This thesis contains no material which has been previously accepted for the awarding of any other degree or diploma in any university, institute or college, and contains no material previously published or written by another person, except where due reference is made.

Sydney, 10 October 2008.

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I also thank my supervisors, Margaret Rossiter and Barry Newell, for their ongoing support and sound advice. It was Barry who introduced me to the work of Lakoff, Johnson and Turner, and set me on a journey to try to understand and describe the 'science' behind the things I was doing intuitively at the time. Barry also gave an inordinate amount of his time proofreading my sometimes quaint prose.

Finally, I would like to thank my colleagues at Taribon for the many stimulating discussions about many of the concepts in this work. I especially thank John Clark. I have worked with John, in business improvement environments, for many years now. His unique take on many of the circumstances we have encountered can generate the dissonance that is so important to support true understanding.
Abstract

The aim of this research was to develop a guide, for business improvement practitioners, on how to create effective business simulations. It was not the intention to develop a technical manual, but to develop a roadmap on how to determine the conceptual structure of simulations, and how to decide the appropriate nature of simulations for the intended purpose.

This work is predicated on the assumption that business simulations are metaphorically structured. It is shown that this is patently the case. When we use simulations we are developing understanding about the business processes through understanding and experience that is derived from the simulation. That is, we develop understanding of one thing (the business process) in terms of another thing (the simulation).

Cognitive science tells us that metaphor is one of the fundamental tools that we use, often tacitly, to understand the world. Because simulations are metaphorically structured, understanding the mechanics of this structure will assist the simulation designer to develop more effective simulations. That is, simulations that will better aide the development of the understanding that is sought.

Although simulations are metaphorically structured they are universally novel metaphors. They do not draw inferences from our cultural and linguistic systems in the way that general metaphors do. Therefore, the metaphor theory needed to be further developed to support the simulation theory proposed in this work.

The approach taken in this work was to:

A. Analyse the mechanics of metaphor and identify those elements of metaphor theory that would be useful to develop an approach for designing and developing metaphorically structured simulations.

B. Review simulations used in business environments, and dissect a sample of them to specify their metaphorical structure.

C. Develop a simulation theory that codifies the rules that should be applied to develop effective business simulations.

D. Integrate this information into a practical guide for the business improvement practitioner.

It is hoped that such a guide will encourage people in business to develop and use simulations which will develop better understanding about how their business processes work, and therefore, how to manage those processes.
In this work a number simulations are described and analysed to develop the simulation theory. This simulation theory is then applied to one class of simulations in particular; simulations that are based on The Big Big Loader (BBL) as the concrete object. It is this application of the simulation theory that (a) demonstrates its validity to the reader and (b) provides the reader with useful examples of how it should be applied.

1 The Big Big Loader is a Tomy™ toy that is based around elements of the Thomas the Tank Engine characters.
Glossary of Terms and Abbreviations

BBL

The Big Big Loader. A Tomy™ toy featuring the Thomas the Tank Engine used as a representation of business processes.

CLD

Causal Loop Diagram. A representation of related states (or process components) that highlights the dynamics (feedback loops) of the system.

Concrete Object

The physical components of the source domain of a metaphorical mapping.

Contingent Attributes

Those characteristics of a source domain that are not intrinsic to the concrete object.

EMU 1

A workshop from the Essential Management Understanding series of workshops that uses dice to represent business process outcomes.

Essential Attributes

Those characteristics of a source domain that are intrinsic to the concrete object.

Generic-Level Schema

A set of generic information that is derived from some specific circumstance.

JIT

Just-In-Time. A business strategy where stock is produced and delivered to the process as it is needed.

Metaphorical Mapping

The relationship or linkage between selected attributes of a source domain to selected attributes of a target domain.

OPE


Scenario

The narrative that, along with the concrete object, completes the source domain.

Specific-Level Schema

A set of specific information that is derived from some specific circumstance.

TPM

Total Productive Maintenance. A management approach that seeks to eliminate failures by focussing on the reduction of defects in a process.
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7.1 Discussion and Conclusions
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Chapter One

Introduction

Simulations have been demonstrated to be very effective tools to support business improvement activities. However, while there is a substantial amount of literature on how to build simulations in a technical sense, it is my observation that there is no material suitable for the business improvement practitioner on how to choose and design a simulation for a particular situation, and how to work that simulation into a workshop. Indeed, Steinman's (2000) treatment of this issue would have this to be work for the experienced modeller. Steinman's view may be appropriate for complex computer models but may be counterproductive in other circumstances. In the case of simulations based around games, they either have become products (The Manufacturing Game or The Beer Game), and are presented to some extent, or they are restricted to demonstrating the original concept held important by the author, such as the case of Godfrey's dice simulations.

