a period of time for a single case study. Due to military security restrictions and specialist knowledge required for inquiry in the field of workforce planning, an ethnographic approach therefore arose as the only economic approach to this study.

Figure 3.2.3-1. Relational map of research techniques for this study.

Adapted from Remenyi et al., 1998

Although the multi-method nature of this study represents a convergence of disparate approaches in terms of paradigms and methods (refer to section 2.5), these approaches also share the common research method of case study, as shown in Figure 3.2.3-1 above. Framing, system dynamics, ethnography, stakeholder analysis and time-series analysis are all conducted in the manner of a case study. Consequently, the significance of the case study method has been acknowledged by discussing its implications first, followed by system dynamics. Interviews and ethnography, where the researcher works alongside the participants as an 'insider', are also founded on the

case study method. These linkages can be explained as the consequence of research that enquires in a descriptive and exploratory fashion, as Remenyi et al. (1998) have identified that these characteristics are common to case study, ethnography and interviews.

3.3.1 Case Study

During the course of this research project the author was inclined to delve into the uniqueness and quality of a subject rather than compare likeness and quantity across a field, possibly due to the author's interest in engineering and specifically the way objects are constructed. The case study method was also a pragmatic choice of topic because it minimised the challenges of accessibility, especially given the security and sensitivity issues associated with military workforce planning. Finally, the author was familiar with the case study format having encountered it routinely through tertiary education, as it is a common teaching device in the field of management (Remenyi et al., 1998). Overall, the reasons for using a case study method hang on preference, pragmatism, expectations and familiarity.

The nature of a case study is to look intensely at the events within a narrowly bounded context, such as an organisation, social culture or physical environment, over a period of time. Case studies were for a long time considered an inferior method of research but recently have become more common, although they are still generally regarded by some as 'high risk' (Remenyi et al., 1998). Flyvbjerg has investigated the reasons for this and has asserted that not only is 'the case study ... a necessary and sufficient method for certain important research tasks in the social science' (2004, p. 432), but also that well executed case studies can be as valuable as studies of large samples and that both types of study are needed. He has also highlighted the significance of the tangible nature of case study findings in management by stating that 'social science has not succeeded in producing general, context-independent theory and has thus in the final instance nothing else to offer than concrete, context-dependent knowledge' (Flyvbjerg, 2004, p. 422).

The case study method used in this study was based on the techniques outlined in Yin (2003). The selection of this case represents what Flyvbjerg refers to as a 'pragmatic case'; whose purpose is 'to develop a metaphor or establish a school for the domain that the case concerns' (2004, p. 426). Finding a paradigmatic case relies

primarily on the researcher’s intuition, as well as the researcher’s ability to prove its paradigmatic properties (Flyvbjerg, 2004). The case of system dynamics workforce model-building in the New Zealand Army is paradigmatic as a framing study because no previous study has attempted to describe the concept of user confidence from an empirical basis, and this knowledge gap arose during the author’s numerous experiences of applying system dynamics model-building to military workforce planning problems. The application of system dynamics to this case study is explained in the following section.

3.3.2 System Dynamics

System dynamics method essentially follows a case study method because it focuses on a particular entity with clearly defined boundaries and delves into rich, non-numerical data, in an iterative manner that unfolds over time. There is general agreement about the generic components or stages that make up the system dynamics method, as the comparison in Table 3.3.2-1 below suggests.

Table 3.3.2-1. *Stages of the WETA model-building project.*

<i>Stages of WETA project</i>	<i>Sterman (2000)</i>	<i>Maani & Cavana (2000)</i>	<i>Vennix (1996)</i>
<i>1. Problem structuring</i>	<i>Problem articulation (boundary selection)</i>	<i>Problem structuring</i>	<i>Problem identification and model purpose</i>
<i>2. Qualitative model-building</i>	<i>Formulation of dynamic hypothesis</i>	<i>Causal loop modelling</i>	<i>System conceptualization</i>
<i>3. Quantitative model-building</i>	<i>Formulation of a simulation model</i>	<i>Dynamic modelling</i>	<i>Model formulation and parameter estimation</i>
	<i>Testing</i>		<i>Analysis of model behaviour: testing and sensitivity analysis</i>
			<i>Model evaluation: model validity</i>
<i>4. Policy analysis</i>	<i>Policy design and evaluation</i>	<i>Scenario planning and modelling</i>	<i>Policy analysis</i>
<i>5. Implementation</i>		<i>Implementation and organisational learning</i>	<i>Model use and implementation</i>

The stages of model-building used in this study are shown in Table 3.3.2-1, showing the sources from which the approach was derived (Vennix, 1996; Maani & Cavana, 2000; and Sterman, 2000). Each text played a distinct role in the way this study was conducted; Maani & Cavana (2000) providing a guide and checklist for the tasks at each step in the process; Sterman (2000) serving as a source of method and technical advice; and Vennix (1996) as a source of theoretical structure and guidelines for the participation of the principal model users. The structure of each section in chapter 4 (case study) is modeled on the five stages of model-building shown above, noting that no implementation had been attempted at the time of writing this report.

Stakeholder analysis was used in this research to complement the system dynamics method, in order to structure the human aspect of the problem. Coyle & Exelby have stated that ‘the client (of a system dynamics model) is the ultimate arbiter of validity *as he has a personal interest at stake*’ (2000, p. 29; italics in original text); so it therefore seemed appropriate to employ stakeholder analysis to identify the principal clients. The technique of stakeholder analysis used in this study was based on Freeman (1984), for identifying the principal model users of the WETA model. This entailed a simplified approach using the first stage of rational level stakeholder analysis. The two elements of this process were the identification of the specific principal model users with a stakeholder map; followed by the identification of the stakes of those model users. The results of stakeholder analysis have been presented in section 4.2.2. An econometric technique referred to as time-series analysis was used to formulate the separation rate variable in the system dynamics model, explained in section 4.4.2. This technique is explained in Hanke, Reitsch & Wichern (2001).

A constant concern throughout this study has been to ensure that the selected workforce planning problem and final computer model possessed the requisite characteristics of a system dynamics model, to ensure the overall research objectives could be achieved. Vennix has provided specific guidelines against which to assess the suitability of a system dynamics model for a given problem, including a component of dynamic complexity caused by ‘underlying feedback processes’; a worse-before-better pattern of behaviour, or vice versa; a ‘reference mode’ showing the problematic behaviour into the future; and the essential structural condition of at least one flow process (1996, pp. 105-107). As chapter 4 has demonstrated, these guidelines have

been variously satisfied within the final system dynamics model. An explanation of the combination of interview technique and framing used in this study follow below.

3.3.3 Framing Interviews

Applying the 10 frame analysis questions from Russo & Schoemaker (1989) provided a convenient and well-defined structure for an interview research technique. An interview technique was used to gather data about the concept of user confidence to allow in-depth analysis of the subject from an interpretivist perspective. Interviews also proved to be an effective way to elicit this data because it is a difficult concept to express and interpret. Although Lave & March have cautioned ‘the circumstances under which respondents are good theorists are limited’ (1975, p. 54), the interview data was only used to develop a conceptual framework in a descriptive nature. This narrower research objective avoided the necessity for an explanatory source of data, as would be necessary to construct a theoretical framework.

Interviews have been used in a number of studies to assess the objective content of system dynamics models (Luna-Reyes et al., 2005) but there have been no reported studies using interviews to understand the subjective content of system dynamics model user perspectives. The interview was a natural choice because it is a commonplace and convenient technique used by model-builders in model-building projects, acknowledging also that interviews on their own are a limited source of data for social research (Rapley, 2004). The general conduct of interviews was based around the guidelines in Cavana et al. (2004, chapter 6).

A structured interview format was used in this study (after Cavana et al., 2000), using the frame analysis questions shown in *Figure 2.4.1-1* above. These questions formed the basis of the interview while the participant was given freedom to explore related issues as they occasionally chose. A copy of the interview questions was provided prior to the interview, since none of the participants were familiar with framing. At the beginning of the second interview it was explained that the same questions would be repeated but the participants were encouraged not to concern themselves with the replication of their initial interview answers. The frame analysis questions were printed on a single side of A4 paper; which was used to make handwritten notes during the interview for later reference, including subsequent interviews.

A second sheet of interview questions was created to explore specific aspects of the participant's view of confidence, degree of confidence, perceived model purpose, assumptions, values and beliefs. These questions were used as precursors to the frame analysis questions in the first interview, but to avoid interview fatigue from repeated questioning, these supplementary questions were abbreviated during the second interview and omitted altogether from the third interview.

3.3.4 Ethnography

Ethnography means the study of a group from the inside, where the researcher comes to be regarded as 'one of them' (Rosenthal & Rosnow, 1991). The author's work as a system dynamics practitioner has been entirely ethnographic as a military officer and middle level manager. Ethnography, like the other methods in this study, has a basis in case study research because it involves intensive enquiry within a single context over a period of time.

Investigating behaviour in the author's former workplace was an approach that emerged from a preference for an interpretivist paradigm and therefore a qualitative method of investigation. To achieve the research qualities of 'trustworthiness' and 'verification' identified by Cavana et al. (2001), it was prudent to gain a rich and personal understanding of the problem of user confidence. Locating this research in the author's workplace reflected the fact that system dynamics projects are iterative activities (Homer, 1996) requiring a continual process of confidence-building (Stermann, 2000) and that little research has occurred into this inaccessible subject.

Participant-observation, as the name suggests, refers to a research method where a researcher is directly involved in the activities of the organisation being observed, and therefore it is inherently ethnographic. Participant-observation was incorporated in the research approach because the system dynamics model-building project was addressed to the area of the author's professional expertise with the explicit possibility that it might be implemented regardless of the academic exercise of research. The author's degree of involvement, level of participation and membership role during this study fell in between passive participation and moderate participation as highlighted in Table 3.3.4-1.

Table 3.3.4-1. *Participation levels for ethnographic research; highlighting actual levels in this study.*

Adapted from DeWalt & DeWalt, 2002, p. 21.

<i>Continuum of Participation (Spradley, 1980)</i>	<i>Membership Roles (Adler & Adler, 1994)</i>	<i>Degree of Involvement (Remenyi et al., 1998)</i>
<i>Nonparticipation</i>	<i>No membership role</i>	<i>Complete observer</i>
<i>Passive participation</i>		<i>Observer as participant</i>
<i>Moderate participation</i>	<i>Peripheral membership</i>	<i>Participant as observer-researcher</i>
<i>Active participation</i>	<i>Active membership</i>	
<i>Complete participation</i>	<i>Full membership</i>	<i>Complete participation as a normal member of the organisation</i>

DeWalt & DeWalt have identified three benefits of participant-observation: the quality of data collected, its interpretation and the tendency for it to encourage ‘the formulation of new research questions and hypotheses grounded in on-the-scene observation’ (2002, p. 8). They have also highlighted the benefit of constant researcher contact with the research subject and the intuitive understanding this generates. The participants in this study were all known personally to the author prior to the study, and it is the author’s assessment that prior familiarity with the participants enhanced the trustworthiness of the research findings on the basis of personal insights.

One of the debated issues of participant observation is the contradictory requirement for the researcher to be both detached as observer but also involved as a participant (DeWalt & DeWalt, 2002), and this has become a matter for the researcher’s judgment. In choosing ethnography and participant-observation the author also considered the possibility of undue bias by ongoing interests within the Army and the workforce planning portfolio. While the risk of bias was unavoidable, this likelihood was minimised by being posted out of the Army workforce planning role from the commencement of this study. The impact of any bias that might arise was mitigated by supervisory critique and by inviting feedback during quarterly project briefs to the author’s defence force workforce planning colleagues.

3.3.5 Sample Selection

Research participants for this study were narrowed down to the candidates for principal model users using stakeholder analysis (refer to section 2.3), subject to a final

decision by the Army's director of personnel. The problem definition, which drove the stakeholder analysis, was dictated by the author's professional interest in current organisational workforce planning issues and moderated by his model-building skills. The author's personal influence on the problem definition and therefore the sample selection was unavoidable but was however controlled by reflective consideration of this research topic for the two years of part-time study prior to the research project and involvement in three previous system dynamics military workforce models.

Research participants were identified partly on the basis of their knowledge of Army workforce planning while also combining sampling design principles of stratification and clustering. Seven participants were chosen because they were the minimum number to span the three employment strata: executive/senior management, middle management and analyst; and six functional clusters: personnel (including recruiting), training, finance, planning and executive. An advantage of this diverse sampling was that it avoided the model becoming 'overly idiosyncratic' (Vennix, 1996) and judgment was used to balance the representation of strata and clusters with the perceived stake of participants in the chosen workforce problem. The final sample design included seven participants who were each interviewed on three separate occasions. Seven participants was a practical limit of the study to fit within the quantum of work for a Masters thesis, to provide a suitable environment for discussion in the group model-building session, and to remain relatively close to the recommended group size of five (Vennix, 2000).

The author proposed a list of seven provisional participants to the Army workforce planner, who made one modification with minimal impact on the clustering or stratification of the sample. A letter requesting the participant's involvement and signed by the director of Army personnel was then sent by mail to all participants, who all agreed to participate. This letter was sent after receiving written approval from the Chief of Army to conduct this research project. Copies of the letter to participants and the Chief of Army's approval to conduct the research have been included in Appendix 2.

3.3.6 Content Analysis

A technique of content analysis known as constant comparative analysis was used to identify validity themes, and has been described in detail by Cavana et al. (2001, pp.

171-175). Content analysis was conducted in four major phases of data coding, as shown in Table 3.3.6-1 below, being the aggregation of the 15 steps described by Cavana et al. (2001) plus the addition of the final step to describe the user frames. Although Cavana et al. (2001) also recommended the mapping of relationships between themes, this was not completed because a descriptive framework was sufficient for the research objective. Nevertheless, further study to explain these relationships and thus develop a conceptual framework of user confidence would be worthwhile future research, to support the development of practical techniques for improving user confidence.

Table 3.3.6-1. *Content analysis stages.*

<i>Phase of analysis</i>	<i>Analytical focus</i>
<i>Open coding</i>	<i>Development of themes</i>
<i>Axial coding</i>	<i>Development of sub-themes</i>
<i>Selective coding</i>	<i>Development of meta-themes</i>
<i>Description of user frames</i>	<i>Integration and refinement of thematic levels</i>

3.4 Research Chronology

This section explains the actual events and the overall development of the study.

3.4.1 System Dynamics

The sequence of system dynamics model-building activities for this project are shown in Table 3.4.1-1 below. The model-building and data gathering phase of this project was completed from June to August 2006, achieving the three-month timeframe to ‘first model results’ recommended by Roberts (1978b). All steps of the ‘extended system dynamics methodology’ (Lane, 1995), except the final step of implementation, were undertaken. While the omission of this ultimate step was an undesirable outcome for the stakeholders, it was not necessary in order to achieve the research objective.

Table 3.4.1-1. *Sequence of major model-building and research activities.*

<i>Dates</i>	<i>Model-building Activity (refer to Table 3.3.2-1)</i>	<i>Framing Activity</i>
<i>1 June</i>	<i>Stage 1. Problem structuring: distribution of a written problem description (15 pages) by mail with a letter requesting participant involvement.</i>	.
<i>8-28 June</i>	<i>Individual discussion of the problem.</i>	<i>First interviews.</i>
<i>3 July</i>	<i>Stage 2. Qualitative model-building: distribution of a revised problem description (18 pages) with a written model description (17 pages).</i>	
<i>17 July – 2 August</i>	<i>Individual explanation of the conceptual model (using a causal loop diagram).</i>	<i>Second interviews.</i>
<i>2 August</i>	<i>Stage 3. Quantitative model-building; and Stage 4. Policy analysis: conducted as a group simulation session.</i>	
<i>8 – 17 August</i>	<i>Individual discussion of the policy options.</i>	<i>Third interviews.</i>

To overcome the tendency of stakeholders to view the problem in non-structural, ‘open loop’ terms the author provided a 15-page written brief of the problematic behaviour, demonstrating the behavioural connections between problem behaviour and management choices. As a supporting measure, the project also included in the system dynamics model several non-essential training policy variables, so that that it was later possible to demonstrate the principle of leverage and the increasing complexity of redundant policy options.

A preliminary model was used in this case study to abbreviate the model-building process, relying on the extensive mental database of the problem gleaned from more than two years experience in the role as the Army’s workforce planner. This preliminary model is referred to in the letter of research authority (refer appendix 2) and consisted of a single stock model with one enlistment inflow, one separation outflow and approximately 30 variables. This preliminary model was significantly modified to suit the narrow concerns of the chosen stakeholders. The reliability of this approach was enhanced by adding redundant variables to the conceptual and computational models, such as intake frequency and recruit course duration, to

demonstrate the relative insensitivity of the chosen workforce problem. Vennix has explained the circumstances in which it may be appropriate to employ a preliminary system dynamics model (1996, pp. 113-115), as a means to either speeding up the process or simplifying the process for an inexperienced model-builder.

The problem structuring for the system dynamics model was based primarily on the author's several years' direct experience in the field of workforce planning. This limitation on the degree and timing of model user participation was satisfactory since the purpose of the study was to elicit the concept of user confidence and interpret confidence criteria, rather than to achieve desired levels of confidence. Although Vennix (1996) has emphasized the importance of the neutral facilitation he does not explicitly warn against 'insider' model-builders.

3.4.2 Framing Interviews

A timeline showing the sequence of system dynamics model-building activities is shown in *Figure 3.4.2-1* below. This chart does not show the further 30-40 hours of model-building that occurred as the report was being written, in order to address additional points raised by model users during the final interviews. The system dynamics activity labels were borrowed mainly from Vennix (1996), as listed in Table 3.3.2-1 above. The truth of Sterman's description of system dynamics model-building process as a 'feedback process, not a linear sequence of steps (where) models go through constant iteration, continual questioning, testing, and refinement' (2000, p. 87) is illustrated in this chart. The problem structuring stage was evidently the most demanding substantial aspect and continued throughout the project. This illustration also clearly shows the three activities of system conceptualization and testing were the fundamental iterative activities of this project, and combined they represented a majority of the volume of system dynamics effort. The conduct of framing interviews, which occurred in parallel with system dynamics model-building, is discussed in the following section.

Figure 3.4.2-1. Sequence of model-building activities.

3.4.3 Framing

The framing research activities in this study unfolded as shown by the stages of model-building in Table 3.3.2-1. The first framing interview was scheduled after the initial phase of problem structuring so the model users could orient themselves within the context of the problem and the project. Although by this early stage the selected model users had not observed any components of the model, their view of confidence were still sought, as recommended by Landry et al. (1981). The second and third interviews were scheduled to occur immediately after the qualitative and quantitative model-building stages respectively, in order to capture the impact of these different approaches on the concept of user confidence. This design choice proved insightful as the results have shown (refer section 5.2).

3.4.4 Analysis

The descriptive framework of user confidence is summarised in appendix 5 by a list of themes, sub-themes, meta-themes and thematic rules for inclusion. This information is the outcome of the content analysis technique described in section 3.3.6. A summary of all interview recordings is included in Table 3.4.4-1 below.

Table 3.4.4-1. *Duration of interview recordings.*

These interview recording durations (in minutes) exclude interview preliminaries, reciting data from previous interviews, demonstrating aspects of the model and interview closure process. (T) denotes the only telephone interview.

<i>Model User</i>	<i>Interview 1</i>	<i>Interview 2</i>	<i>Interview 3</i>	<i>Total</i>	$\mu (\sigma)$
<i>A</i>	51	52	27	130	43.3 (14.2)
<i>B</i>	59	67	30	156	52.0 (19.5)
<i>C</i>	50	46	33	129	43.9 (8.9)
<i>D</i>	50	41	17	108	36.0 (17.1)
<i>E</i>	44	33	21	98	32.7 (11.5)
<i>F</i>	68	(T) 26	11	105	35.0 (29.5)
<i>G</i>	44	23	15	82	27.3 (15.0)
$\mu (\sigma)$	52.3 (8.6)	41.1 (15.5)	22.0 (8.2)	115.4 (24.6)	

All interviews were recorded electronically, with written and confirmatory verbal participant consent at the commencement of each interview. The second interview for model user F was the only telephone interview during this study, precipitated by pressing work commitments. Only one instance of retraction was noted during all 21 interviews, when the participant requested confidentiality for a statement relating to a sensitive work issue. The author personally transcribed the total 13.5 hours of recording and found this exercise useful from the perspectives of reflection and interpretation. The reflective aspect of this task was particularly helpful for the author because it alerted him to his prejudices from recent employment as an organisational insider. This enabled the author to tune data interpretation for personal bias while also providing an opportunity to improve interview and consulting technique as the study progressed. The author's interpretive ability was also enhanced by self-transcription because it led to reflection on all the data from beginning to end, in addition to the three complete readings of the data during content analysis. The impact of transcription was so pervasive that while writing up the results and discussion the author could 'hear' the tone, pitch and tenor of the participant's voice speaking the words in his head.

For each stage of content analysis the interviews were grouped and read by model user, rather than follow the order in which interviews were conducted. This was done

in order to interpret themes in the context of that model user's frame and thus highlight any shifts in that frame. All analysis and reading of interview data was conducted using the typed transcripts, except on a few rare occasions where it was necessary to check the exact wording of a phrase by listening to the digital recording. All themes and sub-themes were reviewed after analysis of each interview transcript.

Content analysis was conducted in general according to the structure in section 3.4.4. During the first reading, sub-themes were grouped under themes; new themes were added and several themes were removed or absorbed into existing themes. Meta-themes also began to emerge at this point but were put aside until a later stage. Several equivocal sub-themes and themes were highlighted for review during the axial coding stage. It was also apparent at the completion of open coding that the quality and rigor of coding increased significantly during the coding process and therefore a follow-up reading of interview data was necessary to ensure consistency between interviews and users. This re-coding was postponed until the selective coding phase.

In contrast to open coding, where the analysis focused on the data, the axial coding phase concentrated on the thematic content and design. A central task of this stage was to verify the uniqueness and coherence of each theme by defining a 'rule for inclusion' of relevant data (Cavana et al., 2000, p. 174). Refinement of the sub-themes included: conversion to nounal phrases; making sure the terms reflected the language used by participants; ensuring the distinctness of each sub-theme and uniqueness across sub-themes; and confirming the assignment of sub-themes to themes and meta-themes. Review of the themes included: ensuring they contained at least one sub-theme; confirming their assignment to meta-themes and ensuring their titles expressed the range of meanings included in the sub-themes.

The focus of analysis during the third reading of the data was the refinement of the thematic structure across all levels, including sub-themes, themes, meta-themes and mega-themes. Descriptions of the mega-themes were created using concepts from the literature. Rules for inclusion were refined by comparing between themes, and then matching against the descriptions for the meta-themes.

The product of the three progressive stages of data codification was a table of observed themes for each model user at each interview stage (refer to section 5.2). A feature of these tables is the recording of six qualities of framing which were assessed

as most useful for frame interpretation: reference points, yardsticks, boundaries, highlighting, shadowing and metaphors. These characteristics were amplified with quotes drawn from the interview transcripts, to create a vivid picture of the user's frame. The combination of tabular results and textual description were then reviewed for coherence and internal consistency, resulting in removal of framing codes from previous stages of the analysis that were not justified by the context of the interview or the frame.

The penultimate stage of data analysis was the comparison of results and findings with issues and themes from the literature and findings of other research. This led to some changes to the sub-themes but no adjustment to the themes or perspectives. It was not appropriate to change the meaning of themes or perspectives at this stage but instead it allow the author to add further richness to any issues the had been overlooked during readings of the interview data.

The number of themes varied only slightly during analysis. After open coding, this list numbered 27, which then reduced to 24 after axial coding. The final list of themes numbered 24. It need also be mentioned that participant answers to closed questions were not coded because this data was invariably in the form of a leading question. As explanation of the character of the final 24 themes, these terms were expressed exclusively in a positive form, which therefore meant that some negative expressions were reversed and a few items were also not coded at all. To illustrate this point, the negative statement 'failure definitely can be unexpected' was coded under the positively worded sub-theme 'surprise' and theme 'challenge'. These explanations conclude the chronological explanation of the model-building, framing and content analysis processes, and therefore draws this chapter to a close.

3.5 Summary of Research Methodology

As noted in this and the preceding chapters, the design of this research study emerged from the author's situation as a system dynamics practitioner working within military workforce planning, and hence the choice of research methodology was as much the result of rational choice as it was the result of a feeling. The paradigm for this study is a mixture of positivism and interpretivism, which matches the general paradigm of the system dynamics method.

This study is built around the case study research method, which some see as risky but is also becoming more common (Remenyi et al., 1998). Case studies are considered essential in social research due to the general weakness of social theory (Flyvbjerg, 2004). This study is put forward as a potentially 'paradigmatic' type of case (Flyvbjerg, 2004) for the field of system dynamics military workforce models.

The 10 frame analysis questions of Russo & Schoemaker (1989) were used as the basis of structured interviews to elicit the concept of user confidence from principal model users. The author transcribed all interview recordings, coded all interview data into themes and structured the data into a descriptive framework using the data coding and structuring technique of constant comparative analysis (based on Cavana et al., 2001).

This research was conducted in an ethnographic manner, approaching the subject from inside the organisation and participating passively in the organisation to a moderate degree. The specific case study was selected after several years of reflective consideration and the conduct of the study was organised to minimize the potential effects of bias due to the author's interests in the subject. The following chapter describes the particulars of this case study and includes the system dynamics workforce planning model.

CHAPTER 4 : CASE STUDY

'The advent of a volunteer armed force, rising manpower costs and tight defence budgets have all served to make military manpower one of the most important issues in defence planning and budgeting.'

Cooper & Roll, 1975, p. 275

4.1 Overview of Chapter 4

This research investigates a strategic challenge facing the New Zealand (NZ) Army towards the beginning of 2006, to grow the headcount of the regular force workforce by approximately 22% over five years. (Refer to the glossary of terms in appendix 1, for a description of specialist terminology, such as 'regular force'.) This scenario was set in the context of high separation rates and persistent personnel shortfalls in the period immediately prior to the period of planned growth. The author became familiar with this problem in the years prior to this study while employed as the Army strategic workforce planner and chose this problem to study because it seemed to display the characteristics of a complex dynamic system. Some particular characteristics that stood out for this problem were time-delays between decision and effect (refer section 4.3.3); counter-intuitive consequences of decisions (refer section 4.4.7) and complex interdependencies between variables (refer Table 4.4.3-1). This chapter explains the details of that workforce problem and the model built to investigate the problem.

This chapter has been organized according to the stages of model-building identified in section 3.3.2: problem structuring, qualitative model-building, quantitative model-building and policy analysis. Section 4.2 concerning problem structuring describes specific workforce management aspects of the NZ Army and identifies the principal users for a system dynamics model of this problem. The qualitative modelling section 4.3 describes the dynamic hypothesis for this workforce planning problem and illustrates its dynamic behaviour using a systems diagram incorporating several feedback loops. Detailed information about the quantitative model then occupies a large part of this chapter, describing the main elements of the model and pertinent results. A number of policy insights for this particular workforce problem are explained in the penultimate section 4.4, followed by the chapter summary.

4.2 Problem Structuring

This section (based on Maani & Cavana, 2000) describes the situation of interest by defining the scope of the problem of retention and military personnel shortfalls. This structuring commences with a broad description of the NZ Army followed by a summation of the relevant external challenges and their problematic connections to structural components of the Army’s workforce management system. The scope of this study is defined by the boundaries of the sector diagram at the end of this section, and was derived from the analysis of stakeholders and their stakes, also summarised at the end of this section.

The NZ Army military workforce can be regarded as a developed form of ‘internal labour market’ (Boxall & Purcell, 2003) because it is highly structured and segmented with a constant upward transition of personnel, and almost exclusive entry into the workforce through the lowest level of employment. The uniformed population has been the larger and more problematic component of the defence workforce, and has been separated into regular force staff, who almost exclusively serve full time, plus a smaller pool of territorial force staff, who normally serve part time. The size of the regular force (RF) population, which makes up the majority of the Army workforce, has remained stable at approximately 4600 for the last decade.

Table 3.4.4-1. *NZ Defence Force and NZ Army workforce on 30 June 2006.*

<i>Personnel</i>	<i>NZ Defence Force</i>	<i>NZ Army</i>
<i>Regular Force</i>	<i>8949</i>	<i>4563</i>
<i>Non-Regular Force</i>	<i>2228</i>	<i>1912</i>
<i>Civilian</i>	<i>2193</i>	<i>745</i>
<i>Total</i>	<i>13,370</i>	<i>7,220</i>

Source: NZDF, 2006b, p. 38

The Chief of Army is responsible for directing the staff of the Army so that the total headcount of the Army achieves the targets set by defence headquarters. The main organizational function in this process is the Army human resources executive. A summary of personnel within the NZ Defence Force and Army is included in Table 3.4.4-1 above, noting that territorial force (“TF”) personnel comprise all the non-regular

force personnel in the Army. Expenditure on personnel consumed 37.1% of all defence expenditure for the period 1 July 2005 – 30 June 2006, including depreciation and capital charge (NZDF, 2006b, p. 40). The total NZ Army budget for RF salaries in the financial year ending 1 July 2007 was approximately \$190M.

4.2.1 Background to the Problem

This section illustrates the significance of the problem of achieving Army workforce planning targets, with particular reference to media reports about this subject. The management of the Army workforce has been the subject of considerable public and political interest in the years prior to this study. During the period 2003-2005 there were at least 34 separate newspaper articles from most of the major New Zealand cities expressing concern about the headcount and separation rate of the Army regular force, which peaked at a rate of 19.3 %p.a. in 2005. One senior Defence Force officer at that time described the state of defence force personnel as ‘a little bit brittle in places’ (The Dominion Post, 2005c) while public commentators identified the high separation rate as an obstacle to achieving its required strength (The Dominion Post, 2005a). Opposition politicians went as far as describing the situation as ‘too big to handle’ (The Press, 2005b). A strong economy and low unemployment have been cited by one senior officer as a cause of personnel leaving (Evening Standard, 2005) although the Minister of Defence hinted at the potential economic benefits to New Zealand of a high separation rate from the Defence Force (NZ Herald, 2005). The challenge to retain skilled staff has emerged as a major challenge for large organizations in the last decade (Holton & Naquin, 2004).

The desire to increase the size of the Army workforce has also been a focus of public interest, with the Army acknowledging that a high operational demand has placed strain on the remaining personnel (Otago Daily Times, 2005). The Chief of Defence Force has also acknowledged that the Army has been the worst of the services affected by the simultaneous challenges of shortfalls and growth demands (The Dominion Post, 2005b). In 2003 Jane’s Defence Weekly stated the NZDF separation rate was ‘too high for long term sustainability’ and apparently ‘attributable to poor pay relative to the civilian sector’ (Jane’s Defence Weekly, 2003).

The management of the Defence workforce has been separated into two distinct levels. Policy has been managed at Defence headquarters while the employment and

recruitment of personnel has been devolved to the three service (Navy, Army and Air Force) headquarters. However, a shift in personnel policy emphasis occurred in 1996 with the launch of a project titled 'Project 21', in reference to the policies that were intended to be in place at the start of the 21st century. The policy of offering a standard period of engagement of 20 years was removed and instead the three services were assigned the discretion to offer lesser periods of engagement to enlisting personnel. This initiative reflected a general move away from centrally prescribed personnel policy and shifted the emphasis towards the ability of the three services to 'strive for excellence in its management, supervision and leadership of people' as the means of creating 'happy employees... that do not want to leave' (NZDF, 2002).

The Army issued a 'retention directive' in 2004, noting 'the attrition rate for Army has remained steady between 16.5 % and 17.5 % for the last two years' and including the objective to 'increase the retention rate ... to 90 %' by December 2006 ('Army Retention Directive', 2004). At about that time, the Chief of Army was quoted as saying: 'our mission is to reduce the rate of attrition to 10 %' (The Press, 2005a). These facts suggest the use of separation targets as 'aspirational' goals for improving the workforce situation. This case study attempts to illustrate that this form of planning approach produced the unintended consequence of further workforce shortfalls.

Despite the intentions of Army managers in 2004, the separation rate subsequently leapt to a 30-year high of 19.3 %p.a. (NZDF, 2005) and then gradually receded to approximately 15 %p.a. in late 2006 and early 2007 (NZDF, 2007). These events suggest that the strategic management and policy measures were insufficient to achieve a sustainable and stable rate of RF separation. The actual separation and corresponding forecasts for the previous three financial years are shown in *Figure 4.2.1-1* below, as specified in the Army's annual plans for each of these years.

Figure 4.2.1-1. Comparison of recent actual and planned Army RF separation rates.
Source: Data obtained from the NZ Army.

Although the Army retention directive implied separation rates would be reduced by planned strategic interventions, there were no formal changes in personnel strategy nor were there any strategic changes to personnel management practice. As unfortunate as these events may seem, they should not have been unexpected according to Herman (2000) who asserts that most senior managers lack and experience of high-separation scenarios and familiarity with appropriate tools of intervention. Ramhall (2004) further adds that a theoretical basis for strategic intervention to reduce separation rates has not been available until recently.

From this historical account, it would appear the Army has adopted an aspirational approach to workforce planning without accompanying changes in personnel management practice or any deliberate method for achieving separation targets. To understand how the Army's workforce planning system has operated challenges it is necessary to consider the defining components of this problem.

4.2.2 Project Definition

This section describes the definitional aspects of the WETA model-building project, including the purpose of the model, the project stakeholders and the boundaries of the problem. The purpose of the WETA model was developed independently of the stakeholders, from professional knowledge of the workforce planning system. That purpose was stated as the identification of the leverage points in the workforce planning system for achievement of RF workforce targets.

Figure 4.2.2-1. Stakeholder map of the principal model users for the WETA model.

The principal model users of the WETA model were identified using stakeholder analysis (refer to section 3.3.2), and are shown in the stakeholder map in Figure 4.2.2-1 above. Only the generic roles of the stakeholders have been shown in this report, in the interests of privacy. Two separate workforce planning stakeholders were identified for this problem, partly because their stakes in the model were distinct but also because their inclusion provided an opportunity to explore differences in confidence criteria between a client and a model-builder.

The stakes of principal model users of the WETA model were identified from personal knowledge of the organisational lines of responsibility and supported by corporate documentation. This information was presented in Figure 4.2.2-2 below. While stakeholder analysis normally identifies individual stakeholders (Freeman, 1984), this study specifies only stakeholder groups as a means of protecting anonymity. From this analysis emerged the importance of the planning as well as training and financial management, the significance of which will become apparent in section 4.3.2 below.

These stakeholders and their stakes define the boundary of the problem of achieving RF workforce targets, and link directly to the sectors and key variables of the causal loop diagram presented in the following section.

Figure 4.2.2-2. Stakeholder map of the principal model users and their stakes.

There are direct linkages between the stakeholders, their stakes and the sectors of the model developed to understand the problem of workforce target achievement. These sectors are shown in Figure 4.2.2-3 below and include the causal linkages; which are described in detail in the following section. The principal model users identified in this section represent all of the sectors defined by these boundaries, with the training and finance sectors being singularly ‘owned’ by their respective stakeholders. This approach for structuring the problem was a clear and effective way to generate model user ownership at the beginning and retain attention on the key aspects of the problem through the model-building process.

Figure 4.2.2-3. Model and sector boundaries for the RF workforce planning problem.

4.3 Qualitative Model

This section of the case study provides a qualitative description of the model for the problem or workforce shortfalls. The key components of that description, following the guide in Maani & Cavana (2000, chapter 3), are an illustration of the reference mode, the causal loop diagram, feedback loops, key variables, generic system structures, key leverage points and potential policy options. All variables included in this system dynamics model-building project were ‘hard’ or quantitative in nature, primarily because at the time of this research insufficient analysis had been undertaken to quantify the relationships between soft workforce variables.

4.3.1 Reference Mode of the Problem

The first step in building a system dynamics model is to identify the nature of the system behaviour and its problematic character. Figure 4.3.1-1 below shows the main event of interest and the pattern of behaviour behind it. The key variables for this problem are RF strength and separations in the four years prior to this research, illustrating a period of personnel shortfalls within an overall pattern of goal-seeking behaviour. The three-year RF strength shortfall was an event of significant concern and corresponded to the pattern of aspirational separation forecasts shown in *Figure*

4.2.1-1 above. This picture suggests that dynamic forces influencing the behaviour of the system are not in balance, causing the system to operate in a non-linear manner. As Forrester (1961) has explained in chapter 4 of *Industrial Dynamics*, such behaviour is characteristic of organisations.

Figure 4.3.1-1. Historic pattern of achievement of the RF workforce target.

Source: Data obtained from the NZ Army.

Having identified the parameters of a problematic situation, the subsequent step in system dynamics model-building is to formulate a dynamic hypothesis (refer to section 3.3.2). With this event and pattern of behaviour in mind, it was apparent that the instability of the RF workforce system arose from dynamic interaction between workforce management policies and conditions of the external environment, complicated by the time delay between striking recruitment plans and implementing them. From this it was hypothesized that workforce shortfalls are the combined consequence of planning flexibility and training capacity being insufficient for the uncertainty and volatility of separation rates. The following sections of this chapter show how this proposed cause of the dynamic problem is linked to the structure of the workforce planning and training system.

4.3.2 Causal Structure

The title of ‘WETA’ was chosen for this workforce planning model as the acronym for ‘workforce enlistment target achievement’. The use of a distinctive name was intentional as a means of stimulating interest in the model and therefore exposing a potential confidence criterion for model use. WETA is both a proper noun, meaning a large and iconic insect species native to New Zealand, as well as a proper noun as the company name for a high-profile film production studio in Wellington.

The key variables defining the boundary of the WETA model were identified using the list extension technique (Coyle, 1996), and are summarised in Table 4.3.2-1 below. Although the RF strength target was adjusted downwards in July 2006 (refer to *Figure 4.3.1-1*), this variable was excluded from the model for the sake of simplicity, and could be considered for inclusion in a future version. The following section specifies the detailed structure and causal relationship between these variables in the WETA model.

Table 4.3.2-1. *Key variables for the WETA model.*

<i>Endogenous (1)</i>	<i>Exogenous (2)</i>	<i>Excluded</i>
<i>Desired separation rate</i>	<i>Strength target</i>	<i>Retention factors</i>
<i>Time to achieve desired separation</i>	<i>TF on operations</i>	<i>Financial constraints</i>
<i>Recruit planning lead-time</i>	<i>Annual separation trend</i>	<i>Trade training capacity</i>
<i>Time to reduce strength shortfall</i>	<i>Separation seasonality</i>	<i>Strength target adjustment</i>
<i>Target review frequency</i>	<i>Enlistment shortfalls</i>	<i>Enlistment seasonality</i>
<i>Trained target</i>		<i>External labour demand</i>
<i>Cadet target</i>		<i>External labour supply</i>
<i>Recruit target</i>		
<i>Recruit training capacity</i>		
<i>Recruit bed capacity</i>		
<i>Recruit intake frequency</i>		
<i>Recruit intake distribution</i>		
<i>Recruit training duration</i>		
<i>Annual pay increase</i>		

Notes: (1) ‘Endogenous’ is defined as ‘originating from within’ (Concise Oxford Dictionary, 1990, p. 387) and (2) ‘Exogenous as ‘originating from outside’ (Concise Oxford Dictionary, 1990, p. 410).

A causal loop diagram of the model’s variables was constructed from these key variables, illustrating the major feedback processes of the WETA model in *Figure 4.3.2-1* below. It is evident from this diagram that the WETA model is a first order population model (Sterman, 2000, chapter 8) whose behaviour is constrained by three balancing feedback loops with varying degrees of delay. The structure of this model contains a

degree of complexity, but less feedback than other recent first order system dynamics workforce models (see for example Holström & Elf, 2005 and Tabacaru, 2005). Nevertheless, the interaction of the specified loops provides sufficient complexity to create the system dynamics behaviour necessary for the research objectives. *Figure 4.3.2-1* has been simplified to show only the main dependent variables of the model. The following section explains the structure of each of the three feedback loops in this model, including the omitted independent variables.

Figure 4.3.2-1. Major feedback processes of the WETA model

4.3.3 Feedback Processes

The separation loop, shown in *Figure 4.3.3-1* below is a fundamental component of the structure of the workforce system and the way it is formulated expresses the expected degree of management influence over the number of personnel leaving. This feedback structure represents the process of population decline which is a standard feature in population models (see for example Maani & Cavana, 2000). The causal logic for loop B1 was structured with the rate of separation being determined by external environmental factors, represented by the separation trend and seasonality variables. This causal explanation is the simplest formulation for a population model and it was utilised because of the time constraints of this research project and some

critical gaps in statistical analysis of retention factors at the time of this study. More recent system dynamics workforce models of retention policy have included a number of internal causes of separation as mediatory factors between the strength and separation variables (as illustrated qualitatively in Cavana, 2004 and simulated quantitatively in Holström & Elf, 2005), although no such model has yet been reported as operationally accepted by its clients. Nevertheless, it would be advantageous to include retention policy variables in future versions of the WETA model, or at least introduce some probabilistic behaviour into this part of the model to simulate uncertainty and randomness.

Figure 4.3.3-1. Loop 1: Separation.

The simplistic linear formulation of loop B1 was judged to be adequate for the purposes of this model-building project due to the apparent dominance of an external employment demand compared to the initial state of Army retention policy (described in section 4.2.1) at the time of this study. One former Assistant Chief of Personnel stated that: ‘We are ... susceptible to voluntary attrition due to external employment opportunities offered by more fully resourced competitors within the public and private sector’ (Human Resources Magazine, 2004). A similar explanation was provided by the NZ Ministry of Defence (2004, p. iii):

‘It is not possible to ‘manage’ retention (or, conversely, the rate at which people leave the Services). Retention will only improve when conditions of service within the NZDF encourage people to stay. Against this, however, will be external pressures. In times of high unemployment (or job shortages) there is less incentive for individuals to leave. On the other hand, when jobs—often at rates of remuneration above that paid to service members—are plentiful, even minor dissatisfiers can persuade an individual to leave.’

The implicit aim of internalising the causes of separation, as the system dynamics method encourages and recent models have demonstrated, would be to increase the degree of managerial control over separation flows. However, there are two substantial

assumptions on which the suitability of this notion of control rests. First is the assumption that it is feasible to specify a separation goal. This notion has been recently explored by the US Department of Defence where it was discovered that ‘no one in the services can define exactly what portion of attrition can be avoided’ (USGAO, 1997, p. 19). This highlighted the consequential risk that ‘establishing arbitrarily defined targets for reducing attrition, without knowing precisely what these targets should be, could result in the services retaining (the wrong) recruits’ (USGAO, 1997, p. 4). In other words, although separation may be a widely acknowledged problem, in most large organisations there is insufficient clarity about what retention actually means. The second and related key assumption is that implementing goal-driven retention management practices in a strategic manner would be cost-effective and therefore a business decision that executives might willingly select. While reported estimates of the cost-effectiveness of retention practices are common (such as Mullich, 2005) these reports generally lack the basic elements of scientific proof such as a sound basis in theory and refutation of plausible alternative explanations.

Noting these caveats and assuming that separation goals are definable, it would then be sensible to accumulate several years of longitudinal separation data concerning specified retention policies or practices in order to confirm their effectiveness (USGAO, 2000). On this basis, it was judged that the introduction of effective goal-based retention management practice in the Army would be beyond the time horizon of dynamic analysis in this study. Notwithstanding the apparent crudeness of this major assumption, it would be wrong to extrapolate it to mean that judgemental separation forecasts are adequate for planning purposes. Instead, the use of judgemental separation forecasts for enlistment planning is precisely how it would seem that the workforce planning approaches of the past have been perpetuating workforce shortfalls into the future. This chapter therefore attempts to show how this problem can arise through the structure of feedback loop B2 and the remainder of this chapter.

The target achievement loop, labeled ‘B2’ (refer to *Figure 4.3.3-2*) represents the enlistment planning and decision-making process through which the Army has sought to achieve previous strength targets. The structure of this loop is a first order feedback process, which seeks the goal of a null strength shortfall. The recruit target has been based on the desired separations, strength shortfall and target growth, noting the period of delay between setting the target and realizing the respective enlistments for that

The diagram illustrates the B2 program's causal structure. Key nodes include Enlistment, Strength, Strength shortfall, Recruit target, and a delay block. Causal links are marked with 's' (same) or 'o' (opposite). A feedback loop is labeled 'B2'.

- Enlistment target shortfall** (grey) → **Enlistment** (grey) [o]
- Enlistment** → **Strength** [s]
- Strength** → **Strength shortfall** [o]
- Strength shortfall** → **Recruit target** [s]
- Recruit target** → **Enlistment** [s]
- Recruit target** → **Strength** [s]
- Recruit target** → **Target growth** [s]
- Target growth** → **Strength target** [s]
- Strength target** → **Strength shortfall** [o]
- Strength target** → **Recruit target** [s]
- Desired separations** (grey) → **Recruit target** [s]
- Trained target** (grey) → **Recruit target** [o]
- Cadet target** (grey) → **Recruit target** [o]
- Review frequency** (grey) → **[delay]** [o]
- Planning lead time** (grey) → **[delay]** [s]
- [delay]** → **Enlistment** [s]
- [delay]** → **Recruit target** [s]

A feedback loop labeled **B2** connects **Recruit target** back to **Enlistment** via **Strength** and **Strength shortfall**.

A feature of the enlistment planning process, as shown in *Figure 4.3.3-2* is that it must incorporate some future estimate of the separation flow. While the strength shortfall and target growth components of this calculation can be anticipated with a high degree of confidence, the volume of future separation is an area of considerable uncertainty, as demonstrated in section 4.2.1. It should be noted that no causal connection has been specified between the separation trend in loop B1 and the separation forecast in loop B2, although there has clearly been some judgemental association in the past. A judgemental forecast of separation, referred to here as ‘desired separation’ has traditionally been used for this calculation, which recent patterns show has been anticipated at an aspirational level with respect to the actual behaviour (refer to *Figure 4.2.1-1*). A similar tendency to over-estimate the degree of control over a crucial rate of change has been observed with the Reserve Bank of New Zealand’s forecast of domestic inflation (Kiernan, 2007). The chain of causal effect shown in loop B2 indicates that a poorly judged forecast could lead to a reduction in strength, and therefore a persistently aspirational target might lead to the long term under-achievement of actual strength cf. strength targets.

The third feedback process in the WETA model is the training capacity loop, B3 (refer to *Figure 4.3.3-3*). This loop demonstrates the impact that training capacity might have on the actual enlistment of RF and like loop B2 it also contains a time delay. It is important to note that any constraining impact of training capacity would be conditional rather than automatic, meaning it would only take effect when the number of recruits under training exceeded the bed capacity.

Figure 4.3.3-3. Loop B3: Training capacity.

An area of policy leverage ‘refers to actions or interventions that can have a lasting impact on the system in terms of reversing a trend or breaking a vicious cycle’ (Maani & Cavana, 2000, p. 37) and implies the multiplying effect of a small effort applied in a judiciously chosen manner. The suggestion to this point has been that the forecast of future separation may be a policy leverage point in the enlistment planning process. While aspirational separation forecasts have been used more recently for enlistment planning, a policy worth further analysis is the incorporation of the more realistic expectation that environmental conditions will continue to be volatile and uncertain. It would appear that changes can be made to separation forecasts for relatively little physical or procedural cost, with potentially significant results. The purpose of the remaining sections of this chapter is to test this and other policy options using computational simulation.

4.4 Quantitative Model

The WETA model was developed in Powersim Studio 7, with input and output data handled using Microsoft Excel. The model was developed using information from

organisational documents and first hand knowledge of planning processes and training systems gained from managerial involvement. The aggregated input data for historical values and future targets and estimates was supplied by staff of the Human Resources Executive within Army General Staff. The major assumptions emerging from the boundary and structure of this model are listed below:

- Separation flows would be driven exogenously, meaning that retention variables would be ignored or dominated by influences in the external environment, particularly demand from the external labour market.
- Separation flows would continue to be a linear function of headcount, although the headcount may increase by up to 17 %p.a. and thus lead to an initial increase in the proportion of junior personnel.
- The main policy variables, such as the desired separation rate or TF deployment duration, would be relatively constant into the future.
- Recruit enlistment would be the main control variable for enlistment, compared to the officer cadet and trained enlistment streams. Similarly, variations in officer cadet enlistment and trained personnel enlistment would not be significant compared to variations in the soldier recruit flows.
- The recruit training capacity could be represented by the bed capacity as this is a suitable proxy for the various other constraints that might affect the flow of recruits into the Army, such as the number of recruit instructors, recruit training budget, training equipment availability or training facility availability. Also, while the number of recruit instructors may temporarily fall below the required number, the model assumes the remaining staff can provide the required level of training despite increased recruit-instructor ratios.
- The size of an operational commitment requiring a block deployment of TF would not change significantly over the duration of the deployment.
- The salaries of TF serving as RF on operations would continue to be paid from the Army personnel budget.

4.4.1 Computational Model

The Powersim diagram of the WETA model is shown in *Figure 4.4.2-1* and a list of WETA model equations and documentary comments is attached as Appendix 4. The WETA model is a first order population model with a co-flow structure to simulate training capacity (Sterman, 2000). The enlistment planning sector incorporates information and planning calculations based on simple, linear adjustment-to-goal decision logic (Sterman, 2000, section 13.2.3).