My own experiences as a business-improvement consultant have supported the above observation. My colleagues and I have often used simulations to support business-improvement activities. While this approach has been successful in developing new understanding within the client organisation, generally the consultant remains the expert in the simulation. Consequently, opportunities for the client to explore other concepts, using simulations of their own, are often not pursued. Similarly, the work and simulations documented by the authors discussed above are very rarely implemented within businesses unless they are introduced by consultants, as tools to assist them in delivering their message.

This situation exists because there is a gap in the literature about simulations, and workshops that use simulations. There is no practical guide for business improvement practitioners on how they should go about observing, designing and using business simulations (and simulation-based workshops) that will meet their specific needs.

My contention is that a practical guide can be developed which will address this gap.

The aim of this thesis is to develop such a guide.
1.1 Statement of the Problem and the Aim of the Thesis

There is a rich tradition of using simulations in business improvement contexts. These simulations range from computer models that attempt to mirror the performance of the business process of interest (Sterman, 2000) to the use of concrete objects such as games (Sterman, 2000; Senge, 1990; Goldratt, 2004; Newell, 2003). The range of complexity inherent in these simulations is extremely large. For example, Sterman discusses the use of a variety of business simulations and how they were used at Du Pont™. These simulations included a complex computer model of Du Pont’s maintenance system, causal loop diagrams and a board game called “The Manufacturing Game”; Senge describes how his group have used a game they developed called “The Beer Game”; while Goldratt and Newell independently have used simple dice to simulate business processes.

Simulations have been demonstrated to be very effective tools to support business improvement activities. However, while there is a substantial amount of literature on how to build simulations in a technical sense, it is my observation that there is no material suitable for the business improvement practitioner on how to choose and design a simulation for a particular circumstance, and how to work that simulation into a workshop. Indeed Sterman’s (2000) treatment of this issue would have this to be work for the experienced modeller. Sterman’s view may be appropriate for complex computer models but may be counterproductive in other circumstances. In the case of simulations based around games they either have become products (The Manufacturing Game or The Beer Game), and are packaged to be presented to some formula, or they are restricted to demonstrating the original concept held important by the author, such as the case of Goldratt’s dice simulations.

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My contention is that a practical guide can be developed which will address this gap.

*The aim of the thesis is to develop such a guide.*
1.2 Scope of the Thesis

In order to do this it is necessary to investigate how and why simulations work. Why they are so effective in helping individuals build understanding about business processes.

The approach is predicated on the assumption that business simulations are metaphorically structured. A number of business simulations will be analysed in the context of modern metaphor theory as described by George Lakoff and Mark Johnson. This amounts to adopting their basic philosophical stance of “embodied realism” (Lakoff and Johnson, 1999, p74). This analysis will support the development of a simulation theory.

The simulation theory will be applied to a particular concrete object, the Thomas Big Big Loader™ (BBL), which has been used in simulations of business processes. A number of business simulations, based on the BBL, will be analysed in detail. The fundamental characteristics of the BBL simulations, and how they can be used to provide effective learning environments, will be explored.

This will be the basis for the development of guidelines for the design, development and use of simulations (and workshops using simulations) in business environments.

This work will be limited to the development of generic guidelines for the design and use of simulations; it does not attempt to address the technical considerations when developing specific simulations. Also, the work will have a theoretical basis that is largely drawn from modern metaphor theory.

1.3 Overview and Structure

The thesis comprises four parts as shown in Figure 1.1.

Part 1 comprises Chapter 1.

Chapter 1 is the introductory chapter. It contains a discussion of the problem that the thesis addresses. The aim of the thesis is stated. Also the scope of the thesis and the approach taken in the development of the thesis are discussed.

Part 2 comprises Chapters 2 and 3 which provide a summary of the situation that the thesis is intended to address.

Chapter 2 is a review of the use of simulations in a business improvement context. The focus is on the structure and use of simulations to facilitate learning in business environments. A definition of a simulation is developed that addresses the question, “What are games, models and simulations?” The concept that there is a hierarchy of business simulations begins to emerge from this review.

Chapter 3 describes aspects of modern metaphor theory that are germane to the development of the approach described in the thesis. In particular, it is focused on the use of metaphor as the basis for the development of
understanding. In this chapter a number of schematic models are developed to assist in understanding the mechanics of metaphor.