Table 4.4.1-1. *Summary of the WETA model input variables.*

<i>Variable Name</i>	<i>Type of variable</i>	<i>Base Case</i>
WORKFORCE SECTOR		
<i>Max_Separation</i>	<i>Scenario</i>	<i>18.0 %/year</i>
<i>Min_Separation</i>	<i>Scenario</i>	<i>12.0 %/year</i>
<i>Sep_Cycle_Time</i>	<i>Scenario</i>	<i>5 years</i>
<i>Sep_Seasonality</i>	<i>Scenario</i>	<i>Ref Figure 4.4.2-2</i>
<i>TF_Ops_Demand</i>	<i>Scenario</i>	<i>80 person</i>
<i>Enl_Target_Gap</i>	<i>Scenario</i>	<i>0 %</i>
<i>Deployment_Length</i>	<i>Policy</i>	<i>8 months</i>
ENLISTMENT PLANNING SECTOR		
<i>Total_Strength_Target</i>	<i>Scenario</i>	<i>Max 5400 person</i>
<i>Recruiting_Lead_Time</i>	<i>Policy</i>	<i>6 months</i>
<i>Target_Review_Freq</i>	<i>Policy</i>	<i>4 months</i>
<i>Time_to_Reduce_RF_Shortfall</i>	<i>Policy</i>	<i>1 year</i>
<i>Desired_Sep_Rate</i>	<i>Policy</i>	<i>14 %/year</i>
<i>Time_to_Reach_Desired_Sep</i>	<i>Policy</i>	<i>2 year</i>
<i>Trained_Target</i>	<i>Policy</i>	<i>120 person/year</i>
<i>Cadet_Target</i>	<i>Policy</i>	<i>60 person/year</i>
TRAINING SECTOR		
<i>Recruit_Trg_Duration</i>	<i>Policy</i>	<i>3 months</i>
<i>Recruit_Bed_Capacity</i>	<i>Policy</i>	<i>320 beds</i>
<i>Intake_Freq</i>	<i>Policy</i>	<i>4 courses/year</i>
FINANCE SECTOR		
<i>AnnI_Pay_Incr</i>	<i>Policy</i>	<i>4.00 \$/year</i>

A summary of the main input variables for the WETA model are shown in Table 4.4.1-1 above. The training and enlistment planning sectors would appear to be highly controllable areas of Army workforce management, because there is only one scenario variable (*Total_strength_target*) to the seven policy variables. In contrast, the central workforce sector is dominated by scenario variables; which suggests that within this crucial part of the organisation the impact of uncertain future events may be considerable. However, the complexity of policy options, evident from the seven enlistment planning variables and five training policy variables, suggest that the implications of management choices may be difficult to anticipate and the location of

the time delays in feedback loop 'B2' suggest that the implications of policy choices may be variable over time.

4.4.2 Workforce Sector

The purpose of the workforce sector is to simulate the main components of the RF population, including the crucial RF separation flow. The structural computational core of the workforce sector is a stock-flow module representing RF serving and separating. This structure simulates the feedback loop 'B1' and has been formulated as a first-order linear negative feedback structure (McLucas, 2005, pp. 195-197).

A crucial variable in this module is the rate of separation, which was formulated as a 'central rate' (Smith, 1976, p. 285) by combining two time series components of seasonality ('Sep_Seasonality') and trend ('Sep_Trend'). The seasonality component of RF separation, following a procedure of time-series decomposition from econometric analysis described in Hanke, Reitsch & Wichern (2001, pp. 157), was extracted from historical data between 1992 and 2006 by removing the 12-month rolling average as a base component. The future seasonality component, or 'index' was then calculated by averaging the same months from the previous two years, with 2/3rd weighting on the more recent index and 1/3rd weighting on the older index to emphasise variations in the most recent year. The seasonal separation indices for simulations of the future are shown in *Figure 4.4.2-2*, demonstrating that generally separation is above the annual average at the start of the year, below at the end of the year and approximately equal in the middle of the year.

Figure 4.4.2-1. Diagram view of the WETA model.

Figure 4.4.2-2. Seasonal RF separation indices calculated for calendar year 2003.

Source: Data obtained from the NZ Army.

A side-by-side comparison of the forecast separation rate and actual separation rate for the previous 14 years using this forecasting technique is shown in *Figure 4.4.5-1* below. The forecast rates shown here were used in the WETA model to simulate historical behaviour. This graph illustrates the annual pattern of seasonal separation variation, peaking in January each year.

Figure 4.4.2-3. Actual RF separation rate and forecast rate for the period 1992-2006.

Source: Data obtained from the NZ Army.

The formulation of a separation trend for the WETA model was crucial to a realistic simulation of future workforce strength. The 12-month rolling average RF separation rate and fitted linear annual trend used for simulating periods prior to 1 July 2006 are shown in *Figure 4.4.2-4*. The linear trend line has been fitted to an annual anchor on 1 July each year to align with the annual financial period within the NZDF. Inspection of the historical separation trend, as Hanke, Reitsch & Wichern (2001) have found with most time series data, revealed no pattern of cyclical separation behaviour for periods greater than 12 months. Nonetheless, this picture of separation flow is instructive because it exhibits a high degree of uncertainty and volatility.

Figure 4.4.2-4. Average Army RF separation rate and annual trend lines: 1992-2006.
Source: Data obtained from the NZ Army.

The grey-shaded area in *Figure 4.4.2-4* represents a band of historically normal separation behaviour between 12 %p.a. and 16 %p.a., showing that values outside this band have occurred with a frequency of about 6 or 7 years. The rolling average has varied erratically in the past, particularly in the last decade, with annual changes in the separation trend of between -3.8 %p.a. and +2.9 %p.a. These variations equate to changes in the separation flow of up to 170 personnel. Given this high degree of variability and uncertainty, a prudent default forecasting rule might be to assume 0 %p.a. change for any coming year. As explained in section 4.2.1, a ‘planned’ rate of separation has been used instead.

A cyclical pattern of separation behaviour was simulated in the WETA model using a sinusoidal waveform with a wavelength at least four times the simulation time step. While the seasonal component of separation was not essential for the demonstration of this dynamic effect it proved useful for illustrating the variability or ‘noise’ for strength levels and satisfying the model users’ desire for a realistic simulation. Stochastic variability was not attempted for this model due to the limited model-building objectives of this project, although it could be used in future versions to demonstrate the implications of uncertainty.

The stock of TF personnel on operations (‘TF_on_Ops’) was constructed as a first order delay module (McLucas, 2005), with an outflow (‘TF_from_Ops’) that exactly imitated the inflow (‘TF_to_Ops’) after a specified delay period (‘Deployment_Length’) where the delay included time spent in RF service for pre- and post-deployment activities. The timing of personnel cycling through this stock was determined by the year in which operations commenced (‘Ops_Surge_Year’), the size of the deployment (‘TF_Ops_Demand’) and the number of consecutive block deployments (‘TF_Ops_Tranches’). The flow of enlistments into the main RF stock (‘RF_in_Army’) was reduced by a factor due to total enlistment shortfalls. This factor was kept constant in the WETA model but after further testing and development, should be converted into a probabilistic variable.

4.4.3 Enlistment Planning Sector

Figure 4.4.3-1. Elements of the recruit planning calculation.

The calculation of a future enlistment target is a complex algorithm. A large part of the uncertainty involved in this forecast is that the major component of this calculation, the future separation rate, is unknown at the time of computation. Another problem is that allowance must also be made for corrective action to reduce any strength shortfall at the time of the estimate, as well as inclusion for any future change in the strength target. The final element of complexity in this policy situation is that because enlistment plans are recast on a frequent basis, the period of forward planning will be extended on average by half the cyclic period of revision. These elements are illustrated in *Figure 4.4.3-1*, where the shaded areas represent the zone within which enlistment targets, once set, are frozen because any significant changes will not be achievable.

The purpose of the enlistment planning sector is to simulate the decision process for enlistment targets, and it should be apparent from *Figure 4.4.2-1* above that these decisions embody a high degree of complexity. The calculation for the planned annual enlistment variable is shown in Table 4.4.3-1 below, incorporating the policy factors discussed above. These variables make up the key variables in

feedback loop ‘B2’ and represent a complex version of the first order linear negative feedback module with explicit goal (McLucas, 2005). The enlistment plan calculation assumes linear interpolation techniques to adjust the strength, separation, target and shortfall components towards their respective future targets (as described in Sterman, 2000).

Table 4.4.3-1. *Components of the enlistment planning calculation.*

Calculation	Components
$Planned_Annual_Enlistment =$	
$+ \frac{Target_Growth}{1year}$	[1] Growth adjustment
$+ \frac{Strength_Shortfall_{delay}}{Time_to_Reduce_Shortfall}$	[2] Shortfall adjustment
$+ \left\{ \left[\begin{array}{l} Average_Separation_{delay} \\ + (Desired_Separation - Average_Separation_{delay}) \\ * \frac{(Planning_Lead_Time + Time_Between_Reviews)}{Time_to_Reach_Desired_Separation} \end{array} \right] \right.$	[3] Expected separations:
$+ \left\{ \left[\begin{array}{l} Average_RF_Str_{delay} \\ * \left(\frac{Target_Growth}{1year} + \frac{Strength_Shortfall}{Time_to_Reduce_Shortfall} \right) \\ * (Planning_Lead_Time + Time_Between_Reviews) \end{array} \right] \right.$	<p>rate at the time of calculation</p> <p>desired change in rate</p> <p>adjustment time for desired change</p> <p>strength at the time of calculation</p> <p>planned strength corrections</p> <p>adjustment time for corrections</p>

The enlistment plan calculation uses a time-delay function, referred to as a ‘pipeline delay’ to simulate the time difference between calculation inputs at the time of planning and the time when enlistment occurs, annotated in Table 4.4.3-1 with the subscript ‘delay’. This time delay consisted of two additive components: the lead-time required for the recruitment process and the average time between reviews of the enlistment plan. The planning lead-time for military recruitment is

considerable due to a range of factors, including advertising lead-times, the large number of military trade specializations (approximately 30), the infrequency of recruit training (annual for some trades), plus screening and clearance requirements. The time between enlistment target reviews is constrained by other demands on the Army workforce planner's time, and synchronization with financial and other planning review cycles.

The all-important Army rate of separation has been forecast by judgemental techniques, which has been surprisingly common in many large organisations (Stermann, 2000). The Army has used a desired separation goal that is expected to achieve the target after a period of adjustment and delay. In the three years prior to this study, the desired separation rate was, on average three percentage per annum below the actual separation rate for that same year, which equates to a forecasting error of approximately 130 enlistments.

4.4.4 Other Sectors

The purpose of the training sector is to show the impact of training capacity constraints and training scheduling on the supply of RF personnel. The main dynamic element of the training sector is the stock of recruit capacity ('Empty_Recruit_Beds'), which was built, much like the module for TF serving short engagements in RF for operational deployments ('TF_on_Ops'), as a first order delay module (McLucas, 2005). The connection of this module to the recruit enlistment flow ('Recruit_Enlistment') means that it operates as a balancing feedback loop ('B3') and was constructed as a first-order linear negative feedback module (McLucas, 2005).

The expenditure, budget and variance variables in the finance sector provide an indicative forecast of financial impacts for the financial planning stakeholder in this project. A recommended area for further development of this model is to 'close the loop' between the budget variance and consequential limits on enlistment.

4.4.5 Model Testing

The tests used in this study are listed in Table 4.4.5-1 below, drawn from the schedule of tests developed by Forrester & Senge (1980).

Table 4.4.5-1. *'Confidence-building tests' used for the WETA model.*

No.	Test Name	Details
1.	MODEL STRUCTURE TESTS	
1.1	Structure verification	The model was audited against the sector diagram and causal loop diagram, and verified in discussion with stakeholders.
1.2	Parameter verification	The model was peer reviewed by model user with model-building experience, leading to the correction of anomalies.
1.3	Extreme conditions	The model was simulated with high and low values of all input variables.
1.4	Boundary adequacy	The model was subjected to repeated stakeholder review, at each interview and the group model-building session.
1.5	Dimensional consistency	Dimensional balance is a mandatory, automated, live test in Powersim Studio 7.
1.6	Statistical tests	Omitted because WETA is a policy rather than a forecasting model.
2.	MODEL BEHAVIOUR TESTS	
2.1	Behaviour reproduction	Simulation results for the historical period 1/07/2002 to 1/07/2006 displayed corresponding patterns, particularly in 2005 and 2006 where the number of recruit intakes was the same as the simulation. Refer to Figure 4.4.5-1.
2.2	Behaviour prediction	Refer to Figure 4.4.6-1.
2.3	Behaviour anomaly	Anomalies were continually identified and investigated during model-building.
2.4	Family member	Components within the model were verified against system dynamics modules in McLucas (2005).
2.5	Surprise behaviour	A number of surprise results occurred during sensitivity analysis, and were verified by further simulation.
2.6	Extreme policy	<i>Not tested.</i>
2.7	Boundary adequacy	<i>Not tested.</i>
2.8	Behaviour sensitivity	<i>Not tested.</i>
2.9	Point-by-point comparison	The comparison against historical data in Figure 4.4.5-1 highlights that some variables held constant in the model were dynamic over the simulation period, such as the number of recruit intakes.
3.	POLICY IMPLICATION TESTS	
3.1	System improvement	Feedback from stakeholders indicated some of the policies were already being considered, such as using a higher desired separation rate.
3.2	Changed-behaviour prediction	<i>Not tested.</i>
3.3	Boundary adequacy	<i>Not tested.</i>
3.4	Policy sensitivity	Refer to Table 4.4.7-1 below.
4.	ADDITIONAL TESTS	Other than Forrester & Senge (1980)
4.1	Mass-balance	Indirectly verified in Figure 4.4.5-1.
4.2	Calculation sequence	<i>Not tested.</i>
4.3	Integration error	<i>Not tested.</i>
4.4	Face validity	Users accepted the model, individually and during the group session.
4.5	Appropriateness	The model structure confirmed the stakes of the principal model users (refer section 4.2).
4.6	Insight generation	Insights about the recruitment planning approach were reported to the model users.
4.7	Importance of model objective	The achievement of workforce targets continued to be an important organisational and public issue during this study.

Confirmation of the dynamic hypothesis (refer to section 4.3.1) was evident from the matching of dynamic patterns rather than the exact correspondence of data points (Sterman, 2000). The jagged appearance of the strength output in Figure 4.4.5-1 suggests an acceptable match between the simulation and actual data.

Figure 4.4.5-1. 'Behaviour reproduction' results for the period July 2000 - July 2006.

Source: Data obtained from the NZ Army. Simulation results from the WETA model.

4.4.6 Simulation Results

The simulation results from the base case scenario are depicted in Figure 4.4.6-1 below, based on the scenario and policy variable values in Table 4.4.1-1 above. This reference scenario suggests that the headcount of Army RF workforce population will continue to undershoot the strength target, particularly when the separation rate rises steeply and during periods of planned growth. Of concern also is that the workforce strength may decline after 2011, rather than remain near the higher target level at the end of the growth period. This possible long term declining behaviour would occur if the separation rate again rose above 16 % per annum since the recruit training capacity is not designed to cope with the larger workforce population of 5400 RF personnel.

Figure 4.4.6-1. 'Base case' simulation for the period 2000-2015.

Source: Data from the NZ Army. Simulation results from the WETA model.

The simulation results in Figure 4.4.6-2 below illustrate the impact of using a desired separation rate value at the high end of the historical range (18 %p.a.) compared to a moderate value (14 %p.a.). The enduring effect of this policy change is an improvement in the strength of at least 50 personnel, including times of high separation rates (18% p.a.). In addition, the remaining shortfall suggests that recruit training policies may be decisive in the achievement of increasing workforce targets.

Figure 4.4.6-2. Simulation results for a reduction in the desired separation rate

Legend: 14 %p.a. (black) and 18 %p.a. (blue).

Source: Data from the NZ Army. Simulation results from the WETA model.

4.4.7 Sensitivity Analysis and Policy Insights

Sensitivity analysis draws comparisons between simulation runs that are identical except for measured changes in the value of one input variable, and cut through the complex dynamics of the model like the opposing blades of a pair of scissors (Ford, 1999). This study employed the technique of sensitivity analysis recommended by Maani & Cavana (2000) using a variance of plus or minus 10% for each variable. The performance variable selected as the basis of sensitivity comparisons was the average workforce shortfall ('Average_Shortfall') over the simulation period, and this calculation excluded instances of surplus where the strength exceeds the target.

The results of sensitivity analysis are shown in Table 4.4.7-1 below, noting the recruit training duration and intake frequency were varied by more than 10% because they were integer numbers. The change in output value for the performance variable is summarised as a proportion ($\pm\%$), with a negative value being an improvement because it represents a reduction in the workforce shortfall over that period.

Table 4.4.7-1. *Sensitivity analysis for the WETA model base case.*

Variable Name	Base Case	+10% Result	$\pm\%$	-10% Result	$\pm\%$
PERFORMANCE VARIABLE					
Average_Shortfall (Base Case)		195		195	
WORKFORCE VARIABLES					
Max_Separation	18.0	19.8	248 +27	16.2	142 -27
Min_Separation	12.0	13.2	222 +14	10.8	176 -10
Sep_Cycle_Time	5	5.5	186 -5	4.5	203 +4
TF_Ops_Demand	80	88	195 0	72	196 +1
Deployment_Length	8	8.8	197 +1	7.2	194 -1
Enl_Target_Gap	5	5.5	200 +3	4.5	191 -2
ENLISTMENT PLANNING VARIABLES					
Recruiting_Lead_Time	6	6.6	190 -3	5.4	201 +3
Target_Review_Freq	4	4.4	194 -1	3.6	197 +1
Time_to_Reduce_RF_Shortfall	1	1.1	203 +4	0.9	187 -4
Desired_Sep_Rate	14	15.4	178 -9	12.6	215 +10
Time_to_Reach_Desired_Sep	2	2.2	195 0	1.8	196 +1
Trained_Target	120	132	188 -4	108	203 +4
Cadet_Target	60	66	192 -2	54	199 +2
TRAINING VARIABLES					
Recruit_Trg_Duration	3	4 [+33%]	245 +26	2 [-33%]	95 -51
Recruit_Bed_Capacity	320	352	161 -7	288	241 +24
Intake_Freq	4	5 [+25%]	119 -39	3 [-25%]	95 -51

These sensitivity analysis results provide insights into the relative influence of variables on the achievement of workforce planning targets. Overall, the workforce shortfall appears to be most sensitive to scenarios with more extreme separation rate values, confirming these scenario variables as the governing assumptions of the model. The potential leverage to reduce workforce shortfalls through management control appears to be greatest using the training policy variables. A reduction in training duration or increase in training capacity would translate into a similar reduction of the shortfall, taking into account the relative impact of changing the training duration using only integer values. This finding is qualified by the caveat that the one-month time step used in these simulations could be a source of mathematical error because it is outside Sterman's guideline of 'one-fourth to one-tenth as large as the smallest time constant' (2000, p. 910); and should be investigated further to improve confidence in the results. Notwithstanding this reservation, the results show a non-linear relationship between the frequency of intakes and the workforce shortfall, with the outcome that any change from four intakes per annum would lead to a reduction of the shortfall. Given that intake frequency is primarily a scheduling matter, this policy insight could lead to significant performance improvement for relatively little effort. These policy insights highlight intake frequency policy as a likely point of management leverage, pending the assessment of other consequential impacts.

Results for the enlistment planning variables suggest that management policies in this area have relatively less impact on the achievement of workforce targets, the most leverage potential being for changes in the desired separation rate. The results for this planning input seem counter-intuitive because planning for a lower separation rate suggests a better performance however, the outcome is a corresponding (10%) increase in the shortfall. This result provides an explanation for the problematic shortfalls during the period 2003 to 2005, when aspirational separation forecasts were used. Further counter-intuitive results are apparent where reducing both the recruiting lead time and frequency of target review would result in worse shortfalls.

4.5 Summary of Case Study

This chapter demonstrates that the Army will face a complex and dynamic problem to achieve increasing workforce targets from 2007 until 2015. This assessment is based on the results of the WETA system dynamics model and is verified, in part, by replication of the pattern of workforce shortfalls between 2003 and 2005. It is likely, based on these WETA simulation results, that this problem will be exacerbated by reliance on ‘aspirational’ separation targets. In this case, using a separation ‘stretch goal’ for recruitment planning causes a counter-intuitively negative impact on workforce shortfalls. The main area of policy leverage for the achievement of future Army workforce targets appears to be in the frequency, duration and capacity of recruit training.

The qualitative and quantitative analysis in this chapter demonstrates that a number of opposing policy and scenario variables appear to be the cause of this dynamic behaviour, and therefore the Army workforce system is unlikely to reach a state of equilibrium in the long term. These results serve as experimental evidence to support the dynamic hypothesis that workforce shortfalls are the combined consequence of planning flexibility and training capacity being insufficient for the uncertainty and volatility of separation rates.

This dynamic problem involves a range of internal stakeholders in the areas of enlistment planning, training management and financial planning; confirming the selection of these personnel as interview participants for this research (see chapter 5). The suitability of the WETA model for eliciting the concept of user confidence was confirmed when one of the WETA model users stated: ‘The issues you are getting into now, as you are getting into the model, is an understanding of the complexities associated with dealing with this issue (of workforce target achievement)’. The following chapter goes on to explain those issues of confidence elicited from users of the WETA.

CHAPTER 5 : FINDINGS AND DISCUSSION

'HR is not scientific.'

WETA model user

5.1 Overview of Chapter 5

This chapter lays out the results and findings of the study, structured in two parts: the content of the views and frames of the model users and the methodological findings concerning framing. These sections answer the two research questions for this study.

5.2 Observations of User Confidence

This section summarises model user views and frames observed during the study. A comparative analysis of model user views and frames follows the observations, demonstrating the advantages of framing. A general discussion of the findings from model user views and frames concludes this section. The technique for collecting, analysing and interpreting the data is explained in Chapter 3. In order to disguise the identity of the research participants, all observations have been reported in the male gender.

5.2.1 Themes of User Confidence

A total of 120 distinct *confidence criteria*, also called sub-themes, were interpreted from framing interview data during this study. A full list of sub-themes and the rules for their arrangement in the descriptive framework of user *confidence* is included in Appendix 5. The interpreted *confidence criteria* were clustered into 24 high-level themes, each qualified by a descriptive 'rule for inclusion'. Those 24 themes were found to lie across the four main theoretical perspectives of operations research, management science and system dynamics literature, the perspectives being: *relativity*, *utility*, *empiricism* and *rationality*. The perspective of *utility* was found to contain the greatest richness of concepts (41 sub-themes spread across 8 themes), while the perspective of *rationality* contained the least (18 sub-themes spread across 5 themes).

Two overarching mega-themes were chosen to illustrate a distinction evident in operations research and management science literature: *proof* and *relevance*. The

concept of proof can be traced to Naylor & Finger (1967) who proposed a theory of validation by prediction, based on *rationalism* and *empiricism*. Lane (1995) has extended the work of Shannon (1975) to highlight the theoretical distinction between representativeness and usefulness, while Sterman (2000, p. 845) has alluded to it as ‘truth and beauty’.

Table 5.2.1-1. *Comparison of confidence themes with other system dynamics descriptive frameworks.*

Perspectives	Themes	‘Measures of validity’ Lane (1995)	‘Quality criteria’ Coyle (1996)	‘Desirable characteristics’ Randers (1980)
Relativity	Affect Discourse Satisfaction Significance Subjectivity Trust	Meaningfulness & communicability Relevance Cultural congruence Trustworthiness	Credibility	Relevance
Utility	Agency Benefit Cost Suitability Solvency Usability Use Usefulness	System improvement Fertility Time & cost Precision of insights Operational validity Ease of enrichment Usefulness of intervention	Creativity Cost Suitability Flexibility, simplicity & transparency Productivity Purpose	Fertility Transparency
Empiricism	Accuracy Analysis Experiment Fidelity Understanding	Data validity Analytical quality Experimental validity Conceptual validity Insight generating	Sensitivity Generality	Formal correspondence with data, & point predictive ability Descriptive realism, and mode reproduction ability Insight generating capacity
Rationality	Caveat Expertise Logic Sophistication Soundness	Guru status Formulational validity Rigour & robustness	Basis Redundancy Promotion	

Similar descriptive frameworks of *user confidence* (in Appendix 5) exist in the system dynamics literature, including the three shown in Table 5.2.1-1 above for comparative purposes. The most comprehensive of these frameworks is Lane’s (1995) hierarchy of ‘measures of validity’ from his ‘folding star’ framework of validity (see section 2.3.4). Lane’s measures of validity appear to fit isomorphically against the themes and perspectives of *confidence* that emerged from this research. In comparison, Coyle’s and Randers quality criteria appear to map unevenly against these *confidence* themes and perspectives, except for the perspective of *utility*.

5.2.2 Model User Views and Frames

At the completion of model-building, the meta-theme of *utility* was identified universally by users as the main criteria of *user confidence*. *Utility* was also the strongest meta-theme throughout the study. The emergence of other meta-themes varied between users throughout the study. The centrality of *utility* as a criterion of *confidence* is consistent with the system dynamics literature, although the variable appearance of *relativity* amongst participants was not a true reflection of the literature.

Shown in Table 5.2.2-1 below is an example of the summary format with which the data for participants are presented. Interview statements were coded against the themes in the second column, which were clustered in perspectives or meta-themes in the first column. Results from the three interviews are shown in sequence from left to right: prior to development of the model, after release of the qualitative model, and ultimately on completion of the quantitative model and the group model-building session. The results for each interview are presented in two adjacent columns representing the observed themes of the model user's view and the interpreted themes of their frame according to the six symbolic framing questions plus their slogan for *user confidence* (refer to section 2.4.1). Results for framing questions 6 and 9 were omitted from coding and results because they did not contribute to the descriptive framework of *user confidence*.

To demonstrate how the results should be interpreted, Table 5.2.2-1 indicates the theme of *accuracy* was observed in all three interviews. In the second interview, the use of the *accuracy* theme was interpreted as a boundary (B) of the model user's frame. The theme of *analysis* was only observed in the first interview while the theme of *experiment* was observed in the second and third interviews. The *fidelity* theme was observed in all three interviews, and interpreted as a metaphor (M) in the second interview and a reference point (R) in the third interview.

Table 5.2.2-1. *Example layout of interpreted confidence criteria from framing interviews.*

The following abbreviations have been adopted as shorthand for framing elements throughout all tables: ‘X’ – interpreted criterion; ‘R’ - *reference point*; ‘Y’ – *yardstick*; ‘B’ - *boundary*; ‘H’ - *highlight*; ‘S’ – *shadow*; and ‘M’ – *metaphor*.

Perspectives	Themes	Pre-Model View	Frame	Qualitative Model View	Model Frame	Quantitative Model View	Model Frame
Empiricism	Accuracy	X		X	B	X	
	Analysis	X					
	Experiment			X		X	
	Fidelity	X		X	M	X	R

The results for each model user are presented in the following sections, followed by a discussion of the results.

5.2.3 Model User A

User A initially expressed a view of *confidence* that appeared to cover a range of theoretical perspectives. He expressed *subjectivity* with the rhetorical statement: ‘how sound is the (model-builder)?’ and wanted to ‘follow the logic’ of the model while also anticipating that ‘failure definitely can be unexpected’. He raised a number of issues which were interpreted as boundaries; noting a *caveat* on the limits of the model’s ability and identifying that both the model-builder’s *expertise* and the *suitability* of system dynamics method were assumed. User A saw models as a means of controlling the subjective impulses of decision-makers who tend to metaphorically leap to conclusions a ‘skip on the surface of the pond’.

The themes of user A’s view changed moderately between the first two interviews. He connected the classical themes of *confidence* and *usefulness* by stating ‘I now have a reference point of *confidence*. Is this model going to do what I want it to do?’ In this second interview, user A added an *assumption* about the accuracy of data for the model and expressed the need for *discourse* because ‘(the model builder) has actually got to understand what (the model user) wants’. Both themes were interpreted as highlight. User A attributed the model-builder and model user with the contrasting *confidence* perspectives of *relativity* and *utility* by stating: ‘What (the model-builder) wants is a model that is accepted. What the model user wants is a model he can use’.

Table 5.2.3-1. *Interpreted confidence criteria for model user A.*

Perspectives	Themes	Pre-Model View	Frame	Qualitative Model View	Frame	Quantitative Model View	Frame
Relativity	Affect	X	R	X		X	R
	Discourse			X	H		
	Satisfaction	X		X	H		
	Significance	X					
	Subjectivity	X	R H			X	S
	Trust	X		X	R		
Utility	Agency	X	R			X	
	Benefit						
	Cost	X	R	X		X	
	Suitability	X		X			
	Solvency	X	R	X		X	R
	Usability	X		X		X	
	Use			X	H		
Empiricism	Usefulness	X		X	R	X	H
	Accuracy	X		X	B	X	
	Analysis	X					
	Experiment			X		X	
	Fidelity	X		X	R	X	R
Rationality	Understanding	X	Y	X		X	R
	Caveat	X	B				
	Expertise	X	B	X			
	Logic	X	B M	X	B	X	
	Sophistication	X				X	S
	Soundness	X		X		X	
Interval	(calendar days)			39		22	
Duration	(minutes)	130	51	52		27	

Legend: ‘X’ – interpreted criterion; ‘R’ - *reference point*; ‘Y’ – *yardstick*; ‘B’ - *boundary*; ‘H’ - *highlight*; ‘S’ – *shadow*; and ‘M’ – *metaphor*.

After exposure to the quantitative computer model, user A confirmed his implicit acceptance of the theme of *utility* by saying he was ‘concerned with ends not means’. He also referred to a range of other themes including *affect*: ‘I am excited’; *solvency*: ‘inherent in the model is the solution’; *fidelity*: ‘does it portray the reality?’ and *understanding*: ‘is it showing us that our thinking may need to be revised’. All of these themes can be interpreted as reference points. Looking back over the project, user A acknowledged his emphasis had ‘definitely changed’ since ‘early on, it was both technical and personal, whereas now it is more generalistic (sic)’. On completion of the project, he was no longer concerned with ‘the personal ...and the personality (of the model-builder)’; themes which were interpreted as shadows.

The *utility* perspective was a prominent and consistent thread throughout the model-building project for user A. Other perspectives were evident in his view but in a scattered and variable manner. The main change in user A’s view occurred after exposure to the qualitative model. An overall sense of user A’s view of *confidence* was evident in his statement ‘You’re just adding an aspect of purity to (decision-making)’; inferring a strong link between scientific proof and managerial relevance.

5.2.4 Model User B

Table 5.2.4-1. *Interpreted confidence criteria for model user B.*

Perspectives	Themes	Pre-Model View	Frame	Qualitative Model View	Frame	Quantitative Model View	Frame
Relativity	Affect	X		X			
	Discourse	X		X	H		
	Satisfaction	X	H				
	Significance	X					
	Subjectivity	X	H	X		X	
Utility	Trust	X	R	X			
	Agency	X					
	Benefit	X		X			
	Cost						
	Suitability	X		X	B M		
	Solvency	X	R	X	RY	X	
	Usability	X		X		X	
	Use	X		X		X	RY H
	Usefulness	X	R	X	RYB	X	Y H M
	Accuracy	X		X	H	X	RY
Empiricism	Analysis	X	R	X	R B	X	Y
	Experiment	X		X			
	Fidelity	X		X	B	X	RY
	Understanding	X		X	H	X	
	Caveat	X		X	B		
Rationality	Expertise						
	Logic	X					
	Sophistication	X		X			
	Soundness			X	H	X	M
Interval	(calendar days)			43		27	
Duration	(minutes)	156	59	67		30	

Legend: ‘X’ – interpreted criterion; ‘R’ - *reference point*; ‘Y’ – *yardstick*; ‘B’ - *boundary*; ‘H’ - *highlight*; ‘S’ – *shadow*; and ‘M’ – *metaphor*.

Initially User B’s view of *confidence* was linked to a wide range of themes, filtering into the meta-themes of *relativity*, *utility* and *empiricism* using framing. He stated the importance of the ‘element of trust that we have in that model, whatever (the model) is based on’, which was interpreted as a reference point for the theme of *confidence*. He also identified that ‘some user might not accept it ... (but) for somebody else it might be (valid)’, leading to an interpretation of the highlighted themes of *satisfaction* and *subjectivity*. Similarly, User B made repeated connections between the themes of *utility* and *relativity*: ‘if it’s useful for some other purpose, it’s valid but for somebody else (not)’ and ‘is something useful or not? It is a personal judgement’.

During the second interview User B expressed a number of *utility* issues in a rhetorical manner and these have been interpreted as reference points for his frame. An example involving *utility* and *solvency* was: ‘So is it doing the purpose you want and giving you the answers that you can use? That’s (the overall) general policy.’ After viewing the qualitative model he identified a diverse range of ‘limitations’ or

‘constraints’ of the model, which were inferred to be boundaries of his frame. He also emphasised the theme of *understanding*: ‘I prefer to understand as much as I can why the results are as they are.’ He explained the *confidence* theme of *suitability* using the metaphor of a motor car race: ‘If I turn up (to a race) in a fast car, I am now in a reality that I can compete, so it is my place to be there’.

User B consolidated his view as resting within the meta-themes of *utility* and *empiricism* during the final interview, exemplified by the physiological metaphor: ‘So if we look at the skeleton, it is a good structure, maybe without enough muscles around it, but a good potential to build more muscles...it is probably not finished, but for usage it can be built on more steroids, more fitness, more yoga!’ The *empiricist* themes of *accuracy* and *fidelity* also came through in User B’s desire for ‘accuracy, and not just numerical but also accuracy in relating all the formulas’.

Throughout the study, User B’s issues of *confidence* appeared to converge on themes of *utility* and *empiricism*, as he became familiar with the quantitative model. By admission, User B’s views within these perspectives reflected the technical ‘nature of the position (he was) in’. Nevertheless his views straddled both the mega-themes of *proof* and *relevance* throughout the study.

5.2.5 Model User C

When interviewed prior to the development of the model, User C spoke about *user confidence* in terms of *empiricist* themes like *fidelity* and *accuracy*: ‘a better representation ... (and) an accurate predictor’. His preference for a ‘qualitative measure’ of *confidence* inferred a yardstick of *subjectivity*. His statement about ‘(having) intrinsic trust in the process’ was further evidence of a *relativistic* viewpoint, while his recognition of ‘the requirement for it to be a rigorous process’ suggested highlighting of the theme of *logic*. While User C talked of *confidence* issues across all meta-themes, his statement that ‘my focus is on the end product’ implied a highlight on *usefulness*.

After viewing the conceptual model, User C appeared to concentrate his view on themes of *utility* when saying: ‘if someone uses it and believes it can be used as a tool; that makes it valid’. He also stated that if the model ‘has replaced another model, then I think it is a useful measurement’, suggesting *suitability* as a yardstick of *confidence*. At the same time, User C saw that *confidence* was constrained by

‘restrictions or boundaries to the number of variables that you can put in there because it will get too complex for people to use’, suggesting boundaries around the concept of *utility*. On the issue of *confidence*, User C clearly favoured *relativity* over *empiricism* by stating that ‘HR is not scientific’.

Table 5.2.5-1. *Interpreted confidence criteria for model user C.*

Perspectives	Themes	Pre-Model View	Frame	Qualitative Model View	Model Frame	Quantitative Model View	Model Frame
Relativity	Affect						
	Discourse	X		X		X	
	Satisfaction						
	Significance	X	H			X	B
	Subjectivity	X	Y	X	BH	X	Y H
Utility	Trust	X	H	X		X	
	Agency			X	RY	X	RY H
	Benefit	X	R	X	Y	X	RY H M
	Cost					X	R
	Solvency	X		X	RY	X	R
	Suitability			X	Y	X	
	Usability	X		X	YB	X	RYB
	Use	X		X	RY	X	RY H
	Usefulness	X	H	X	YB	X	H
Empiricism	Accuracy	X	R	X		X	
	Analysis	X	R	X	R	X	
	Experiment						
	Fidelity	X	R	X		X	
Rationality	Understanding	X		X		X	H
	Caveat	X		X		X	
	Expertise	X	H			X	H
	Logic	X	H	X			
	Sophistication	X		X		X	S
Soundness		X		X			
Interval	(calendar days)			41		21	
Duration	(minutes)	129	50	46		33	

Legend: ‘X’ – interpreted criterion; ‘R’ - *reference point*; ‘Y’ – *yardstick*; ‘B’ - *boundary*; ‘H’ - *highlight*; ‘S’ – *shadow*; and ‘M’ – *metaphor*.

User C’s views, after exposure to the computer model, centred on *utility*: ‘it needs to be useful. I mean the amount of effort you put into doing something and getting organised needs to be worth it...’. Also present was a continuing thread of *relativity*: ‘I know that a different person doing this project could come up with a completely different (model) or a different answer’. User C explained that ‘there is a level of complexity you can get to for which things are not useful, so it has to be simplified to an extent that it is actually useful and useable.’ User C illustrated his *utility*-centric view of *confidence* with a metaphorical tale which began: ‘I have a PDA (personal digital assistant) and I ordered this because I thought I would find it really useful...’.

The most noticeable change in user C’s views occurred after the development of the qualitative model, where his emphasis shifted to *utility*, almost to the exclusion

of other perspectives. As the model-building project progressed, user C exhibited a strong preference for issues of computer model *relevance* over *proof*.

5.2.6 Model User D

Table 5.2.6-1. *Interpreted confidence criteria for model user D.*

Perspectives	Themes	Pre-Model View	Frame	Qualitative Model View	Model Frame	Quantitative Model View	Model Frame
Relativity	Affect			X		X	
	Discourse					X	
	Satisfaction			X		X	
	Significance			X		X	
	Subjectivity			X		X	H
	Trust	X				X	H
Utility	Agency	X		X	RY H	X	
	Benefit			X			
	Cost						
	Solvency			X	Y		
	Suitability					X	H
	Usability			X	Y	X	
	Use			X	Y	X	
	Usefulness	X		X	R	X	H
Empiricism	Accuracy	X	R	X	R	X	Y H
	Analysis	X	R	X		X	R H
	Experiment	X		X			
	Fidelity	X	R	X	Y		
	Understanding	X		X	R H		
Rationality	Caveat	X	R B M	X			
	Expertise			X	R		
	Logic	X	R B	X			
	Sophistication			X		X	B
	Soundness	X	R	X		X	
Interval	(calendar days)			42		22	
Duration	(minutes)	108	50	41		17	

Legend: ‘X’ – interpreted criterion; ‘R’ - *reference point*; ‘Y’ – *yardstick*; ‘B’ - *boundary*; ‘H’ - *highlight*; ‘S’ – *shadow*; and ‘M’ – *metaphor*.

Initially, the dominant themes of user D’s view were contained within the perspectives of *empiricism* and *rationality*, for example: ‘the model needs to be reasonably accurate’ and ‘if the model can provide reasonably robust forecasts, then it means value to us’. User D did not expect the project to be completely rational, saying: ‘circumstances that are beyond the control of the modeller have got to be thought of outside of the terms of this (project)’. This was interpreted as a boundary of his frame. User D used metaphor to *caveat* the use of the model: ‘If you put garbage in you get garbage out’.

After viewing the qualitative model, the themes of user D’s view expanded into the *utility* perspective of *confidence*, for instance whether: ‘the organisation is able to utilise the information and make decisions’ and concerning ‘what the organisation is trying to do’. When asked about yardsticks, user D spoke about the ‘information

coming from the model (being) provided to the decision people ... in a timely manner' and the model users 'utilising the information'.

In the final phase of the model-building project, user D expanded his view of *confidence* further still, to include the perspective of *relativity*, reducing his emphasis on the perspective of *rationality*. For example, he stated that: 'I am more than comfortable to have (the model), and use it, and to feel confident in the predictions it is giving us'. However, user D demonstrated his continued focus on *empiricism* by stating: 'to be a valid model it needs to be accurate'. He explicitly cited his reference point as the model's ability to *forecast* accurately and his yardstick as '(being) accurate to that degree of accuracy' (sic).

Changes to user D's view were noticeable through all stages of the model-building project, particularly after development of the qualitative model. The upward movement of themes in the table of confidence criteria, from left to right, suggest a progressive shift of interpreted *confidence criteria* during the model-building project, moving away from issues of the *proof* of model validity and towards issues of the *relevance* of the model.

5.2.7 Model User E

User E initially cited *confidence* issues across a range of themes, including *utility*: 'Does (the model) meet people's requirements from a *utility* perspective, in a timely manner?' and *relativity*: 'if something is seen as valid, then people will have *confidence* in it'. When asked to identify yardsticks he talked about *relativity* themes: 'There will be a variable expectation amongst the group (of model users)'. When asked about his frame boundaries, user E cited the limit of knowledge: 'I don't know if I have missed some (variables)'; and the exclusion of *utility* from his definition of *confidence*: 'the role of the users and ... what their user requirements are'. Although user E saw *utility* as 'separate' from *confidence*, he ultimately recognised the importance of both themes: 'I would be measuring the success criteria against its validity and its *utility*; both'. When asked to identify highlighted issues, he expressed his view using *empiricist* themes: 'correctness of inputs, completeness of variables and the relationship between variables', although he also pointed out this did not represent the view of others, because 'you will find some people that won't believe in modelling'.

Table 5.2.7-1. *Interpreted confidence criteria for model user E.*

Perspectives	Themes	Pre-Model View	Frame	Qualitative Model View	Frame	Quantitative Model View	Frame
Relativity	Affect			X			
	Discourse			X		X	Y
	Satisfaction	X		X	B	X	R
	Significance	X	R	X			
	Subjectivity	X	Y	X			
	Trust	X	Y	X			
Utility	Agency	X		X			
	Benefit	X	RY	X	YB	X	B
	Cost	X		X			
	Solvency	X	R	X	R	X	R
	Suitability	X	R B	X	Y	X	
	Usability		R				
	Use	X		X	RY S	X	
	Usefulness	X	RYB S	X	R B M	X	R BHS
Empiricism	Accuracy	X	R	X	R H	X	R
	Analysis	X		X	M	X	
	Experiment	X		X			
	Fidelity	X	R BH	X	R H	X	Y
	Understanding	X		X		X	
Rationality	Caveat	X					
	Expertise	X		X		X	
	Logic	X		X			
	Sophistication						
	Soundness	X		X	H		
Interval	(calendar days)			48		10	
Duration	(minutes)	98	44	33		21	

Legend: 'X' – interpreted criterion; 'R' - *reference point*; 'Y' – *yardstick*; 'B' - *boundary*; 'H' - *highlight*; 'S' – *shadow*; and 'M' – *metaphor*.

User E's views after the qualitative model bore significant resemblance to his initial views, both in the use of themes and the interpretation using framing. His declared reference points and yardsticks shifted towards *utility* themes because 'I don't think you can measure purely through the validity. This is where you have got to have utility as well'. When asked about frame boundaries he again identified his separate concepts of *confidence* and *utility*: 'this might be valid...but is it really useful?' User E used the metaphor of a butcher's shop to explain that such a model would not be useful for a small organisation, and the metaphor of the military appreciation process to show the importance of *analysis*: 'you can't predict what someone else is thinking or doing, but pieces of it you can quantify'.

During the final interview, User E restated his qualified emphasis on *utility*, declaring it in terms of the framing elements of reference point, frame boundary, highlight and shadow: '(The model) is a tool—it is not a decision-maker.' and '(The model) is used as a tool—that's all it is—as a tool... .' His rather 'scientific' view of *confidence* was made explicit in his statement: 'Validity equals accuracy and completeness.'

The distribution of framing elements in Table 5.2.7-1 illustrates that the interpreted themes of user E's view were relatively stable throughout the study, although the number and scope of observed themes reduced during the final interview. The perspective of *rationality* was noticeably absent from an interpretation of user E's frame. A moderate preference for issues of computer model *relevance* was detectable throughout the model-building project.

5.2.8 Model User F

Table 5.2.8-1. *Interpreted confidence criteria for model user F.*

Perspectives	Themes	Pre-Model View	Frame	Qualitative Model View	Model Frame	Quantitative Model View	Model Frame
Relativity	Affect	X		X			
	Discourse						
	Satisfaction			X	Y		
	Significance	X		X		X	
	Subjectivity	X		X			
	Trust	X		X	Y		
Utility	Agency			X	R	X	RY H M
	Benefit	X		X			
	Cost						
	Solvency	X				X	
	Suitability	X		X		X	
	Usability	X	H			X	
	Use	X	R	X	R		
	Usefulness	X	R	X			
Empiricism	Accuracy	X	R			X	R
	Analysis	X	R	X		X	R
	Experiment	X		X			
	Fidelity	X		X		X	
	Understanding	X					
Rationality	Caveat	X	B	X		X	B
	Expertise	X					
	Logic	X		X		X	
	Sophistication	X					
	Soundness	X		X		X	
Interval	(calendar days)			37		9	
Duration	(minutes)	105	68	26		11	

Legend: 'X' – interpreted criterion; 'R' - *reference point*; 'Y' – *yardstick*; 'B' - *boundary*; 'H' - *highlight*; 'S' – *shadow*; and 'M' – *metaphor*.

Although User F initially identified a broad range of *confidence* themes, his frame referenced themes only from the two perspectives of *utility*: 'I would rather see...it being used'; and *empiricism*: 'I would hope it is accurate'. He expressed a strong pragmatist view 'Does it give me something I can use?' and used the idea of a 'smorgasbord' menu as the way that output from the computer model should assist Army training managers. User F identified his frame boundary as the *caveats* on his *confidence* in the model due by unknown factors: 'I don't know what I don't know'. When asked to specify frame highlights, user F spoke about the model being

‘updateable’ and being ‘in time for budgeting’; which both fell under the theme of *usability*.

After observing the qualitative model, user F stated that ‘I want to see this system working’; thus reinforcing the interpretation of *use* and *utility* as embracing reference points for his frame. Another reference point could be interpreted as organisational control in the form of ‘the RF strength being maintained’. When asked about yardsticks, he stated that ‘(the model) is not going to be right minute one; it is going to be 80% (right; and completed) on time’; which draws on the pragmatist military cliché of 80% completion of a task as the benchmark for acceptance. He subsequently added that ‘I think, initially, it is going to be pretty well off the mark, but I am not concerned’; demonstrating *confidence* in the model structure as a further yardstick of *confidence*. User F was not able to provide responses to questions relating to highlight, shadow and metaphor.

Agency was the central issue of *confidence* for user F at the end of this study. It was interpreted as providing his reference point: ‘achieves the intent’; yardstick: ‘that lunacy (of personnel leaving the Army) will cease’; highlight: ‘task achievement; objectives met’; and metaphor: ‘the home foundation ... if we get it wrong the rest of the Army suffers.’ He also mentioned ‘accuracy...and the ability to ...work out what went wrong’, which were interpreted as also providing implicit reference points.

The issues observed for F’s views of the computer model varied between interviews, particularly after development of the qualitative model. However, the framing elements interpreted from user F’s views showed more consistency over time than his views (shown as crosses in the table of confidence criteria Table 5.2.8-1), generally emphasising *utility* and *empiricism*. User F appeared to place more importance on issues of *relevance* of the computer model than *proof*.

5.2.9 Model User G

Table 5.2.9-1. *Interpreted confidence criteria for model user G.*

Perspectives	Themes	Pre-Model View	Frame	Qualitative View	Model Frame	Quantitative View	Model Frame
Relativity	Affect			X			
	Discourse	X		X		X	
	Satisfaction	X		X		X	
	Significance	X					
	Subjectivity	X		X	S	X	
	Trust	X	H				
Utility	Agency	X		X		X	R
	Benefit	X	R	X	R H	X	
	Cost	X		X			
	Solvency	X		X	R H	X	H
	Suitability	X		X		X	H
	Usability	X		X			
	Use	X					
	Usefulness	X	H	X	RY	X	
	Accuracy	X		X			
Empiricism	Analysis	X	Y	X	H	X	R H
	Experiment	X	H	X	H		
	Fidelity	X	Y	X	H	X	R H
	Understanding	X	H	X	R	X	
Rationality	Caveat	X	BH M				
	Expertise	X				X	
	Logic					X	
	Sophistication	X		X		X	
	Soundness	X				X	
Interval	(calendar days)			40		9	
Duration	(minutes)	82	44	23		15	

Legend: ‘X’ – interpreted criterion; ‘R’ - *reference point*; ‘Y’ – *yardstick*; ‘B’ - *boundary*; ‘H’ - *highlight*; ‘S’ – *shadow*; and ‘M’ – *metaphor*.

The view of user G initially embraced all perspectives, and all but two themes. When asked for a reference point of *confidence* he stated: ‘show me how (the model) is adding more value’; and when asked for the yardsticks of his frame he cited the model’s ability to ‘predict history’. When asked for his boundaries of *confidence*, user G explained that knowledge was limited. He identified the theme of *usefulness* as a highlight: ‘Give us something that is practical and common sense’, as well as the theme of *caveat*: ‘There is a tendency to default to models and there should be a disclaimer at the front: ‘Use this model at your peril’.’ He provided a metaphor for the theme of *confidence* by describing how a bike salesman might sell the customer a bicycle for ‘double the price’ because ‘he is just a good salesman’. User G’s initial view of *confidence* was synthesised in his statement: ‘The model is the science; the added value is the art’. This sentiment echoes Sterman’s labelling of the subject of system dynamics model validation as *Truth and Beauty* (2000, p. 845), as well as Lave and March’s (1975) three criteria for evaluating social science models: truth, beauty and justice.

After viewing the conceptual model, user G made statements about *utility* and *relativity* in response to the questions about reference points. For example, he asked rhetorically: ‘Are we making better decisions?’ and ‘Are we more responsive?’ When he explained the purpose of the model, he appeared to base his perspective within *rationality* as a point of reference, while also shadowing the perspective of *relativity*: ‘...the whole point of validity (is) when I go up in front of people I can explain the circumstances, and I get away from agendas and suppositions and intuition’.

At the end of the study, user G reinforced the *utility* element of his perspective by saying ‘success is that ... we (are) actually able to respond’. He reinforced the *confidence* theme of *solvency* by highlighting ‘the importance of good decisions’ and spoke of his ‘target’, or reference point as the model having ‘impact’ because it had the analytical ability to ‘run a series of policy initiatives’. The strength of user G’s assertion of the *empiricist* perspective came through in his frequent reference to ‘evidence’: ‘we should ... and pull (an assumption) apart in relationship to the evidence’; ‘some people (make decisions) intuitively; some people don’t do it on any evidence’ and ‘I have evidence based criteria to make decisions’.

A subtle incongruity was apparent in user G’s statement that ‘my emphasis has been on ... relating it to evidence from other models.’ At face value, this idea reflects an *empiricist* perspective because it refers to observations; however, the observations he spoke of were of the behaviour of other models rather than patterns of the workforce planning problem. User G’s view showed the most significant changes following development of the qualitative model. His frames consistently emphasised *utility* and *empiricism*, suggesting a desire that the model satisfy criteria of both *relevance* and *proof*.

5.2.10 Comparative Analysis

The holistic qualities of the observed themes making up the views of each model user are shown in Table 5.2.10-1 below, organised by the notions of *content*, *emphasis* and *changes*. *Content* refers to the breadth of theme coverage, while *emphasis* describes the distribution of themes, and *changes* is used to mean the way themes changed over successive interviews.