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**Figure 1.1 Thesis structure.** The thesis comprises four parts. Part 1 is an introduction and statement of the problem the thesis addresses. Part 2 is a review of relevant simulations used in business environments, and modern metaphor theory. In Part 3 a simulation-metaphor model and the hierarchy of simulations are developed. These theories and models are applied to simulations with the BBL providing the concrete-object component of the source domain. In Part 4 the design criteria for simulations and guidelines for facilitators are developed. The conclusions of the thesis are stated.

Part 3 comprises Chapters 4 and 5 which focus on simulations used in businesses. A simulation theory and supporting models are developed.

In Chapter 4 the concepts raised in Chapter 3 are discussed in terms of their application in simulations. The metaphor models developed in Chapter 3 are elaborated to develop a simulation-metaphor model and a simulation theory. The hierarchy of simulations is considered. It is shown that, just as is the case for poetic metaphor, there exists a hierarchy of simulations. As the
metaphorical construct becomes more complex the conceptual understanding becomes more specific. Conversely, as the metaphorical construct becomes less complex the conceptual understanding becomes more generic.

Chapter 5 contains a detailed description of the BBL, how the simulation-metaphor model applies to it, and how it is used in workshops. It contains three examples of simulations that use the BBL as the concrete object. One example is used to demonstrate the application of the simulation theory to simulations using the BBL as the concrete object. The other two examples are presented as case studies that demonstrate the use of simulations in dynamic workshops. The case studies lay the foundation for developing an understanding of the role of the scenario, and the hierarchy within a group of simulations based on the same concrete object.

Part 4 comprises Chapters 6 and 7 which provide analysis and conclusions from the thesis.

Chapter 6 focuses on the design criteria for simulation-based workshops. A workshop design model is proposed. The design issues to be considered are (a) the nature of the concrete object, and (b) the conceptual content of the simulation scenarios. A case study of a simulation, based on a causal loop diagram as the concrete object, is used to demonstrate the application of the model.

It is in this chapter that a practical guide for the design, development and facilitation of simulation-based workshops is presented. This guide, along with the simulation theory presented in Chapter 4 and the case studies in Chapter 5, provides the reader with materials that can support the creation of effective simulation-based workshops.

In Chapter 7 the conclusions that have been drawn throughout the thesis are presented. The discussion in this chapter also presents the evolution of the simulation theory, and the guide for developing simulation-based workshops. The key concepts are presented in an order which demonstrates the logic behind the development of this work.

This chapter also includes some comments on how the material developed in this work might be used more broadly.
Chapter Two

Review of Simulations

2.1 General

Simulations are widely used in business, and the ability to model and predict outcomes is essential. However, it is crucial to understand the limitations of simulations and their applications. In this chapter, we will review the fundamental concepts of simulations and their role in decision-making processes.

2.2 Simulations and Games

In his paper "On a Resurgence of Management Simulations and Games," Lane (1996) proposes descriptions of simulations and games.

Lane offers two propositions.

The first is an intervention proposition according to which a simulation is an activity that does not require human intervention or decision-making, whereas a game does. Lane rejects this proposition.

The second is a Verisimilitude proposition it is based on the statement by Karski and Weis (1990: p.305) that "a simulated experiential environment is a simulated and controlled situation that contains enough verisimilitude, or illusion of reality, to induce real-world-like responses by those participating in the exercise," whereas a game does not. Under this proposition, Lane observes: "A simulation is designed to convey lessons to the participants on the properties of a real-world situation. A game is designed to convey benefits to the participants. (Lane 1996: p. 625-630)"

Lane recognizes difficulties with this proposition as well, in particular that the verisimilitude is not necessarily either present or not present, but could be a continuum. Nevertheless, it is the proposition that he chooses.

Lane’s discussion is relevant to the notion of a game as we would experience it outside of the classroom. That is, considering the game at face value. But this is not how games are used in business environments and, therefore, is too generic in view. When games are used in specific business environments, it is in the context of the set of rules and conditions that are designed to evoke specific taxonomies intended to be learned by the participants. This context in which the game is played and the environment set always have a degree of verisimilitude.

The continuum of how much the verisimilitude of simulations and games is not very useful. If games are simulations and vice versa, verisimilitude why do we need a category at all? Perhaps we do, or perhaps we need a category of simulations and games as two different environments.
2.1 General

If the term ‘business simulations’ is entered into Google™ a plethora of games and models are presented. It would serve no great purpose to review all such simulations. The literature tends to focus on the technical construction of particular simulations; there is little discussion about aspects of simulations, and their design, that is relevant to this thesis.

What this chapter will do is define what is meant by the term simulation, and then list a number of simulations that are either important for the development of the thesis, or are significant in the evolution of games as business simulations. Each one will be briefly described with some emphasis on those concepts that will be developed in the thesis.