Table 5.2.10-1. *The qualities of WETA model user interpreted views.*

<i>User</i>	<i>Content</i>	<i>Emphasis</i>	<i>Changes</i>
<i>A</i>	<i>inclusive</i>	<i>even</i>	<i>shifting</i>
<i>B</i>	<i>inclusive</i>	<i>weighted</i>	<i>narrowing</i>
<i>C</i>	<i>inclusive</i>	<i>even</i>	<i>stable</i>
<i>D</i>	<i>inclusive</i>	<i>weighted</i>	<i>shifting</i>
<i>E</i>	<i>inclusive</i>	<i>even</i>	<i>narrowing</i>
<i>F</i>	<i>inclusive</i>	<i>even</i>	<i>narrowing</i>
<i>G</i>	<i>inclusive</i>	<i>even</i>	<i>stable</i>

From Table 5.2.10-1 it is apparent that no model users expressed a single-perspective view of *confidence* in this case study. However, their views were thematically inclusive. The *emphasis* of user views were either evenly distributed across all perspectives or weighted to particular perspectives. In other words, whilst the views of model users displayed the breadth of their *confidence* issues, they did not associate any quality of the depth to *confidence* issues. The *changes* in model user views over successive interviews did not follow a consistent *emphasis* and was could not be inferred from the static qualities of *content* or *emphasis*. Since the content of user views was not stable across the three interviews, it was not meaningful to attach perspective labels to the separate views of each model user. In contrast, this proved to be a feature of framing.

The qualities of the interpreted frames for each model user are shown in Table 5.2.10-2 below, organised by the notions of *character*, *structure* and *changes*. *Character* is used to mean the way the model user's perspectives appear in the frame. *Structure* means the way the frame is organised and *changes* refer to the way the frame varies over successive interviews.

Utility emerged as the dominant perspective of model user frames, while the *empiricist* perspective was also common to all users. The frames of these model users encompassed themes from almost all perspectives at each stage of the study. The

occurrence of reference points and highlights was common; boundaries and yardsticks were infrequent; and shadows and metaphors were rare.

Table 5.2.10-2. *The qualities of WETA model user interpreted frames.*

<i>User</i>	<i>Character</i>	<i>Structure</i>	<i>Changes</i>
<i>A</i>	<i>referencing all perspectives, bounding rationality</i>	<i>sparse</i>	<i>refining</i>
<i>B</i>	<i>highlighting utility & empiricism; metaphorical</i>	<i>dense</i>	<i>convergent</i>
<i>C</i>	<i>highlighting utility</i>	<i>dense</i>	<i>convergent, initially diffuse</i>
<i>D</i>	<i>referencing & highlighting all perspectives, bounding rationality</i>	<i>scattered</i>	<i>shifting</i>
<i>E</i>	<i>referencing all perspectives, except rationality</i>	<i>dense</i>	<i>stable, focussing</i>
<i>F</i>	<i>referencing utility & empiricism, bounding rationality</i>	<i>sparse</i>	<i>stable, refining</i>
<i>G</i>	<i>highlighting utility and empiricism</i>	<i>sparse</i>	<i>convergent</i>

Most of the frames of model users were either stable or tended towards convergence during the study; except the frame of model user D which shifted from *proof*-based perspectives towards *relevance*-based perspectives. The frames of the three model users B, C and E were relatively similar because the perspective of *utility* was prominent, the interpreted structure of their *confidence* issues was dense, and their *confidence* issues were stable and convergent during the model-building project.

This section has presented a comparative summary of the views and frames of WETA model users. It is apparent from this analysis that the views of model users were wide-ranging, indistinct and generally inclusive, while the views changed over time in various ways. In contrast, the content of frames was distinctive for each model user and identifiable by the structure and changes between frames. The description of the qualities of model user views and frames above, suggest an important difference between views and frames: views provide an extensive

inventory of *confidence* issues and themes, while frames provide a distillation of the qualities of the user's view

5.2.11 Discussion of Findings

The *confidence* themes of model users which emerged using the processes associated with grounded theory and content analysis method covered all of the themes present in the operations research, management science and system dynamics literature reviewed in Chapter 2. The descriptive framework of *confidence* (see appendix 5 and Table 5.2.1-1) provided a comprehensive span of the themes present in the system dynamics literature and matched the perspectives of user *confidence* found in operations research and management science literature: *rationality*, *empiricism*, *utility* and *relativity*. To summarise and present a collective view of *confidence* amongst the model users, it may be stated that they expected the model to be firstly *useful*, secondly *true*, preferably *acceptable* and *rational*. Overall, model users desired a model that was *relevant* as well as *proven*.

Model users expressed views that were inclusive of the four main perspectives of *user confidence*, at each of the three stages of this model-building project. This is apparent from the even spread of user views across the spectrum of model user themes at the different stages of the model-building project. Significantly, the user views of *confidence* were unique, yet variable throughout the model-building project.

The literature reviewed for this study did not address the way that views of *user confidence* can change over time. Most authors have identified that model user views of their problem tend to change during the model-building project, as they learn about the nature of the problem. Vennix has referred to this phenomenon as 'team learning' (1996, p. 31). The results of this study suggest that change also occurs in terms of model *proof* and *relevance*. A similar degree of change in model user views occurred after exposure to the qualitative model as it did after participation in the group model-building session with the quantitative model. In contrast, the frames of model users changed significantly after the qualitative stage of model-building, but thereafter remained more stable. This result means that although *user confidence* issues changed throughout the project, their frame of *confidence* remained relatively stable after the qualitative stage of model-building.

All users expressed opinions for some issues that were not stable over time; the main changes occurring after the qualitative model was introduced. This was particularly noticeable in the views of model users A and D. The number of issues cited by model users also decreased during the model-building project. However, the fact that the frames did not change significantly in span or depth suggests that this was not due to the decreasing duration of interviews. In other words, model users appeared to refine their *confidence* issues during the project progressed. This finding accords with Mitroff's (1969) assertion that *user confidence* in a computer model is formed progressively and iteratively, in the user's mind, through successive stages of model-building.

There was an apparent consistency in the degree to which model user expressed their issues using framing concepts, and there was a significant variability in the extent to which different model users expressed framing concepts. There was no apparent relationship between the duration of each interview and the extent of a model user's view or the richness of his or her frame, but rather this appeared to be an independent quality of each person's expressiveness. In fact, the shorter interviews were generally more expressive and rich in *confidence* information than the longer interviews.

The model users who were more expressive about their *confidence* issues and their interpretation of framing concepts seemed also to settle more rapidly on their chosen *confidence* issues; see for example Table 5.2.7-1. In contrast, the model users that took longer to express their views and frames expressed views that either shifted during the project, or were spread sparsely across many themes and perspective. This could mean that framing can assist model users to express their issues clearly and definitively. Alternatively, it might mean that some model users are also more decisive about what *confidence* means to them and those people find it relatively easy to express their views using framing concepts. This area would be a potential subject for further research.

These results provide some empirical support to the supposition that model users seek *utility* from the model. However, it is also possible that the interviewing and model-building methods influenced the model users to emphasise the *utility* perspective. For example, the yardstick and reference point questions of the frame analysis worksheet refer to: 'success'; which intones a utilitarian idea of

accomplishment and attainment. Since model users were also asked to define a purpose for the model during the early stages of the project, this may have encouraged them to adopt a utilitarian perspective where such a perspective might normally have arisen.

A limitation of this study is that the few negative statements about *user confidence* were omitted from the results, rather than being explicitly included. Their exclusion was not considered significant because of the low frequency of negative statements. To illustrate this point, user F's statement: 'I also will be expecting it not to be incredibly accurate to start with' was not included in the analysis, although it suggested a connection with the themes of *expectation* and *accuracy*.

Confidence proved to be an elaborate and extensive concept that crystallised and emerged gradually from the framing data. For example, user C stated: '(Confidence) actually isn't confined, but it probably would take me some time to tell you...'. Model users tended to list *confidence criteria* in a descriptive manner as if telling an unfolding story; rather than use a prescriptive or explicit form. The concept of *confidence* was complicated by the social context within which it occurred. For example, user C commented that: '...it is extremely complex because there are so many potential users in this (situation); so many people that are important.'

The model users did not voluntarily make explicit their level of *confidence* in the computer model. For instance: 'I don't think I would seriously sit down and say 'Is this valid?' In that sense I would be—not in a formal tick-off checklist process—but as I'm saying, I'm pretty sure it happens subconsciously throughout when you are dealing with a modeller'. They also tended to approach the topic of *confidence* informally: 'Do I formally go through a process and check for validity? No I don't.'

Each model user's view contained a multitude of issues spanning all the main perspectives of knowledge in this field. The views of model users showed no discernible common emphasis or logic, except that some themes were expressed more consistently than others. The views of model users about *confidence* were expressed differently at each interview. We may infer from this that framing assisted the model-builder to understand the key features of each model user's view despite these complicating characteristics.

Some statements made by model users during the interviews suggest a generic difficulty understanding the idea of *confidence*. One user observed that: ‘This all comes down to personal opinions.’ Another commented that: ‘...everybody uses their own frame of reference; and that is fine.’

The concept of *confidence* ‘grew’ in complexity as it was explored, and for some user became too difficult to conceive or consider. One model user stated during their third interview that: ‘...there are a lot of things that I think are important... I can’t think this time; because the more I look at it the more things that are important...’. Most model users perceived *confidence* as a vague and ambiguous concept. For instance, the first words spoken in interview by one of the model users was: ‘And what does validity mean?’ Another model user observed that ‘The word ‘valid’ is starting to confuse me.’ and ‘I am a little bit confused about validity as a concept.’ These statements demonstrated, just as Mitroff (1969) discovered in his own model-building study; the concept of *user confidence* is ‘elusive’ and difficult to express.

A desire to make the concept of *confidence* more cognitively manageable may explain why one model user split the concept into *validity* and *usefulness*. That user explained that: ‘I think language use needs to be quite precise and...so we need to be quite precise about what validity means. What is the root of the word validity? It’s about being valid’. Another user observed how it was difficult to think of *confidence* without some way of simplifying it: ‘There are probably mechanisms for proving or disproving or giving a quantifiable degree of validity, but to do that I’ve actually got to build a model of your model’.

Although the WETA model was a relatively simple example of system dynamics, some model users found it difficult to understand. For example, user A stated: ‘I can see some flow—the dynamics of the system—in a modeled representation. It took me a while to. I struggled with—you know: Forrester’s dynamics anyway—I liked them, but mentally I struggled’. One user also perceived that the outcome of the project was dependent on the particular model-builder: ‘...I know that a different [model-builder] doing this project could come up with a completely different [model] or a different answer.’

5.2.12 Summary of Interpreted Confidence Criteria

A total of 120 *confidence criteria* were interpreted in this study using a grounded theory method of enquiry. Twenty-four of those sub-themes were identifiable as distinct, higher-level themes. Those 24 themes were spread across the four main theoretical perspectives of operations research, management science and system dynamics literature; of which *utility* had the densest and broadest thematic description while *empiricism* had the lightest and narrowest. Two principal themes of *user confidence* emerged during this study: their *social validity* or *relevance*, and their *technical validity* or *proof*.

The results of this study indicate that model user views of *confidence* are extensive, complex and changeable. The distinctive perspectives of all model users were *relativity*, *utility*, *empiricism* and *rationality*, and these can be further collapsed into the mega-themes of *proof* and *relevance*. The views of model users were found to contain a mixture of all of these meta-themes and mega-themes. Whereas model user views appeared to show the diversity of their issues, their interpreted frames revealed qualities of the depth within a more cognitively manageable breadth of issues.

The breadth of *confidence* issues expressed by model users is demonstrated by the following defining statements made by users of the WETA model: ‘You’re just adding an aspect of purity.’ (User A); ‘is it useful or not? It is a personal judgement’ (User B); ‘if someone uses it and believes it can be used as a tool; that makes it valid’ (User C); ‘to be a valid model it needs to be accurate’ (User D); ‘Does it meet people’s requirements from a utility perspective, in a timely manner?’ (User E); ‘Does it give me something I can use?’ (User F); and ‘the model is the science; the added value is the art’ (User F).

Users of the WETA model did not express a view of *confidence* that was limited to any one perspective, although some perspectives were more dominant than others. In general, their views were inclusive of a wide range of *confidence* themes, which was generally not helpful from the model-builder’s perspective. The central perspective of *confidence* expressed by model users was *utility*; however, the empiricist perspective was also common to all model users.

Although model *users’ confidence* issues changed at each stage of this model-building project, their frames of *confidence* remained relatively stable after the

qualitative model-building stage. The dense coupling of particular *confidence* themes and their stability over time was found to be a useful property of user frames compared to their observed views. The more expressive model users displayed more stable and definitive frames.

The experience of most model users in this study was that *confidence* in the system dynamics intervention was a difficult concept to express. This finding is supported by the variability of model *user confidence* issues within their views, the complexity of the structure of their frames and the dynamic changes in their frames. The cognitive challenge encountered by the model users may be related to the perception of some WETA model users that system dynamics is conceptually complex. To the extent that model users could clearly express their views of *confidence*, framing assisted the model-builder to tackle this problem of cognitive manageability.

5.3 Methodological Findings

During this study, the author kept notes about the research methodology, including the model-building and interview process. The methodological findings that follow are based on these notes and structured in five parts: the benefits of frames analysis, the challenges of framing, other framing matters, interviewing and model-building.

The term ‘frame analysis’ was used by Russo & Schoemaker (1989) in their book *Decision Traps* for the use of frames as a decision-making aid. ‘Analysis’ means ‘a detailed analysis of the elements or structure of a substance etc.’ (Concise Oxford Dictionary, 1990, p. 38). During this series of framing interviews, it became evident that frames were not a tool for examining the detail within text. That is, framing did not follow a reductionist or investigatory path but rather it took a holistic and exploratory approach to the problem of *confidence*. Frames proved to be an interpretative filter of what may be meaningful within the dialogue of the problem, and in the process of building a computer model. The term ‘frame interpretation’ might therefore be a more accurate label for this method.

5.3.1 Benefits of Framing

Whereas the number of themes varied significantly between users—usually decreasing as the model-building project unfolded—the number of framing elements was relatively consistent for each model user. This result may be because the initial interviews included supplementary questions, while the final interviews were limited to the 10 questions of frame analysis. Regardless, the framing of each model user's statements provided a clearer picture of their *confidence* themes and perspectives than direct observation of their views. Using framing revealed the progressive development of a user's views about the objectives of model-building. Framing also revealed how the relevance of themes changed over time, which was not evident from the content of model user views.

The act of enquiring about *user confidence* turned the attention of the project participants to underlying issues. Issues such as comparative benefit, the perceived value of models and experiences were brought to the fore. However, the mode of investigation was also at times the source of negative affect for all model users, primarily because the repeated and intensive investigation of the single concept of *confidence* did not have immediate utility for the project. As this study demonstrates, *utility* was the central issue of *confidence*.

When it was apparent that interview participants were experiencing discomfort (for example, scowling their face) the author found himself returning to previously discussed issues and asking leading questions in order to keep the participant talking. In response to certain frame analysis questions, some users simply stated 'I don't know.' Answers to difficult questions were prompted by feeding back interviewee statements about the particular issue and asking for confirmation. This approach proved successful for exploring already stated issues and then leading onto other related issues.

The formal process of interview recording and transcription led to changes in the researcher's attitude. Focusing closely on the words spoken by users, rather than what the researcher thought they meant, led to reflection and correction of some inaccurate views and assumptions. The result of this reflection was an increased attention to the model user's views and the way they expressed them. This activation of listening skills improved the quality of the process and consequently led to improved realism of the model. This can occur because of the circumstances

of the interview (exogenous) and the perspective of the researcher (endogenous). Since the researcher was also the model-builder, the benefits of reflection on interview data were transferred directly into the model.

5.3.2 Challenges of Framing

It was problematic to inquire directly into model user's views of *confidence*. When the model-builder asked about the issue of a *user's confidence* it implied that there was a problem with their existing views. Persistent, explicit, repeated questions about a person's understanding of validity also aroused annoyance and defensiveness. For example: 'Let's stop asking it. I have answered it six times... what valid means, in different ways. And I can't think of any other way to say it'. The constant reference to *confidence* was used to achieve reliability. However, this also led to discomfort for the interviewees. Another model user commented that: 'Sometimes you try and hold onto—oh I said that before, so therefore it must be true—then you realize that we are in a different phase now, so therefore that whilst the underlying philosophy still holds, certain aspects that come to the surface are different, because we are in a different phase'.

The conceptual (or 'theoretical', as some interviewees termed it) nature of the framing questions provided some challenges to the interviewees. It was evident that the key model users did not normally think conceptually about management problems. For example: 'What boundaries do I put on the issue? That is a good theory question. Pass.' These sentiments seemed to echo the gulf that Schön (1983) has observed between researchers and practitioners, particularly when the participants in this study used the term 'academic' to refer to this research in a mildly pejorative sense. Participants were unclear what the term validity meant and the constant reference to validity led them to reflect on why they did not think about it, rather than encouraging them to think about it with an open mind. As one model user stated: 'We don't talk about validity.'

Participants displayed the most difficulty when disclosing their boundaries. This issue was also one of the more difficult to obtain from other interview data. In response to this question, it was common for interviewees to state 'I don't know what I don't know.' This question seemed to be asking the impossible, or at least

impractical. It became evident that boundaries held different meanings depending on context.

The ability to make immediate interpretations of a model user's frame was limited by a degree of incompleteness, ambiguity and occasionally misleading data. Incompleteness occurred because the full range of questions was not answered fully, especially over multiple interviews. Ambiguity was evident because the interview data could have multiple interpretations or layers of meaning. The responses were sometimes misleading because the model user occasionally misunderstood questions and the model-builder was at risk of frame misinterpretation or missing important data. This last issue arose because the interviewer was simultaneously making sense of both the content and meaning streams within the data.

The interview data provided by some model users was vague, ambiguous and at times not suitable for coding, while other model users were more able to understand the questions and communicate their thoughts. It therefore may have helped to demonstrate the process of framing to the model users prior to the first interview.

Although model users were able to make explicit their highlighted *confidence criteria*, those highlights did not correlate well with the more frequently expressed *confidence criteria*. This result could suggest a difference between the declared and actual importance of *confidence* issues, or alternatively it could mean that participants viewed highlight as a quality, independent of the number of times it was mentioned.

Some model users asked for assistance or advice from the researcher to help define concepts, such as *confidence*. They also asked the researcher to fill in the answers to questions they could not answer themselves, such as the issues outside the boundaries of the interviewee's frame. For example: 'Targets and reference points? Give me another word to describe it. I am not on (the same communication) net(work).'

5.3.3 Boundaries

In general, users had difficulty identifying boundaries. User F admitted not being able to identify any boundaries: 'None; that I can think of'. Russo & Schoemaker define boundaries as the limits 'set on a problem' (1980, p. 20), although they describe boundaries as being 'among a problem's simplest elements'

(1980, p. 21) the model users found this aspect more complex, or at least more diverse.

There are several possible meanings within the literature for the term boundary, one being a limit of understanding. Alternatively it can mean the scope of a person's or an organisation's responsibility. A third possibility is the extent of information or options available to a decision-maker. A complicating aspect of mental boundaries is that they are usually implicit or unconscious. They can also be either endogenous or exogenous to the perspective being considered; that is either a limit created by the individual or an external limit that shapes the individual's view.

Several possible meanings of the term boundary emerged during this study, illustrating the richness of the concept. All these meanings were legitimate from the model user's perspective and may assist the model user and model-builder to understand the key issues of *confidence*.

- Limit of knowledge (for example: 'I don't know what I don't know.' and 'Assumptions are just the things on the outside of the boundaries.')
- Limit of thought and action (For example: 'Where is the boundary? ... That belongs to [the model-builder]. That belongs to me.'; '...there will reach a point where you can't keep adding variables because you can't keep doing it until the cows come home...there are going to be restrictions or boundaries to the number of variables...'.')
- Limit of *confidence* (For example: '...letting (the model) be flexible is a boundary for getting invalid (results) which is kind of opposite. You (are) allowed to do (that) but then you have a model that has no value.')
- External limitation (For example: '...I don't know if those (are) constraints that we are talking about...those constraints are more kind of life itself.')

5.3.4 Framing Questions

The model users at times had difficulty specifying yardsticks explicitly. (For example: 'I don't know how you would measure (use of the model) either' and '...it is a little bit difficult. It is not really a quantitative measure. ... I think effectiveness of a process is a difficult thing to measure.')

However, model users seemed to implicitly recognise the utility of reference points, judging by the comment that: 'It is

always easy to measure or compare something that is already there, rather than something that is not. It is always easier to change a plan than actually write one from scratch.’ These results could be interpreted to mean that model users naturally think in terms of reference points and yardsticks. However, telling yardsticks and reference points apart seemed to prove difficult for the model users who specified the same issues as reference points and yardsticks. The author also found it difficult to differentiate yardsticks from reference points. A possible direction for further research would be to explore the utility of making accurate distinctions between reference points and yardsticks.

The ability and propensity of model users to employ metaphors was polarized between those few who used metaphors freely and the majority who found it difficult to identify any metaphors at all. One model user commented that ‘I am not greatly into metaphors’; and later: ‘There must be the wrong side of my brain turned on; the creative stuff.’ A different model user suggested that humour was important in relation to model-building: ‘As everything (humour) should have a place and quantity, and not overdo it. And I am always for having that part of it. It helps in actually every area—but not to overdo it...’

Some examples of slogans used in the study were: ‘Over promise and under deliver’; ‘Success has many fathers—failure is an orphan’; and ‘Shit in—shit out’. In most cases, the same users that could not provide a metaphor were also the ones who struggled to volunteer a slogan.

Shadowing was not seen by all model users as the opposite of highlighting, as shown in this statement: ‘...just because I think being simple is important ... doesn’t mean that I think the opposite is true.’ Some model users also found the concept of shadowing difficult to understand. For example, ‘I am struggling to understand what you are driving at: minimize or shadow. Does it hide things?’ and ‘I am not sure...you are talking about hidden?’

5.3.5 Interviewing

Interviewing proved to be a difficult but revealing approach to understanding model user views. The interview subjects did not appreciate being asked the same questions three times, and they were also conscious that their answers might be different to their previous answers. Initially, most model users contributed freely

and helpfully although cautiously, but their motivation appeared to change subsequently. In general, they appeared reluctant and occasionally evasive regarding the second interview then typically accepting about the final interview.

Although interviews provided a rich source of data about *confidence* themes, the utility of this approach was variable. The extent of disclosure, level of thinking and creativity of thinking of model users varied between users and between interviews. Some model users spoke only about the level of the problem and the content of the model while other users answered the frame questions more directly by talking about their thinking towards the concepts and wider context of the project.

The use of the interview sheet during the interview evolved during the process. Two copies were used initially, one blank copy for the interviewee to refer to and one working copy for the interviewer to fill out as the interview unfolded. The interviewee initially referred to their copy of the questions as they grappled with the unfamiliar questions but as the first interview progressed, they shifted their eye contact and posture towards the interviewer. In the second interviews, the interview subject seldom referred to the question sheets.

5.3.6 Summary of Methodological Findings

Framing provided a more useful picture of a model *user's confidence* issues than the direct observation of their view. Framing drew attention to the more important themes and showed how the users' thinking changed during the project. However, the repeated use of framing detracted from the overall utility of framing, by causing a negative response amongst the model users. Nevertheless, analysing frames forced me, the model-builder, to be more reflective, and therefore more effective at building a useful model.

The concept of *confidence* proved to be a difficult idea for model users to talk about. Model users expressed complex and diverse ideas about the meaning of frame boundaries, although the idea of a boundary has been given a simple meaning in the literature. The immediate use of framing question responses was limited by a degree of missing data, ambiguity of responses and the occasional anomalous statement. Some prior experience with framing is therefore suggested, for both the model-builder and clients.

In this study, model users employed the idea of a boundary to mean a range of things; limit of knowledge, limit of action, limit of *confidence* and external limitations. Framing questions were at times difficult for the model users to answer and some users found the concepts of yardsticks and shadowing difficult to understand and specify explicitly. Most users also had difficulty providing metaphors and slogans for *confidence*.

The tone of some interviews became strained during the study; apparently due to the repetitive nature of the questions. Although interviews provided a large volume of rich data about *confidence*, the extent and depth of enquiry varied between users and interviews. A sheet of paper with the printed framing questions proved to be a useful aid to enquiry and model-building, for both the client and the model-builder.

5.4 Summary of Findings and Discussion

There were several major findings in this study, in the areas of model users' views and the use of framing. A large number of distinct *confidence criteria* were interpreted from the views of *user confidence* in the model, which were grouped into 24 themes of *user confidence*, and further categorized under four theoretical perspectives of *user confidence*. The views of model *user confidence* in the model were unique to each stage of the model-building project. Despite the change in user views expressed during the project, user frames were relatively stable after the qualitative model-building stage. However, the model user views of *confidence* were elusive, and difficult for the model-builder to elicit and interpret.

Framing provided the model-builder with a clearer and more stable picture of the model *user's confidence* issues than a thematic summary of their views. Whereas the literal meaning of a model user's view only showed the breadth of their *confidence* issues, framing revealed the depth of their view. While most model users reacted negatively to the repeated use of frame analysis questions, framing also improved the model-builder's efficacy through reflective practice and engagement with the model users.

CHAPTER 6 : CONCLUSIONS

'The reason why it may be wise to distrust the political judgment of scientists qua scientists is not primarily their lack of "character"—that they did not refuse to develop atomic weapons—or their naïveté—that they did not understand that once these weapons were developed they would be the last to be consulted about their use—but precisely the fact that they move in a world where speech has lost its power. And whatever men do or know or experience can make sense only to the extent that it can be spoken about.'

Arendt, 1998, p. 4

6.1 Overview of Chapter 6

The purpose of this study has been to explore the perception of model users towards the scientific work of model builders and this has been undertaken, as Arendt (1998) has implied above, by examining the language of model users through their frames. This purpose was served by eliciting the concept of user confidence in a system dynamics model of a military workforce planning problem. The method of enquiry employed Russo & Schoemaker's (1989) framing questions in face-to-face interviews, leading to a descriptive framework of user confidence. This framework was synthesized using constant comparative analysis and thus became the basis for interpreting the views of the model user.

The framework of user confidence from this study has the potential for use in other system dynamics model-building projects, particularly in the area of military workforce planning. In addition to the theory-building objective of this study, the system dynamics model was used to test a dynamic hypothesis for the underachievement of workforce targets and provide policy insights for future Army workforce planning.

This chapter provides a summary of the interpreted confidence criteria for users of the WETA model as well as observations about the use of framing. The subsequent sections go on to describe other findings from this study and conclude with limitations and recommendations for this research project.

6.2 Interpreted Confidence Criteria

In response to the first research question of this study, 120 identifiable themes of confidence, referred to in this dissertation as confidence criteria, were elicited

from the principal users of the WETA. A descriptive framework of confidence was generated by clustering these criteria into 24 distinct themes, a further four perspectives and ultimately across two mega-themes. These higher-level themes of confidence are shown in Table 5.3.6-1 below. The full descriptive framework, including sub-themes and rules for inclusion, is attached in Appendix 5.

Table 5.3.6-1. *Descriptive framework of user confidence for the WETA model.*

<i>Mega-themes</i>	<i>Meta-themes, or Perspectives (from Table 2.3.3-1)</i>	<i>Themes (Table A5-1)</i>
<i>RELEVANCE</i>	<i>Relativity</i>	<i>Affect</i>
	The art or aesthetics of model-building.	<i>Discourse</i>
	'Personal' confidence	<i>Satisfaction</i>
		<i>Significance</i>
		<i>Subjectivity</i>
		<i>Trust</i>
	<i>Utility</i>	<i>Agency</i>
	The ends or purpose of model-building.	<i>Benefit</i>
	'Practical' confidence	<i>Cost</i>
		<i>Solvency</i>
		<i>Suitability</i>
		<i>Usability</i>
		<i>Use</i>
		<i>Usefulness</i>
<i>PROOF</i>	<i>Empiricism</i>	<i>Accuracy</i>
	The science, validity or truth of model-building, arising <i>a posteriori</i> .	<i>Analysis</i>
	'Scientific'/'observed' confidence	<i>Experiment</i>
		<i>Fidelity</i>
		<i>Understanding</i>
	<i>Rationality</i>	<i>Caveat</i>
	The verity or compliance with rules of model-building, arising <i>a priori</i> .	<i>Expertise</i>
	'Reasoned' confidence	<i>Logic</i>
		<i>Sophistication</i>
		<i>Soundness</i>

As the descriptive framework above demonstrates, the *interpreted confidence criteria* of WETA model users cover an extensive range of issues. Importantly, the non-positivist perspectives of *utility* and *relativity* emerged as substantial components of user confidence for all the model users. This result gives legitimacy to the views of model users of a system dynamics intervention by treating them appropriately as

evaluators of the model (Forrester & Senge, 1980). The views of model users were more diverse at the beginning of the WETA project, becoming more focused and coherent towards the end of the project. The implication for system dynamics model-building projects is that principal model users may not have had clear expectations of the model until some way into the project. In this case, the concept of user confidence appeared to crystallize when the qualitative model was explained to the model users.

The study findings indicate that the interpreted confidence criteria making up the views and frames of the principal model users did not converge on any particular themes or perspectives of confidence. However, confidence criteria belonging to the perspective (or meta-theme) of utility emerged as a common component of all user views in this case study. As one WETA model user stated: ‘if someone uses (the model) and believes it can be used as a tool, that makes it valid.’ This result conforms to the emphasis on utility in system dynamics literature (such as Forrester, 1961) and is intuitively reasonable because the Army is an operationally focused organisation.

Despite the opportunity for in-depth enquiry created by the use of an interview method of data collection, the concept of user confidence proved to be elusive (Mitroff, 1969), difficult for the model user to express and difficult for the model-builder to interpret. This challenge is illustrated by the model user statement: ‘I don’t know what I don’t know’. Framing proved to be useful because it helped the model-builder to interpret the each model user’s view of confidence and thus to interpret them as *confidence criteria*. Framing also appeared to be useful when used by the model users, because the frames of the more expressive model users were noticeably more stable and precise, compared to the users who made less use of the framing concepts. Of great interest was the finding that the most noticeable change in the concept of user confidence occurred during the qualitative model-building stage. In other words, the delivery of a quantitative model and its demonstration within a group model-building session did not significantly change the interpreted confidence criteria.

The themes of WETA model user confidence were consistent with system dynamics literature, where a number of prominent authors have highlighted the non-positivist concepts of usefulness and confidence. The interpretivist confidence

criteria from this study, such as affect, subjectivity and trust; contrasts with the paradigm of positivist science that persists in some research into system dynamics (Berends & Romme, 1999). WETA model users did not see the issue of confidence in such terms, as the following rhetorical remark from a WETA model user suggests: ‘...is (the model) useful or not? It is a personal judgement’.

6.3 Framing Method

The framing method, defined for this study as the use of cognitive structures to understand a socially-embedded experience, gave legitimacy to the views of model users about their confidence in a system dynamics model. This finding supports the proposition of Davies & Mabin (2001a) from applications in managerial problem-solving. In answer to the second research question for this study, Russo & Schoemaker’s (1989) framing method proved to be instrumental as a tool for eliciting data about the views of user confidence at a point in time during the model building project. At the same time, however, some difficulty arose from the repeated use of framing questions and some care and effort was required when interpreting user responses. The logical structure and simple style of the frame analysis questions served as a convenient framework for enquiring about a complex subject. Over 21 interviews, the set of 10 guiding questions provided a degree of control over the direction and range of responses across a diverse group of research subjects. While at times, the interviewees did not find the frame analysis questions engaging, they seemed to have an interest in the interpretation of their responses.

At times, the interviewees experienced difficulty with some interview questions, wrestling with concepts such as boundaries, shadow, metaphors and slogans. For example, one user stated: ‘What boundaries do I put on the issue? That is a good theory question. Pass!’ Another disclosed that: ‘I am not greatly into metaphors’. Nevertheless, I found that framing provides a useful interpretive filter for ascertaining and organizing the views of model users about their confidence in a model. These findings help address the lack of knowledge about the application of framing (see section 2.4), and potentially assist to draw together the disparate worlds of research and practice, of thought and action (Schön, 1983).

Three of Russo & Schoemaker’s (1989) origin 10 framing questions were omitted from the summaries of confidence criteria in section 5.2: question 6: ‘Why

do I think the way I do?’ question 9: ‘Do other people think differently?’ and question 10: ‘What is your slogan?’ These three questions explore the ‘social context’ of a frame; while the other questions focus on symbolic aspects (refer section 2.4.1). These same omissions have appeared in Russo & Schoemaker’s (2000) revised book *Winning Decisions*, confirming the abridged list of seven questions.

6.4 System Dynamics

This project has developed the empirically based framework of user confidence missing in system dynamics (see section 2.3). This framework demonstrates that the concept of confidence for the WETA model is extensive, but also somewhat elusive and difficult to interpret. In addition, by demonstrating that the concept of user confidence can be elicited from model users, this might eventually mean that model-building projects can be designed around designated confidence criteria. This approach could potentially bypass the problematic debate about the validity of a model, which is ‘often more a debate about philosophies than about a model’ (Forrester, 1973a, p. 24).

Although system dynamics authors have favoured the use of the term *validity* (including Coyle & Exelby, 2000) rather than *confidence*, the former term has traditionally been associated with technical criteria such as accuracy, fidelity, soundness and sophistication. Such terms represent a positivist paradigm (see Table 5.3.6-1) and a bias towards absolute proof not reflected in confidence issues obtained from the model users in this study. This finding seems to reinforce the appropriateness, in system dynamics, of the concept of *user confidence* rather than *model validity*. This matter was highlighted by a model user who stated, in an apparent mixture of irony and hyperbole: ‘Oh! All models are cooked.’

The confidence criteria interpreted in this study suggest that utility may be a common perspective of user confidence in system dynamics models, and therefore more important to the success of a model-building project than the traditionally emphasized perspectives of rationality and empiricism. Nevertheless, system dynamics model-builders could expect that model users have different concepts of user confidence and these concepts will change during the project. Nevertheless, it seems likely from the findings of this study that the concept of user confidence

becomes more stable once the user is presented with a qualitative model of the problem.

The general response of model users to the WETA model at the end of the study were positive: ‘the model is a good result of the effort of the project’; ‘it has already created some thinking’; and ‘I have acquired validity of the model’. It must be noted, however that the WETA model was not in use with Army workforce planners at the time of submitting this dissertation for examination, which is approximately eight months after the last interviews. This would suggest that the model-building project did not satisfy the important utilitarian perspective of user confidence. A possible explanation is that while the model was perceived as useful, it was viewed as having relatively lower utility than existing mental models of workforce planning. It is also possible that the project did not satisfy the relativist aspects of user confidence (see Table 5.3.6-1 above) with which some users may perceive an academic project.

This case study highlights aspects of Army workforce planning that suggest it might be appropriately described as a wicked problem (see section 2.2.1). To the users of the WETA model, Army workforce planning seemed like a ‘Pandora’s box’ (McLucas, 2004), and that trying to tame the problem served to make it more problematic (Mason & Mitroff, 1981). Although the outcome of this model-building project tends to confirm that ‘the big problem with management science models is that managers practically never use them’ (Shannon, 1975, p. 243), this could feasibly be a consequence of the prevalence of wicked problems in management. It was not possible to ascertain why the WETA model was not initially adopted, leaving this explanation open to the possibilities that either workforce planning problems are resolved when a state of ‘ripeness’ is reached (Bakken et al., 2005), or possibly that some military managers do not accept the value of systems analysis of military problems (Schmidtchen, 2006). This is an area of practical application deserving of further research.

This project appeared to confirm that exemplary system dynamics model-building requires a high degree of skill and a broad range of experience; not simply proficiency in the technical skills and techniques, but also empathy for the needs of each model user. The author was further convinced by interaction with the model users in this project and supported by the confidence criteria raised by the model

users that the more difficult challenges facing system dynamics are not the technical ones.

6.5 Army Workforce Planning

This research is presented as a potentially paradigmatic case study of the dynamic behaviour of a military workforce planning problem (refer section 3.6.1.). The simulation results of the WETA model demonstrate that while the New Zealand Army's enlistment planning function acts as a balancing component of the workforce system, the leverage points for achievement of workforce targets are relatively ineffective against uncertain and volatile separation flows. The persistently aspirational forecasts of separations, arrived at by professional judgement, have contributed to the underachievement of strength targets during conditions of high demand for skilled labour. Without any major policy changes to this workforce planning approach and in the likely event that separation rates remain high, the Army could expect to fall short of growth targets.

The outputs from the WETA model suggest several leverage points for the achievement of workforce targets. A low separation target value can cause a counter-intuitive increase in workforce shortfalls. A policy of low separation targets is therefore questioned, because these targets are primarily judgemental, based on an unproven expectation of control over workforce outflows and despite a lack of knowledge about the appropriateness and attainability of those targets. Several recruit training variables may also provide policy levers for this problem, particularly the frequency of recruit intakes. Although some of these policy insights require further investigation before they can be considered for implementation, the WETA model imparts understanding about the relative impact of policy options that can be utilized immediately in a practical manner by Army workforce planners.

6.6 Research Contribution

This study contributes to a broad debate in system dynamics concerning user confidence in models. The empirically based, descriptive framework of user confidence for the principal model users of the WETA model is the main contribution from this research. The secondary contribution to both system dynamics and framing methods is the demonstration and review of framing as a

means of eliciting model user views and analysing their frames. This second part may help address a challenge posed by Sterman (2000), for the integration of model-building methods. Additionally, this research demonstrates the application of framing to a management context in the form of an interview tool.

The study has the capacity to contribute across a range of dimensions: system dynamics models, management science in New Zealand, and military workforce systems. The resulting descriptive framework could have relevance for other system dynamics model-building projects. The relevance could also be extended to the general case of computer simulation models of management problems, since the first interviews were conducted at a stage where most model users had no pre-existing knowledge of system dynamics.

This case study of Army workforce planning, described in chapter 4 of this dissertation, makes a unique research contribution because the method of case study research is relatively uncommon (Remenyi et al., 1998). In time, it is possible that this case may come to be viewed as a paradigmatic case (Flyvbjerg, 2004) to be used in related applications in system dynamics, framing or military workforce planning.

6.7 Research Limitations

This study has not explored the extent to which the academic purpose of this study may have affected each model user's concept of confidence in the model. Neither has the study attempted a theoretical explanation of the causal structure for model user views, although the interview data was suitable for such analysis. Instead, the study has assumed that the selection of a current and visible organisational problem was sufficient to convince the model users that this project was a legitimate activity for their time and interest. It was the researcher's deliberate decision to define the workforce planning problem without a structured group model-building session involving the model users. This step was taken due to the time limitations of the Masters thesis and was assessed as an acceptable risk due to familiarity with the problem and the stakeholders from three years' work in this field.

The scope of knowledge used in this research has been centred mainly on operations research, management science and system dynamics sources, primarily from the United States and Europe. While workforce planning material has been

gleaned from a range of military sources, these have primarily been publicly available and exclusively from western nations. The focus of the literature search was on model-building and management literature, and has therefore not explored the literature of framing, sociology or multi-methods in as much depth.

Some limitations of the WETA model should be considered alongside any interpretation of the simulation outputs and policy insights from the WETA model. The key assumptions of the model have been included in section 4.4 as an aid to understanding these limitations. A major caveat for the use of this model is that the cause of separation flows has been formulated simply as an external environmental variable, therefore neglecting the potential dynamic influence of motivational or retention factors. As explained in chapter 4, this simplification was considered adequate because the purpose of the model was to understand the process for achieving strength and enlistment targets, rather than to understand how retention policy or practice might work. This later purpose would be a worthy objective for further development of this model-building approach.

The workforce problem considered in this case study is only pertinent to a large contiguous workforce, of say more than about 1000, due to the way that separation behaviour is formulated. As military workforce systems are characterized by a bottom-fed, deep-hierarchical structure, it is unusual to find these defining behavioural characteristics in non-military workforces. It is therefore anticipated that the dynamic hypothesis underlying the WETA model will only be relevant to other military workforces and similarly structured organisations.

6.8 Recommendations

Several directions for future work are proposed for the fields spanned by this research. In the field of system dynamics, a suggested direction is the investigation of the relationship between a model user's interpreted confidence criteria, the measurable qualities of a model-building project and the success of that project. Secondly, it is suggested to test the link between the degree of initial stabilization of interpreted confidence criteria, with particular attention to the order in which the qualitative and quantitative results of model-building are presented to the model user. There may also be profit in the use of Russo & Schoemaker's (1989) framing questions as an aid to improving the technique of system dynamics model-building.

This would serve the dual benefits of helping the model-builder to understand the user's confidence in the model and encourage a more reflective approach to model-building. Thirdly, further study is suggested to develop a conceptual framework of user confidence, to support the development of practical techniques for improving user confidence.

The following specific recommendations are provided for the development of the WETA model:

- An additional feedback control loop is suggested, to link the model's finance and workforce sectors. This relationship would simulate the adjustment of workforce targets after successive years of workforce shortfalls, as observed in the financial year ending 30 June 2006. Sterman (2000) has referred to this dynamic behaviour as a 'floating goal' (Sterman, 2000).
- Another suggested feedback control loop linking the finance and workforce sectors would limit the planned flow of enlistments due to budget constraints (as suggested in section 4.4.4). Based on discussion with WETA model users, the impact of a salary budget cap is likely to be felt during the period of workforce growth.
- The time step of 1.0 month may be a source of error, compared to the smallest time constant in the WETA model of 3.0 months training duration. These values breach the guideline for the simulation time interval to be less than $\frac{1}{4}$ of the shortest time delay value in the model (Sterman, 2000). Experimentation with a smaller time step would be prudent.
- While the simulations for this study used fixed policy values, variable values would be more realistic for planning purposes. For example, it makes practical sense to vary recruit training capacity for bold changes in the separation rate. Dynamic capacity levels have been used widely in manufacturing and economic models of production and capacity (refer Sterman, 2000, chapter 20).
- Given the Army's stated intention to improve the retention of personnel, it would be sensible to include variables that simulate the impact of specific policy interventions and control measures. This would involve a number of qualitative (or 'soft') variables to represent antecedents of separation behaviour, some of which the Army has recently operationalised such as, 'involved management',

‘respect’, ‘military belonging’, ‘satisfaction’ and ‘work-life’ (NZDF, 2006a). The potential impact of this work would be to reduce the uncertainty and volatility of separation rates, which this study concludes is the primary cause of workforce shortfalls.

- The assumption about management influence over the separation rate, or any other endogenous behaviour regarding separation, is a potentially contentious simplification. Further research into this part of the model is recommended as managers will continue to seek to control the rate of personnel leaving and the WETA model has shown (refer Table 4.4.7-1) that workforce planning outcomes are sensitive to the degree of fluctuation in the separation rate.

Appendix 1: Glossary of terminology

'We can count, but we are rapidly forgetting how to say what is worth counting and why.'

Weizenbaum, 1976, p. 16

A1.1 Definition of Terms

Causal loop diagram. 'A causal loop diagram is a convenient way of representing the principal feedback loops and related causal relationships relevant to a particular problem situation, without distinguishing between the nature of the interconnected variables. In the first instance causal loop diagrams serve as preliminary sketches of causal hypotheses. Later, they enable the essential components and interrelationships to be summarised. Arrows are used to indicate direction of causal influences. Signs (+ or -) adjacent the arrows indicate polarity, that is, how a change in the variable at the tail of the arrow produces a change at the head of the arrow. ... For a detailed explanation of causal loop diagrams, see Sterman (2000; 137-190). For an expose of the problems in the use of causal loop diagrams, see Richardson (1986). As an enabling tool to inform development of quantitative system dynamics models, causal loop diagrams suffer the significant limitation that they do not force the modeller to identify and discriminate between rate variables and those special variables which describe the state of the system under study, that is, state variables (stocks, levels or accumulators).' (McLucas, 2002, pp. 233-234)

Client (for the model). Refer to the section on Model-Building Terminology below.

Complexity. 'Complexity describes that which comprises myriad parts, or which is complicated in nature. Complexity can be considered as comprising two forms, detail and dynamic. Detail complexity describes too many factors to be considered at any one time. Dynamic complexity describes behaviour we observe which changes over time, where the patterns of change are familiar but the underlying factors that produce change over time may be obscured. Fundamentally, a system is complex when we cannot understand it through simple cause-and-effect relationships or other standard methods of systems analysis. In a complex system, we cannot reduce the interplay of individual elements to the study of individual elements considered in isolation. Often, several different models, each at a different level of abstraction, are needed.' (McLucas, 2002, p. 234)

Concept. A (research) concept is 'an idea expressed as a symbol or in words'. (Cavana et al., 2001, p. 78)

Confidence (of a model user). Forrester (1961) has stated that *confidence* is an 'interim' measure of the success of a model, pending judgement of the model-based intervention, while Vennix has explained that *confidence* is necessary because validity can 'never be established' (1996, p. 89). *Confidence* has also been described as 'central' to *validity* (Wolstenholme, 1990); a recognition of the trade-off between satisfaction and effort (Forrester, 1994); something which accumulates gradually (Maani & Cavana, 2000); the threshold for a

consultant to use the model to provide practical advice to a fee-paying client (Coyle & Exelby, 2000); and the end or outcome of model-building (Forrester, 1961, chapter 13; Forrester & Senge, 1980; and Sterman, 2000). Given this broad range of usage, I have chosen a common meaning for *confidence*: ‘firm trust; a feeling of reliance or certainty; a sense of self-reliance, boldness.’ (Concise Oxford Dictionary, 1990, p. 239) In this sense of the word, judgement is a feeling about the quality of an object, rather than a measure of that quality.

Dynamic hypothesis. ‘The dynamic hypothesis in a system dynamics study is a statement of system structure that appears to have the potential to generate the problem behaviour.’ (Richardson & Pugh, 1981, p. 55) ‘Dynamic hypotheses are sets of statements and representations of the causes and how these produce changes over time. Dynamic hypotheses are evaluated through iterative processes that involve building and testing systems dynamics models then critically comparing their behaviour with that we see in the real world. The purpose of any model we create is to provide an experimental framework for testing our dynamic hypotheses and new managerial policies ‘ye might be considering for subsequent implementation. Every model must be built with the aim of enhancing our understanding of complex problems that we cannot fully understand without having a model to help us.’ (McLucas, 2002, p. 236)

Endogenous. ‘Endogenous literally means growing or originating from within. In system dynamics the internal structure of a problem, notably the internal feedback mechanisms, create behaviour over time quite independently of, or without the need for, external forces. Dynamic behaviour created by endogenous feedback mechanisms, therefore, is internally generated.’ (McLucas, 2002, p. 236) See also *exogenous*.

Exogenous. ‘Exogenous literally means growing or originating from without, or from outside. In system dynamics, external forces are identified and are frequently treated quite separately until the forces and mechanisms internal to the problem have been analysed. Dynamic behaviour of complex systems can be created by both the internally generated action of endogenous feedback mechanisms and forces applied at the boundary of the problem space under consideration, that is, by exogenous forces.’ (McLucas, 2002, p. 237) See also *endogenous*.

Face validity (of research). ‘(Face validity is) the possibility of a construct being valid as a result of a superficial or on the face of it enquiry or inspection.’ (Remenyi et al., 1998, p. 283)

Frame. In this study, I have used the term *frame* to mean the cognitive structure applied to personal experience, embedded within a particular social context. Refer also to *framing*.

Framework. The (*descriptive*) *framework* is the integrated description and structuring of all *themes* from the empirical data that make up the *concept* being studied, as called a *conceptual framework* by Cavana et al. (2001). Refer also to *concept* and *themes*.

Leverage point. ‘A leverage point is where a small difference can make a large difference. Leverage points provide kernel ideas and procedures for

formulating solutions. Identifying leverage points helps us create new courses of action, develop increased awareness of those things that may cause a difficulty before there are any obvious signs of trouble, and figure out what is causing a difficulty.’ (McLucas, 2002, p. 239) Leverage has been defined by Senge (1990) as ‘small, well-focused actions can sometimes produce significant, enduring improvements, if they’re in the right place’. (p. 64)

Method. Although the meaning of the term *method* has become ambiguous and confusing in research (Mingers & Brocklesby, 1997) it is a necessary means of discriminating between high-level methodologies and subordinate levels of research practice. For this study, method is defined as the combination of techniques and practices that together represent a particular, identifiable school of research or problem-solving practice. See also *paradigm*, *methodology*, *technique* and *tool*.

Methodology. ‘A *methodology* is a structured set of guidelines or activities to assist people in understanding research or intervention.’ (Mingers & Brocklesby, 1997, p. 490; italics in original text) See also *technique*.

Model. A model is ‘an approximation of reality that emphasizes some features at the expense of others.’ (Schrage, 2000, p. 7) Refer also to *simulation model*.

Model-builder. Refer to the section on Model-Building Terminology below.

Model user (or user). Refer to the section on Model-Building Terminology below.

Operations research and management science.

Paradigm. ‘A paradigm is a very general set of philosophical assumptions that define the nature of possible research and intervention.’ (Mingers & Brocklesby, 1997, p. 490) ‘Adopting a particular paradigm is like viewing the world through a particular instrument such as a telescope, an X-ray machine or an electron microscope.’ (Mingers & Brocklesby, 1997, p. 492) Refer also to *positivism* and *relativism*.

Perspective. I use the term (*theoretical*) *perspective* selectively and explicitly in this dissertation to refer to the *meta-themes* within the *descriptive framework* of (*user*) *confidence*. In this study, I adopted the four paradigms of *rationality*, *empiricism*, *utility* and *relativity*, from the literature of system dynamics, as the *meta-themes* of confidence. The definitions for these four *perspectives* are contained in Table 2.3.3-1. Refer also to *themes*, *framework* and *confidence*.

Positivism. ‘Positivism was adopted by Comte (1798—1857) to express the idea that phenomena were real, certain, and precise. All knowledge consists in the description and coexistence and succession of such phenomena. It became an extremely influential intellectual trend from the mid-nineteenth century, forming, until very recently, the generally accepted view of science. Positivism is a theory of the nature, omniscience and unity of science as understood in the physical world’ (Remenyi et al., 1998, p. 287). Refer also to *paradigm*.

Principal model user. Principal model user means a stakeholder of the model-building project with ‘a vested interest in the problem situation and its solution’ (Landry, Malouin & Oral, 1981, p. 216).

Regular force (personnel). Regular force personnel are the permanently employed, uniformed component of the New Zealand Defence Force workforce. Regular force (abbreviated 'RF') are enlisted into military service as volunteers, and the majority enter through initial training.

Relativism. Cavana et al. Refer also to *paradigm*.

Reliability. '[Reliability] implies that similar results will be obtained by researchers on different occasions (Easterby-Smith et al., 1994) and the concern is therefore with how replicable the research study is.' (Remenyi et al., 1998, p. 288)

Simulation model. Simulation is a particular model-building technique of operations research and management science that has proven popular for organisational problems (De Greene, 1982). In its simplest terms, a simulation is 'a virtual model of a process' and a model is 'an approximation of reality that emphasizes some features at the expense of others' (Schrage, 2000, p. 7). 'Simulation experiments allow finding leverage points for designing more robust policies and structures which cannot be derived from qualitative analysis only.' (Größler, 2004, p. 2) Refer also to *model*.

Stakeholder. 'Simply put, a stakeholder is any group or individual who can effect, or is affected by, the achievement of a corporation's purpose.' (Freeman, 1984, p. vi)

System dynamics. 'The "dynamics" in "system dynamics" refers to the fundamental patterns of change such as growth, decay, and oscillations. System dynamics models are constructed to help us understand why these patterns occur. Our purpose is improved understanding, not prediction.' (Ford, 1999, p. 10) In this study 'system dynamics' is used to refer to the method that produces a quantitative computerised stock-flow model including feedback and using the integration of simultaneous equations.

Social system. I use the term 'social system' to mean organisations of people where the defining characteristic is that choice and free will is a characteristic of both the individual and the organisation as a whole (Ackoff, 2001).

Technique. 'A *technique* is a specific activity that has a clear and well-defined purpose within the context of a methodology.' (Mingers & Brocklesby, 1997, p. 491; italics in original text) Refer also *methodology* and *tool*.

Territorial force (personnel). Territorial force personnel are the part-time, uniformed workforce. For the purposes of this case study, this population (abbreviated 'TF'), serves as a reserve of personnel to supplement or substitute for RF personnel, particularly for operational deployments. Refer also *regular force*.

Themes. *Themes* are names, labels given to the topics that represent the clusters of *sub-themes* that emerge from the data. *Sub-themes* are the actual ideas that emerge from the data, like indexes for a book (Cavana et al., 2001). *Meta-themes* are the labels for the grouping of themes, and *mega-themes* are one further level of aggregation higher.

Tool. 'A *tool* is an artefact, often computer software, that can be used in performing a particular technique.' (Mingers & Brocklesby, 1997, p. 491; italics in original text) Refer also to *methodology* and *technique*.

User (or model user). Refer to the section on Model-Building Terminology below.

Validity (of research). '[Validity is] the degree to which what is observed or measured is the same as what was purported to be observed or measured.' (Remenyi et al. 1998, 291)

Validity (of a computer model). 'The system dynamics paradigm handles the problem of model validity qualitatively and informally.' (Meadows, 1980, p. 36) I have adopted the definition of *validity* provided by the system dynamics group at the Massachusetts Institute of Technology (MIT); which states that '*(validity is the) judgment of a model's suitability for a particular purpose. A model is valid when it accomplishes what is expected of it.*' (Zhu et al. 1995) The elements of this definition are that: *valid* models are purposive; *validity* is a judgment of the suitability of the model; the judgment of *validity* is subjective and relative to the model user's expectations; and *validity* is utilitarian, because it alludes to an outcome or intervention from the model-building project.

Validation. Forrester & Senge (1980) have defined *validation* as the 'process of establishing confidence in soundness and usefulness of a model.' (p. 210) I have adopted this definition for this dissertation, noting that Coyle (1997) has similarly explained that *validation* has come to mean 'confidence-boosting'. (refer to section 2.3.1) '(Validation) tests are aimed more at invalidating than validating the model.' (Greenberger et al., 1975, p. 71)

Verification. 'Verification of a model indicates that it has been faithful to its conception, irrespective of whether or not it and its conception are valid.' (Greenberger et al., 1976, p. 70) Verification is a 'necessary check that mechanisms of the model are in fact doing what the modeler thinks they are doing.' (Kitching, 1983, p. 42) McLucas has defined *verification* as 'the process of determining whether or not the products of a given phase of the system dynamics development cycle fulfil the requirements established during the previous phase.' (2002, p. 151) Therefore, while *validation* concerns the overall process and assessment of the model from an external perspective, *verification* refers to the linkages between elements of the process and their internal consistency. *Validation* and *verification* are the elements of *validity*. (refer to section 2.3.1)

Workforce. '(The workforce is) the labour pool in employment. It is generally used to describe those working for a single company or industry. The term generally excludes the employers or management, and implies those involved in manual labour. It may also mean all those that are available for work.'

(www.wikipedia.com) This definition, as is commonly implied in the use of the term, wrongly infers that supervisors, those engaged in non-manual labour (whatever that may be) and those temporarily away from their normal employment situation are not 'at work'. This is an outdated meaning with Taylorist overtones which has no practical application. The contemporary meaning of the workforce has been extended to reflect changes in the management of employees.

A1.2 Model-building terminology

I have employed the term *model user* or simply *user* to refer to those involved in the model-building project or those who make some use of the results. This is meant in a broad sense, including core users such as *clients* and *model-builders* as well as discretionary users such as peer *model-builders*, critics or persons affected by the model results. The term *principal model user* has a utilitarian focus, being defined as the *users* with a significant stake in the results of a model-based intervention. This utilitarian view is consistent with system dynamics literature (refer section 2.3).

The *client* and *model-builder* categorization has been used by a number of system dynamics authors including Vennix (1996); Forrester & Senge (1980); and Roberts (1978a). In this report, *client* refers to a manager or practitioner who is affected by the problem being modeled and is likely to be involved in the planning or implementation of any intervention or policy change that may result. *Model-builder* refers to the model-building practitioner who produces the product, or operates it, and includes peer *model-builders* and not simply the designated computer *model-builder* or team. These definitions are utilitarian and consistent with the theoretical perspective of system dynamics as described in section 2.3.

Table A1.2-1. *Examples of model user terminology.*

Author(s)	Field	Technical Role	Non-Technical Role
Sterman, 2000	SD	modeler	client
Kleijnen, 2000	SD	simulationist	-
McGregor, 2000	OR/MS	simulation practitioner	-
Lane, 1998	SD	simulator	-
Mingers & Brocklesby, 1997	OR/MS	agent	agent
Vennix, 1996; Forrester & Senge, 1980; and Roberts, 1978a	SD	model builder	client
Pidd, 1996	OR/MS	-	client
Coyle, 1996	SD	analyst	sponsor
Little, 1994	SD	model builder	manager
Greene, 1993	OR/MS	analyst	client
Quade & Carter, 1989	OR/MS	scientist	decision-maker
Yewlett, 1984	OR/MS	scientist	practitioner
Gass & Joel, 1981	OR/MS	analyst	decision-maker
Greenberger et al., 1976	OR/MS	designer	sponsor
Shannon, 1975	OR/MS	-	client-user
Forrester, 1973a	SD	observer	operator
Ansoff & Hayes, 1972	OR/MS	model-builder	manager
Forrester, 1961	SD	investigator	-

Note: 'OR/MS' refers to *operations research* and *management science*; and 'SD' refers to *system dynamics*

A1.3 Workforce planning terminology

The use of workforce planning terms has varied substantially between authors, fields of application and countries. The most confusing of these terms is for the identification of personnel leaving, and the manner in which they leave. *Attrition*, *churn*, *exit*, *separation*, *termination*, *turnover*, *quitting* and *wastage* are such terms found sprinkled through textbooks and published documents; normally without definition or explanation. *Separation* has been used in this study because it is defined in official New Zealand defence publications (such as NZ Ministry of Defence, 2004) and is therefore easier to operationalise for research and model-building. Using *separation* for this purpose avoids potential confusion associated with other terms of similar meaning, such as *turnover*, which can mean the double count of both leaving and enlistment; *attrition*, which infers a net change in the headcount and negative impact on the total workforce; or *wastage*, which implies that the loss of a single person is undesirable (meaning wasteful). *Separation* as a term is not without its problems, because it can be used to mean the physical separation of the serviceperson from their family or home location, however these considerations are relatively minor compared to the complications inherent with the alternatives.

Table A1-2. *Workforce planning terms.*

<i>Terminology and Definition in This Study</i>	<i>Related Terminology and Definition</i>
Workforce (System): <i>The personnel who are members of the, typically and, in the case of a military organisation, treated as serving at the time of measurement but not necessarily paid or fully employed.</i>	Personnel, or Human Resources
Internal labour market: <i>A highly structured and segmented workforce, with a constant upward internal flow of personnel, and a few main points of entry at the lower levels.' (Boxall & Purcell, 2003)</i>	
(Workforce) headcount: <i>'number of employees in an organization' (Heery & Noon, 2001, p. 152)</i>	Manpower: <i>'number of workers in an organization' (Ivanovic & Collin, 1998, p. 118); also</i> Inventory: <i>'the people in the workforce' as in 'commonplace usage in the (Department of Defense)' (Emmerichs et al., 2004, p. xi); or</i> Strength, or Employees
(Workforce) flow: <i>'the process by which employees pass through the organization ... inflow (recruitment and selection), throughflow (promotion and lateral career moves), and outflow (resignation, retirement, dismissal and redundancy)' (Heery & Noon, 2001, p. 161)</i> <i>'The movements into, out of and between parts of an organisation.' (Smith, 1976, p. 285)</i>	Turnover: <i>'changes in staff, when some leave and others join' (Ivanovic & Collin, 1998, p. 180); or</i> <i>'the degree of individual movement across the membership boundary' (Price, 1977, p. 4)</i>

<i>Terminology and Definition in This Study</i>	<i>Related Terminology and Definition</i>
Enlistment: <i>Personnel who become members of the workforce.</i>	Hiring: <i>'to engage new staff to work for you' (Ivanovic & Collin, 1998, p. 90); or</i> Recruitment: <i>'to search for an appoint new staff' (Ivanovic & Collin, 1998, p. 153);</i> <i>'The process by which people enter an organisation' Smith (1976, p. 286); also</i> Entry, Engagement, or Accession
Separation: <i>'Separation refers to the departure of individuals from the NZDF (New Zealand Defence Force), for whatever reason.'</i> (NZ Ministry of Defence, 2004, p. iii) <i>'Voluntary and involuntary departures from the NZDF (New Zealand Defence Force).'</i> (NZ Ministry of Defence, 2004, p. 1)	Separation: <i>'leaving a job (resigning, retiring or being fired or made redundant)' (Ivanovic & Collin, 1998, p. 165)</i> <i>'resign, transfer, be dismissed, or retire' (IPMA, 2002, p. 24)</i> Termination: <i>'end to a contract of employment', leaving a job (resigning, retiring or being fired or made redundant)' (Ivanovic & Collin, 1998, p. 178); but not necessarily</i> Attrition: <i>'Loss other than from compulsory retirement due to age.'</i> (Cotterill, 1970, p. 198). Wastage: <i>'The process by which people leave an organisation, including retirement but usually excluding redundancy. NB: If the organisation is part of a larger system, wastage will include transfers out of the organisation to other parts of the system.'</i> (Smith, 1976, p. 287)
Voluntary Separation: <i>'individual movement across the membership boundary of a social system which is initiated by the individual' (Price, 1977, p. 9)</i>	Voluntary Separation: <i>'losing workers because they resign or retire, not through redundancy or dismissals' (Ivanovic & Collin, 1998, p. 190); and</i> <i>'to resign or to leave (a job)' (Ivanovic & Collin, 1998, p. 149) ; or</i> Casual Wastage: <i>'The process by which people leave an organisation for reasons other than retirement or redundancy.'</i> (Smith, 1976, p. 284) Unmanaged Separation, or Quits
Involuntary Separation: <i>'involuntary separation is not initiated by the individual' (Price, 1977, p. 9)</i>	Managed Separation
Discharge	Redundancy
Dismissal	Firing
Cohort: <i>'individuals who experienced a particular event during a specified period of time' (Glenn, 2005, p. 2)</i>	
Cohort Separation	Attrition: <i>'failure of recruits to complete their first enlistment</i>

<i>Terminology and Definition in This Study</i>	<i>Related Terminology and Definition successfully' (Walker, 1996, p. i)</i>
Retention: <i>'the ability to hold onto employees' (Heery & Noon, 2001, p. 309)</i>	
Induction Crisis: <i>'a very high rate of leaving in the first few months of service' (Bennison & Casson, 1984, p. 11)</i>	Recruit (trainee) separation
(Workforce) Growth (or Decline): <i>accumulation of the workforce headcount due to a net positive enlistment (inflow)</i>	Expansion (or Contraction)

A1.4 Abbreviations

The following abbreviations in common usage have been employed in this dissertation:

CLD	causal loop diagram
IPMA	International Personnel Management Association
MIT	Massachusetts Institute of Technology
MoRST	Ministry of Research Science and Technology
MS	management science
NZ	New Zealand
NZDF	New Zealand Defence Force
NZ MoD	New Zealand Ministry of Defence
OR	operations research
RF	regular force (personnel)
SD	system dynamics
US	United States of America
US DoD	United States Department of Defence
VV&A	verification, validation and accreditation
WETA model	workforce enlistment target achievement model

Appendix 2: Research documentation

1. Army approval to conduct research
2. Letter to participants

NEW ZEALAND ARMY
Army General Staff
MINUTE

5000/7/1

**AUTHORITY TO CONDUCT PERSONNEL RESEARCH:
FRAMING THE VALIDITY OF A SYSTEM DYNAMICS WORKFORCE MODEL**

Reference:

A. DFO 21/2002: Authority to Conduct Personnel Research

1. This request for authority to conduct personnel research in the NZ Army covers a Masters thesis research project proposed by Maj Markham to investigate the views of users about the validity of a system dynamics model. Authority for this research is requested under the auspices of the relevant Defence Force Order, Ref A.

2. Maj Markham will undertake this research as a student on the Masters of Management Studies programme at the Victoria University of Wellington. This project is supervised by Associate Professor John Davies from the Victoria Management School. The research report will be submitted for academic purposes and the findings may also be submitted as an academic journal article or conference paper. It is intended that the results of the study will assist with the design and management of future use of simulation workforce modelling projects in the NZ Army.

Workforce Modelling

3. This research focuses on the application of system dynamics modelling to Army RF workforce analysis. System dynamics is a management simulation technique based on the causally-structured relationships of a problem. System dynamics is intended to address problems of a time-related or long term nature.

4. The workforce problem used in this study is the relationship between RF workforce goals and the stability of recruitment flows. The model takes into account the main constraints and external influences for this problem, such as recruiting seasonality, training capacity and variability in separation rates. The system dynamics workforce model for this problem was developed for an early course as part of the same Masters of Management Studies program.

Framing Methodology

5. The aim of this research is to assess the use of "framing" as a research methodology. Framing is based on the technique of frame analysis presented in the 1989 book *"Decision Traps"* by Russo and Schoemaker. Framing can be used to describe the way a person thinks about a particular issue, by exploring aspects of the person's thinking such as boundaries, yardsticks, reference points, metaphors and slogans. This study will use interviews to elicit the thinking frames of the principal users of the workforce model.

6. This study will assess the effectiveness and efficiency of the framing methodology. If framing proves to be useful it may be employed in future Army workforce modelling and analysis projects. The summarised user views of the model's validity may also serve as a guide for the design and use of valid future simulation models.

Research Design

7. The objective of this research is to assess the efficacy of framing methodology. This will be done by answering the research questions:

- a. What are the principal model users' thinking frames for the model's validity?
- b. How do users' thinking frames differ and vary over time?

8. A research sample of between six and eight staff is preferred, including at least one person familiar with the use of system dynamics models. The selection of participants will be made in consultation with ACGS HR and will be designed to ensure the involvement of the principal staff concerned with the problem of oscillations and instability in RF strength and recruitment.

9. This research process will include two interviews with each participant over the period June-August 2006. The format for the interviews is described in the interview guides enclosed.

Administration

10. The interviews will occur at minimal marginal cost to the Army. This research will be conducted in accordance with the Privacy Act 1993 and the ethical guidelines in Schedule Two of Annex B to Ref A.

11. The Information Sheet and Consent Form for this research project are also enclosed. All documents provided with this request have been submitted with the application for approval by the Pipitea Human Ethics Committee at Victoria University of Wellington.

J.Y. MARKHAM
Maj
Masters Student

Dated this 11th day of May 2006

3

[Approvals page for framing methodology research proposal.]

Recommended / ~~Not Recommended~~
Comments:

H.M. HORN
Maj
Senior Psychologist (Army)

Approved / ~~Not Approved~~ / ~~Resubmit~~

Sir, this is useful
research for Army.
ACGS HR.

L.J. GARDINER
MajGen
Chief of Army

Enclosures:

1. Information Sheet
2. Consent Form
3. Interview Guides

NEW ZEALAND ARMY
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| June 06

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REQUEST FOR RESEARCH PROJECT ASSISTANCE

References:

- A. DFO 21/02: Authority to Conduct Personnel Research
- B. Army 5000/7/1 dated 11 May 2006
- C. Victoria University of Wellington 2006-22 dated 25 May 06

1. As part of the requirements for a Masters degree in Management Studies at Victoria University, T55217 Maj J. Markham, RNZE is completing research into 'The Use of Framing Methodology for User Perspectives of a Model's Validity: The Case of a System Dynamics Workforce Model in the NZ Army'. This study complies with the NZDF research requirements in Ref A and is authorised by the Chief of Army in Ref B. This research is an academic study and not an Army-directed project. It will provide value for the Army as well as professional benefit and personal development for the individuals.

2. The Victoria University Ethics Committee require that the approach to potential participants be made by the Army rather than Maj Markham (Ref C).

3. The addressees have been identified as the principal users for Maj Markham's workforce model because they have critical knowledge and expertise for the achievement of RF strength targets. The problematic issue addressed by this workforce model is described in the attached briefing document. Participation in this study is voluntary.

4. This study will involve approximately two hours of interviews, spread over the next three months, as well as participation in a group model simulation session. Selected users may also be requested to provide data for the model.

5. Addressees are invited to take part in this research on an individual basis, and should advise Maj Markham directly of their intention to participate (email to: jason.markham@nzdf.mil.nz). Your assistance in this worthwhile study is encouraged.

A.G. McCone
Col
ACGS HR

Appendix 3: Frame analysis worksheet

<u>FRAME ANALYSIS WORKSHEET</u>
1. What issue or issues does the frame address?
2. What boundaries do I (we/they) put on the question? In other words, what aspects of the situation are left out of consideration?
3. What yardsticks/performance criteria do I (we/they) use to measure success?
4. What reference points do I (we/they) use to measure success?
5. What metaphors—if any—do I (we/they) use in thinking about this issue?
6. Why do I (we/they) think about this question the way I (we/they) do?
7. What does the frame emphasize or highlight?
8. What does the frame minimize or shadow?
9. Do other people in the industry think about this question differently from the way I (we/they) do?
10. Can I (we/they) summarize my (our/their) frame in a slogan?

Figure A3-1. Frame Analysis Worksheet.

Source: Davies & Mabin, 2001a; adapted from Russo & Schoemaker, 1989

Appendix 4: Documentation for the WETA model

Figure A4-1. Diagram view of the WETA model.

Table A4-1. *Equations for the WETA model.*

Variable	Type	Unit	Definition	Comment	History Case 01.07.02	Base Case 01.07.06
			WORKFORCE SECTOR			
<i>RF_in_Army</i>	Stock	Person	INITIAL VALUE: <i>RF_in_Army_Init</i> INFLOWS: <i>Recruit_Enlistments</i> + <i>Cadet_Enlistments</i> + <i>Trained_Enlistments</i> OUTFLOW: <i>RF_Separate</i> IN/OUTFLOW: <i>Net_Tfr_non_Army</i>	Headcount of RF population in Army posts. The enlistment flows into this population are recruits, (officer) cadets and trained (former serving) personnel. The main flow out is for personnel separating from RF service. There is also a net transfer flow of personnel back and forth between Army and non-Army posts. Personnel separating from non-Army posts are incorporated in the separation flow from this stock.	4281	4327
<i>RF_not_in_Army</i>	Stock	Person	INITIAL VALUE: <i>RF_Non_Army_Init</i> IN/OUTFLOW: <i>Net_Tfr_non_Army</i>	Headcount of RF population in non-Army posts. This stock represents the segment of the RF population not paid from the Army budget.	173	176
<i>Net_Tfr_non_Army</i>	Flow	Person/mo	<i>Tfr_Non_Army_Curr</i> * 12	The net transfer of RF between Army and non-Army posts, the main difference being that salary costs for personnel in non-Army posts are not paid from the Army's personnel budget.	-5	0
<i>RF_Separate</i>	Flow	Person/mo	<i>Avg_RF_Str</i> * <i>Sep_Seasonality</i> * IF (YEAR (TIME - 6<<mo>>) < 2007, <i>Historic_Sep_Trend</i> , <i>Future_Sep_Trend</i>)	Flow of RF separating from Army employment, excluding TF returning from operations. This flow is simulated differently for historical time periods compared to future time periods.	57.22	51.15
<i>Historic_Sep_Trend</i>	Auxiliary	%/yr	100 * LOOKUP (<i>Propensity_to_Leave_XL</i> , INTEGER ((YEAR (TIME) - 1990) * 12 + MONTH (TIME)))	The base separation trend (without monthly seasonality fluctuations) to simulate past patterns. The historical trend changes annually as is the best fit of straight lines against the rolling average.	13.46	14.43

Variable	Type	Unit	Definition	Comment	History Case 01.07.02	Base Case 01.07.06
<i>Future_Sep_Trend</i>	<i>Auxiliary</i>	%/yr	$(Max_Separation + Min_Separation) / 2 + SINWAVE (((Max_Separation - Min_Separation) / 2), Cycle_Time, (DATE(2007,7,1) - STARTTIME))$	The base separation trend (without monthly seasonality fluctuations) to simulate a wave form pattern of trend behaviour into the future.	15.00	12.15
<i>Sep_Seasonality</i>	<i>Auxiliary</i>		$LOOKUP (Monthly_Sep_XL, INTEGER ((YEAR (TIME) - 1990) * 12 + MONTH (TIME)))$	A seasonally varying factor to simulate the monthly fluctuations of personnel separating.	1.16	0.97
<i>Min_Separation</i>	<i>Constant</i>	%/yr	12	The minimum level that the RF separation rate will fall to in any future period.	N/A	12.00
<i>Max_Separation</i>	<i>Constant</i>	%/yr	18	The maximum level that the RF separation rate will rise to in any future period.	N/A	18.00
<i>Sep_Cycle_Time</i>	<i>Constant</i>	Yr	8	The wavelength of the sinusoidal wave simulating the trend of the separation rate.	N/A	5
<i>Avg_RF_Str</i>	<i>Auxiliary</i>	Person	$SLIDINGAVERAGE (RF_in_Army + RF_not_in_Army, 12<<mo>>, Tot_Str_Prior_to_Start)$	Rolling average 12-month headcount of all RF, excluding TF serving on operations. This figure is used to calculate the separation rate.	4383.4	4385.3
<i>Avg_Army_Str</i>	<i>Auxiliary</i>	Person	$SLIDINGAVERAGE (RF_in_Army + TF_on_Ops, 12<<mo>>, Army_Str_Prior_to_Start)$	Rolling average 12-month headcount of RF in Army plus TF on operations. This figure excludes RF posted to non-Army posts (such as headquarters) and is used to calculate annual expenditure from the Army's pay budget.	4357.8	4278.8
<i>RF_Sep_Rate</i>	<i>Auxiliary</i>	%/yr	$SLIDINGINTEGRATE (RF_Separate, 12<<mo>>, Sep_Prior_to_Start) / 1<<yr>> / Avg_RF_Str$	12-month cumulative total rate of separation from the Army RF population, including non-Army posts but excluding TF on operations. This variable is used for estimating the number of enlistments to	13.32	14.91

Variable	Type	Unit	Definition	Comment	History Case 01.07.02	Base Case 01.07.06
				<i>achieve the workforce target.</i>		
<i>TF_on_Ops</i>	<i>Stock</i>	<i>Person</i>	<i>INITIAL VALUE: TF_on_Ops_Init</i> <i>INFLOW: TF_to_Ops</i> <i>OUTFLOW: TF_from_Ops</i>	<i>Headcount of TF serving on operations, under RF conditions of service.</i>	148	60
<i>TF_from_Ops</i>	<i>Flow</i>	<i>Person/mo</i>	<i>DELAYPPL (TF_to_Ops, Deployment_Length, TF_from_Ops_Init)</i>	<i>Rate of TF returning from operational service, which is the same as the rate commencing operations, delayed by the average time spent on operations (including pre-deployment and post-deployment activities).</i>	24	9
<i>TF_to_Ops</i>	<i>Flow</i>	<i>Person/mo</i>	<i>TF_to_Ops_Hist + PULSE</i> <i>(Ops_Surge_TF_Demand, DATE</i> <i>(Ops_Surge_Year), 6<<mo>>) – PULSE</i> <i>(Ops_Surge_TF_Demand, DATE</i> <i>(Ops_Surge_Year) + Ops_Surge_TF_Tranches * 6<<mo>>, 6<<mo>>)</i>	<i>Rate of TF commencing operational service. This is determined by the year in which the operation commences, the number of personnel deployed and the number of tranches (deployment cycles) for that operation.</i>	7	4
<i>Deployment_Length</i>	<i>Constant</i>	<i>mo</i>	8	<i>The length of time TF spend on operations, including pre- and post-deployment activities.</i>	8	8
<i>TF_Ops_Demand</i>	<i>Constant</i>	<i>Person</i>	80	<i>Number of TF personnel deploying in each cycle of a major operational commitment.</i>	N/A	80
<i>TF_Ops_Tranches</i>	<i>Constant</i>		4	<i>The number of cycles of deployment for a TF contingent on a major operation.</i>	N/A	4

Variable	Type	Unit	Definition	Comment	History Case 01.07.02	Base Case 01.07.06
<i>Ops_Surge_Year</i>	<i>Constant</i>		2009	<i>The year in which the operational deployment commences.</i>	N/A	2010
<i>Enl_Target_Gap</i>	<i>Constant</i>	%	5	<i>The shortfall of actual enlistment against the target for all enlistment streams, as a percentage of the target.</i>	5	5
<i>Army_Strength</i>	<i>Auxiliary</i>	<i>Person</i>	<i>RF_in_Army + TF_on_Ops</i>	<i>Total headcount of all RF, plus TF on operations.</i>	4429	4387
<i>Army_Hist</i>	<i>Auxiliary</i>	<i>Person</i>	<i>RF_in_Army_Hist + TF_on_Ops_Hist</i>	<i>Historical values of total headcount for all RF, plus TF on operations.</i>	4429	4387
			ENLISTMENT PLANNING SECTOR			
<i>Army_Target</i>	<i>Auxiliary</i>	<i>Person</i>	<i>SAMPLEIF (MONTH (TIME) = 7, Total_Strength_Target - RF_not_in_Army, Total_Strength_Target - RF_not_in_Army)</i>	<i>Strength target for the RF population, including those employed outside Army posts but excluding TF on operations. This figure is not used for the enlistment planning calculation but it is often reported because it is the basis</i>	4403	4287
<i>Total_Strength_Target</i>	<i>Auxiliary</i>	<i>Person</i>	<i>LOOKUP (Strength_Target_XL, YEAR (TIME + 6<mo>>) - 1990)</i>	<i>Strength target for the population paid from the Army RF personnel budget for the current financial year.</i>	4576	4463
<i>Army_Shortfall</i>	<i>Auxiliary</i>	<i>Person</i>	<i>Army_Target – SAMPLEIF (MONTH (TIME) = 7, Army_Strength, Army_Strength)</i>	<i>Shortfall of personnel paid from the Army budget for RF pay, compared to the target (excludes TF on operations). This calculation involves a first order information delay due to the lead-time required for setting recruit targets.</i>	-26	-99.96
<i>Average_Shortfall</i>	<i>Auxiliary</i>	<i>Person</i>	<i>RUNAVERAGE (IF (Army_Shortfall ></i>	<i>A measure of the average shortfall of RF personnel for the period of the simulation, excluding surplus</i>	0	

Variable	Type	Unit	Definition	Comment	History Case 01.07.02	Base Case 01.07.06
			$0 << \text{Person} >> , \text{Army_Shortfall})$	values.		
Target_Growth	Auxiliary	Person/yr	$(\text{Str_Target_CY} - \text{Total_Strength_Target}) / 1 << \text{yr} >>$	The change in the strength target over the year for which enlistment is being planned.	0	108.35
Str_Target_CY	Auxiliary	Person	LOOKUP (Strength_Target_XL, YEAR (TIME + 6 << mo >>) - 1989)	The strength target for the current year, used to calculate the growth in strength target between consecutive years.	4576	4571.40
Desired_Sep_Rate	Auxiliary	%/yr	14	The forecast of the separation rate used to plan the enlistment targets for the current financial year.	15.00	15.00
Planned_Enlistment	Auxiliary	Person/yr	$(\text{DELAYPPL}(\text{Avg_RF_Str}, \text{Recruiting_Lead_Time} + \text{Target_Review_Freq}/2, \text{Avg_RF_Str}) + \text{Target_Growth} * (\text{Recruiting_Lead_Time} + \text{Target_Review_Freq}/2) + \text{Army_Shortfall} * (\text{Recruiting_Lead_Time} + \text{Target_Review_Freq}/2) / \text{Time_to_Reduce_RF_Shortfall}) * (\text{DELAYPPL}(\text{RF_Sep_Rate}, \text{Recruiting_Lead_Time} + \text{Target_Review_Freq}/2, \text{RF_Sep_Rate}) + (\text{Desired_Sep_Rate} - \text{DELAYPPL}(\text{RF_Sep_Rate}, \text{Recruiting_Lead_Time} + \text{Target_Review_Freq}/2, \text{RF_Sep_Rate})) * (\text{Recruiting_Lead_Time} + \text{Target_Review_Freq}/2) / \text{Time_to_Reach_Desired_Sep}) + \text{Target_Growth} + \text{Army_Shortfall} * (\text{Recruiting_Lead_Time} + \text{Target_Review_Freq}/2) / \text{Time_to_Reduce_RF_Shortfall} / 1 << \text{yr} >>$	Total enlistment target for RF, calculated on the basis of the rate at which the current workforce gap is to reduced, any change in the workforce target and the forecast rate of separation. This calculation involves an information delay due to the lead-time required for setting recruit targets.	569.03	621.22
Recruiting_Lead_Time	Auxiliary	mo	6	The delay between estimating the recruit target and actually enlisting the recruits.	6	6
Recruit_Target	Auxiliary	Person/yr	$\text{Planned_Enlistment} - \text{Cadet_Target} - \text{Trained_Target}$	The enlistment target for recruits is the remainder of the total enlistment target once officer cadet and trained enlistment targets have been deducted. The target is frozen at the anniversary of the target	389.03	441.22

Variable	Type	Unit	Definition	Comment	History Case 01.07.02	Base Case 01.07.06
				<i>review period, commencing from the first month of the simulation.</i>		
<i>Target_Review_Freq</i>	Constant	mo	4	<i>The period between revisions of the enlistment plan.</i>	4	4
<i>Time_to_Reduce_R_F_Shortfall</i>	Constant	yr	1	<i>The time period over which any strength gap will be reduced using additional enlistment.</i> <i>A value of 0.5 years was used to simulate the period 01.07.02 to 01.07.06 to imitate attempts over this period to catch up on strength shortfalls within each financial year. This 'fudge factor' was reduced to 1.0 for simulating the period beyond 01.07.06.</i>	0.5	1
<i>Time_to_Reach_Desired_Sep</i>	Constant	yr	2	<i>The time period over which the separation rate is expected to move from the current value to the desired rate.</i>	2	2
<i>Trained_Target</i>	Constant	Person/yr	120	<i>The number of trained (former serving) personnel to be recruited per year.</i>	120	120
<i>Cadet_Target</i>	Constant	Person/yr	60	<i>The enlistment target for officer cadets. This target includes specialist officers and university cadet schemes, but excludes TF officers undertaking initial training at Officer Cadet School.</i>	60	60
			TRAINING SECTOR			
<i>Recruit_Enlistments</i>	Auxiliary	Person/mo	$\text{MIN}(\text{LOOKUP}(\text{Recruit_Intakes}, \text{MONTH}(\text{TIME})) * 12 * (1 - \text{Enl_Target_Gap}) * \text{Recruit_Target}, \text{Empty_Recruit_Beds} / 12)$	<i>The number of recruit soldiers actually enlisted for training at the army depot. The number of enlistments is limited by the available bed space.</i>	0	0

Variable	Type	Unit	Definition	Comment	History Case 01.07.02	Base Case 01.07.06
<i>Empty_Recruit_Beds</i>	<i>Stock</i>	<i>Person</i>	<p>INITIAL VALUE: $\text{Recruit_Bed_Capacity} - \text{ARRSUM}(\text{FOR } (i=1..12) \text{IF } (1 < \text{Recruit_Trg_Duration} / 1 <<\text{mo}>>, \text{LOOKUP}(\text{Recruit_Enlist_Prior_to_Start}, i) * 1 <<\text{mo}>>, 0 <<\text{Person}>>)))$</p> <p>INFLOW: <i>Recruit_Beds_Vacated</i></p> <p>OUTFLOW: <i>Recruit_Beds_Occupied</i></p>	<i>The number of beds available at the army training depot for recruits attending initial training.</i>	297	320
<i>Recruit_Bed_Capacity</i>	<i>Constant</i>	<i>Person</i>	320	<p><i>The total number of beds available for use by recruits at the army training depot.</i></p> <p><i>A value of 360 has been used for simulating the period 01.07.02 to 01.07.06 because the training depot took exceptional measures over this time to accommodate an extra platoon of recruits at the start of each year. A value of 320 is used for simulations beyond 01.07.06 due to the shortage of experienced staff available for posting to the recruit training depot.</i></p>	360	320
<i>Intake_Freq</i>	<i>Constant</i>	<i>course/yr</i>	4	<i>The number of recruit intakes occurring in each year.</i>	4	4
<i>Recruit_Intakes</i>	<i>Auxiliary</i>		$\text{LOOKUP}(\text{Intake_Distribution}, \text{INTEGER}(\text{Intake_Freq} * 1 <<\text{yr}>> / 1 <<\text{course}>>))$	<i>The spread of recruit intakes over the year.</i>	{0.37, 0, 0.2, 0, 0, 0.2, 0, 0, 0.23, 0, 0, 0}	{0.37, 0, 0.2, 0, 0, 0.2, 0, 0, 0.23, 0, 0, 0}
<i>Recruit_Training_Duration</i>	<i>Constant</i>	<i>mo</i>	3	<p><i>Duration of recruit training at the army training depot.</i></p> <p><i>A value of 3 months was used for simulating the period 01.07.02 to 01.07.06 however this is expected to increase to as much as 6 months with the introduction of the 'enhanced basic' recruit</i></p>	3	3

Variable	Type	Unit	Definition	Comment	History Case 01.07.02	Base Case 01.07.06
				course.		
<i>Beds_Vacated</i>	<i>Flow</i>	<i>Person/mo</i>	<i>DELAYPPL (Recruit_Beds_Occupied, Recruit_Trg_Duration - 1<<mo>>, Recruit_Enlist_Prior_to_Start)</i>	<i>The rate of beds becoming available at the army training depot, as recruits leave the unit.</i>	31	0
<i>Beds_Occupied</i>	<i>Flow</i>	<i>Person/mo</i>	<i>Recruit_Enlistments</i>	<i>The rate at which empty recruit beds are occupied at the army training depot.</i>	0	0
<i>Trained_Enlistments</i>	<i>Auxiliary</i>	<i>Person/yr</i>	<i>Trained_Target * (1- Enl_Target_Gap)</i>	<i>The number of trained (former serving) personnel actually enlisted.</i>	9.5	9.5
<i>Cadet_Enlistments</i>	<i>Auxiliary</i>	<i>Person/mo</i>	<i>PULSEIF (Cadet_Intake_Month = INTEGER (MONTH (TIME)), Cadet_Target * 12<<mo>>) * (1 - Enl_Target_Gap)</i>	<i>The number of officer cadets actually enlisted.</i>	0	0
<i>Cadet_Intake_Month</i>	<i>Constant</i>		1	<i>The time of year in which officer cadets enlist (1 = January to 12 = December)</i>	1	1
			FINANCIAL SECTOR			
<i>Budget_Variance</i>	<i>Auxiliary</i>	\$	<i>Pay_Budge - Pay_Spend</i>	<i>The difference between the RF pay budget (for baseline salary costs) and the pay expenditure.</i>	- 5,206,788	4,774,491
<i>Pay_Spend</i>	<i>Auxiliary</i>	\$	<i>SAMPLEIF (MONTH (TIME)=7, Avg_Annual_Str * 365<<da>> * Avg_Daily_Pay)</i>	<i>The amount spent on RF baseline salary, as a rolling 12-month total.</i>	164,282,566	185,007,767
<i>Pay_Budget</i>	<i>Auxiliary</i>	\$	<i>LOOKUP (Pay_Budget_XL, YEAR (TIME + 6<<mo>>) - 1989)</i>	<i>The annual budget for RF baseline salaries.</i>	159,075,778	189,782,259

Variable	Type	Unit	Definition	Comment	History Case 01.07.02	Base Case 01.07.06
Avg_Pay_Rate	Auxiliary	\$/Person/da	$Avg_Daily_Pay_Hist + Annl_Pay_Incr * (YEAR (TIME + 6<<mo>>) - YEAR (STARTTIME + 6<<mo>>))$	The average daily rate of pay for all RF personnel.	102.68	118.46
Annl_Pay_Growth	Constant	\$/Person/da	4	The amount by which pay will increase per year.	4.00	4.00
			INITIAL AND REFERENCE VALUES			
RF_Non_Army_Init	Auxiliary	Person	$LOOKUP (RF_Non_Army_Hist_XL, ((YEAR (STARTTIME) - 1990) * 12) + (MONTH (STARTTIME)))$		173	
Tot_Str_Prior_to_Start	Auxiliary	Person	$FOR (i=1..11 LOOKUP (RF_Army_Hist_XL, (180 + I + MONTH (STARTTIME) - (2006 - YEAR (STARTTIME)) * 12))) + FOR (I = 1..11 LOOKUP (RF_Non_Army_Hist_XL, (180 + I + MONTH (STARTTIME) - (2006 - YEAR (STARTTIME)) * 12)))$		{4356, ...}	
RF_in_Army_Init	Auxiliary	Person	$LOOKUP (RF_Army_Hist_XL, ((YEAR (STARTTIME) - 1990) * 12) + (MONTH (STARTTIME)))$		4281	
RF_Non_Army_Hist_XL	Auxiliary	Person	XLDATA ("RF Data.xls", "Str", "I3:I314")<<Person>>		{180, ...}	
RF_Army_Hist_XL	Auxiliary	Person	XLDATA ("RF Data.xls", "Str", "L3:L314")<<Person>>		{5181, ...}	
Total_Str_End_PY	Auxiliary	Person	$LOOKUP (RF_Army_Hist_XL, (198 - (2006 - YEAR (STARTTIME)) * 12)) + LOOKUP (RF_Non_Army_Hist_XL, (198 - (2006 - YEAR$		4421	

Variable	Type	Unit	Definition	Comment	History Case 01.07.02	Base Case 01.07.06
			(STARTTIME)) * 12))			
Tot_Str_Hist	Auxiliary	Person	RF_in_Army_Hist + RF_Non_Army_Hist		4454	
RF_Annl_Avg_Hist_XL	Auxiliary	Person	XLDATA ("RF Data.xls", "Str", "G3:G195")<<Person>>		{5157, ... }	
AnnI_Avg_Strength_PY	Auxiliary	Person	LOOKUP (RF_Annl_Avg_Hist_XL, INTEGER ((YEAR (STARTTIME - 6<<mo>>) - 1990) * 12) + 7)		4531	
RF_Non_Army_Hist	Auxiliary	Person	LOOKUP (RF_Non_Army_Hist_XL, (YEAR (TIME) - 1990) * 12 + MONTH (TIME))		173	
RF_in_Army_Hist	Auxiliary	Person	LOOKUP (RF_Army_Hist_XL, (YEAR (TIME) - 1990) * 12 + MONTH (TIME))		4281	
Strength_Target_XL	Auxiliary	Person	XLDATA ("RF Data.xls", "NEIL's Data", "Q4:Q33")<<Person>>		{4576, ... }	
Intake_Distribution	Auxiliary		XLDATA ("RF Data.xls", "TAD Intakes", "B3:M10")		{{1, ... }}	
Recruit_Enlist_XL	Auxiliary	Person/mo	XLDATA ("RF Data.xls", "Enl", "K2:K302")<<Person/mo>>		{0, ... }	
Recruit_Enlist_Prior_to_Start	Auxiliary	Person/mo	FOR (i=1..12 LOOKUP (TAD_Enlist_XL, (192 - I + MONTH (TIME) - (2006 - YEAR (TIME)) * 12)))		{32, 31, 31, 31, 31, 29, 4, 3, 3, 3, 3, 2}	
RF_Enlist_Hist	Auxiliary		LOOKUP (RF_Enlist_XL, (YEAR (TIME) - 1990) *		5	

Variable	Type	Unit	Definition	Comment	History Case 01.07.02	Base Case 01.07.06
			$12 + \text{MONTH}(\text{TIME})$			
RF_Enlist_XL	Auxiliary		XLDATA ("RF Data.xls", "Enl", "D2:D302")		{99, ... }	
RF_Sep_Hist	Auxiliary	Person/mo	LOOKUP (-1 * Historical_Sep_XL, (192 + MONTH (TIME) - (2006 - YEAR (TIME)) * 12))			
Historical_Sep_XL	Auxiliary	Person/mo	XLDATA ("RF Data.xls", "Sep", "D2:D220")<<Person/mo>>		{-96, ... }	
Sep_Rate_Hist_XL	Auxiliary	%/yr	XLDATA ("RF Data.xls", "Sep", "G2:G220")<<%/yr>>		{0, ... }	
Sep_Prior_to_Start	Auxiliary	Person/mo	FOR (i=1..12 LOOKUP (-1 * Historical_Sep_XL, (192 - I + MONTH (STARTTIME) - (2006 - YEAR (STARTTIME)) * 12)))		{49, ... }	
Propensity_to_Leave_XL	Auxiliary	%/yr	XLDATA ("RF Data.xls", "Sep Forecast", "M5:M316")<<%/yr>>		{0, ... }	
Init_Sep_Rate_Start_PY	Auxiliary	%/yr	100 * LOOKUP (Sep_Rate_Hist_XL, INTEGER ((YEAR (STARTTIME - 18<<mo>>) - 1990) * 12) + 7)		17.49	
Init_Sep_Rate_End_PY	Auxiliary	%/yr	100 * LOOKUP (Sep_Rate_Hist_XL, INTEGER ((YEAR (STARTTIME - 6<<mo>>) - 1990) * 12) + 7)		17.48	
Monthly_Sep_XL	Auxiliary		XLDATA ("RF Data.xls", "Sep Forecast", "N5:N316")		{0, ... }	
Tfr_Non_Army_XL	Auxiliary		XLDATA("RF Data.xls", "Str", "H3:H314")		{0, ... }	

Variable	Type	Unit	Definition	Comment	History Case 01.07.02	Base Case 01.07.06
<i>Tfrs_To_Non_Army</i>	<i>Auxiliary</i>	<i>Person/yr</i>	$Tfr_Non_Army_XL * 1 \llcorner Person \gg / 1 \llcorner yr \gg$		{0, ... }	
<i>Tfr_Non_Army_Curr</i>	<i>Auxiliary</i>	<i>Person/yr</i>	LOOKUP (<i>Tfrs_To_Non_Army</i> , (YEAR (TIME) - 1990) * 12 + MONTH (TIME))		-5	
<i>TF_from_Ops_Init</i>	<i>Auxiliary</i>	<i>Person/mo</i>	-1 * FOR (i=1..8 LOOKUP (TF_from_Ops_XL, (183 + i+ MONTH (STARTTIME) - (2006 - YEAR (STARTTIME)) * 12)))		{9, 41, 26, 6, 4, 6, 10, 24}	
<i>TF_from_Ops_XL</i>	<i>Auxiliary</i>	<i>Person/mo</i>	XLDATA ("RF Data.xls", "Sep", "C2:C302") $\llcorner Person/mo \gg$		{-1, ... }	
<i>TF_to_Ops_XL</i>	<i>Auxiliary</i>	<i>Person/mo</i>	XLDATA ("RF Data.xls", "Enl", "C2:C302") $\llcorner Person/mo \gg$		{1, ... }	
<i>TF_to_Ops_Hist</i>	<i>Auxiliary</i>	<i>Person/mo</i>	LOOKUP (TF_to_Ops_XL, (YEAR (TIME) - 1990) * 12 + MONTH (TIME))		7	
<i>TF_on_Ops_Hist_XL</i>	<i>Auxiliary</i>	<i>Person</i>	XLDATA ("RF Data.xls", "Str", "C3:C314") $\llcorner Person \gg$		{31, ... }	
<i>TF_on_Ops_Hist</i>	<i>Auxiliary</i>	<i>Person</i>	LOOKUP (TF_on_Ops_Hist_XL, (YEAR (TIME) - 1990) * 12 + MONTH (TIME))		148	
<i>TF_on_Ops_Init</i>	<i>Auxiliary</i>	<i>Person</i>	LOOKUP (TF_on_Ops_Hist_XL, ((YEAR (STARTTIME) - 1990) * 12) + (MONTH (STARTTIME)))		148	

Variable	Type	Unit	Definition	Comment	History Case 01.07.02	Base Case 01.07.06
<i>Avg_Daily_Pay_Hist</i>	<i>Auxiliary</i>	<i>\$/Person/da</i>	<i>LOOKUP (Avg-Daily_Pay_XL, YEAR (TIME + 6<<mo>>)-1989)</i>		<i>102.68</i>	
<i>Avg-Daily_Pay_XL</i>	<i>Auxiliary</i>	<i>\$/Person/da</i>	<i>XLDATA ("RF Data.xls", "NEIL's Data", "R4:R33")<<\$/Person/da>></i>		<i>{0, ... }</i>	
<i>Pay_Budget_XL</i>	<i>Auxiliary</i>	<i>\$</i>	<i>XLDATA("RF Data.xls", "NEIL's Data", "O4:O33")<<\$>></i>		<i>{0, ... }</i>	
			SIMULATION VARIABLES			
<i>Start_Time</i>		<i>@mo</i>	<i>STARTTIME</i>	<i>Simulation start time</i>	<i>1/07/2002</i>	<i>1/07/2006</i>

Appendix 5: Descriptive framework of user confidence

Listed below are the elements of user confidence for the WETA system dynamics model, ordered in alphabetical order. Refer to the glossary in appendix 1 for an explanation of framework and themes. The meta-themes have been listed in relative progression from relativist to positivist perspectives.

Table A5-1. *Descriptive Framework of User Confidence.*

<i>META-THEMES and definitions</i>	<i>THEMES and confidence criteria (sub-themes)</i>	<i>Rules for inclusion</i>
<i>RELATIVITY</i> Confidence is relative to the user, not absolute.	<i>AFFECT</i> Discomfort Excitement Playfulness Surprise	<i>Emotional response towards the model; either positive or negative.</i>
	<i>DISCOURSE</i> Debate Discussion Humour Participation Relationship	<i>Involving purposeful social interaction, therefore recognising the legitimacy of different perspectives.</i>
	<i>SATISFACTION</i> Acceptance Adequacy Intuition Match	<i>Fulfillment of a desire.</i>
	<i>SIGNIFICANCE</i> Importance Relevance Seriousness	<i>Prominence within a personal context.</i>
	<i>SUBJECTIVITY</i> Expectation Interests Perception Prejudice Quality Relativity	<i>Partiality of view; principally towards other persons in the project.</i>
	<i>TRUST</i> Belief Confidence Convincingness Credibility Judgement	<i>A judgemental perspective based on sense or feeling.</i>
<i>UTILITY</i> Confidence is in the practicality or usefulness of the model.	<i>AGENCY</i> Alleviation Assistance Effect Control	<i>Enabling intentional action towards the problem.</i>
	<i>BENEFIT</i> Efficiency Improvement Profit	<i>Positive or favourable consequence of the model or project.</i>
	<i>COST</i> Affordability Effort	<i>Resource commitment or consumption, including foregone opportunity.</i>

<i>META-THEMES</i> and definitions	<i>THEMES</i> and confidence criteria (sub-themes)	<i>Rules for inclusion</i>
<i>UTILITY (continued)</i>	<i>SOLVENCY</i> Answer Decision-making Guidance Hypothesis Prescription	<i>Direct and intended relevance to the problem, independent of concrete action.</i>
	<i>SUITABILITY</i> Appropriateness Benchmark Replacement Required	<i>Fit for a specified, extant or general purpose.</i>
	<i>USABILITY</i> Accessibility Clarity Ease of use Flexibility Simplicity Timeliness	<i>Features making use of the model easier</i>
	<i>USE</i> Demand Implementation Integration Operation Support	<i>Employment of the model, including support or requests for further model-building effort.</i>
	<i>USEFULNESS</i> Pragmatism Responsiveness Tool Utility	<i>Producing good or serviceable results.</i>
<i>EMPIRICISM</i>	<i>ACCURACY</i> Precision	<i>Exactness or numerical consistency as compared to observations</i>
Confidence is 'a posteriori'; arising from correspondence between the model and observations.	<i>ANALYSIS</i> Forecast Investigation Monitor Prediction Prediction Policy analysis Quantification Sensitivity analysis Scenario analysis	<i>Refinement or manipulation of data for decision-making. Excludes speculative methods (c.f. Experiment).</i>
	<i>EXPERIMENT</i> Trial and Error Test	<i>Speculative assessment for the sake of proof by comparison with observations, including 'playing' for the purpose of proof</i>
	<i>FIDELITY</i> Completeness Correctness Reality Replica Representation Trueness	<i>Resemblance to observations of the particular problem, usually in a holistic sense.</i>
	<i>UNDERSTANDING</i> Description Education Explanation Illuminance Informing Insight Knowledge	<i>The act of revealing a thing previously unknown or unclear.</i>

<i>META-THEMES and definitions</i>	<i>THEMES and confidence criteria (sub-themes)</i>	<i>Rules for inclusion</i>
RATIONALITY Confidence is 'a priori', arising from the application of a system of logic, reason, design or method	CAVEAT Control limits Limitations Limited liability Strengths & weaknesses Unknown	<i>The bounds of user confidence in the model.</i>
	EXPERTISE Expert management Expert model-building	<i>Quality of knowledge or skill in the application of method.</i>
	LOGIC Assumptions Coherence Methodology	<i>Consistent with a formal or explicit structure of reason.</i>
	SOPHISTICATION Detail	<i>Complex or developed to an advanced level.</i>
	SOUNDNESS Provability Robustness	<i>Technical quality of the model, resting on the quality of design, structure or logic.</i>

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