2.2 Simulations and Games

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Lane’s discussion is based on the notion of a game as we would experience it outside of the business. That is, considering the game at face value. But this is not how games are used in business environments and, therefore, is too generic a view. When games are introduced into business environments it is in the context of a set of rules and conditions that are designed to evoke some understanding about the business by the participants. The context in which the game is played and facilitated will always have a degree verisimilitude.

The continuum nature of the verisimilitude of simulations and games is not very useful. If games and simulations are on a continuum of verisimilitude why do we need a category for each anyway? What is required is a term that includes both games and simulations as they are used in business learning environments.
My proposed solution is to define a simulation as follows:

**Simulation**: Any activity where a concrete object is used in conjunction with a scenario that supports developing understanding of a target domain (the business) through a mapping from a source domain (the concrete object plus the scenario).

The important subtlety here is that the simulation not only includes the device (concrete object) but also the scenario.

A set of red and white beads (See section 2.4.1) can be ‘played’ in the absence of any business context, but as soon as business titles are allocated to participants the beads become a simulation of the business.

Similarly The Big Big Loader (See section 2.4.6) can be played as a toy without a business\(^2\) context, however, as soon as it is introduced to the participants in terms of the business it becomes a simulation of the business.

The BBL is designed to represent real world phenomena, but these representations are relatively unsophisticated. Other games are designed to have much stronger representations of some real-world concepts, for example, consider the board game Monopoly™. The game is so heavily laced with essential attributes about real-life real estate and real estate markets that any adult playing the game could not fail to see the connections to real life situations. Furthermore, they could infer other life lessons from the game, such as;

- The need to make ends meet
- The win-lose nature of business
- The value of sharp practice in business

The adult’s view of the game, and consequently the adult’s metaphorical structure around the game is a product of the game itself and the life experiences of the adult. Does this mean that the game is now a concrete object for a metaphorical schema? The adult playing the game could be considered to be self facilitating a simulation of aspects of life that relate to real estate and business generally. This facilitation will be via the subconscious narrative that the adult playing the game applies to make the linkages from the game to the real world. The adult may oscillate between seeing the game as a metaphor for business life and just enjoying it as a game. On the other hand, consider a young child playing Monopoly™. The child has not had to earn a wage, pay rates or rent, buy or sell property etc. The child’s world view will involve a much reduced schema than that of the adult’s. In fact, the child will experience Monopoly™ as just a game. Now consider the adult and the child playing monopoly together. The adult may choose to just play the game, or may

\(^2\) Note that in mining environments there are physical attributes of the BBL that may encourage players to see it as a simulation of a mining operation.
choose to use the game as a life coaching experience for the child. In the later case the adult will highlight aspects about the game in terms of the potential life experiences ahead of the child. That is, the adult will elaborate the game by introducing a scenario that explicitly makes the game a metaphor for aspects of life.

How should Monopoly™ be categorised in these three situations? Is it a game or a concrete object for a metaphorical schema? In the first case it can be seen as either the basis for a metaphor or just a game. In the second case it is just a game. And in the third case the adult has made a conscious decision to use the game as a tool to teach the child something about life. The adult has created a scenario around Monopoly™ that builds an explicit metaphorical schema for a desired purpose. In this case Monopoly™ becomes the concrete object in a metaphorical schema for a simulation. In this thesis a device will be considered to become a concrete object for a metaphorical schema in a simulation when there is a conscious act to use it as such.

More generally, as soon as any concrete object is consciously presented in the context of some target domain then the concrete object plus the scenario presented comprise a simulation of that target domain.

2.3 The Du Pont Experience

In his book Business Dynamics (Sterman 2000), Sterman goes into quite some detail about a process improvement project at Du Pont. The project was the development of a new maintenance policy. Led by Winston Ledet, it culminated in the development of a sophisticated dynamic model of the business from the view of maintenance. This modelling work was very successful in driving a change in the maintenance approach at Du Pont. The policy change was from a predominately reactionary one (of fixing breakdowns) to one of elimination of defects (through planned maintenance and operator engagement). Sterman observed that the modelling process was a key factor in achieving the changed policy. Key participants were engaged in a discussion, over a long period, about the approach to maintenance. Their existing mental models were challenged, and they were able to develop new mental models supported by the modelling work.

It was decided that implementation of the new policy would need to be supported by a simulation suitable for all operations and maintenance personnel. It was also thought that the sophisticated model was not the appropriate tool to support the change throughout the business. Ledet recognised that to achieve the new maintenance paradigm many stakeholders, including operators and maintainers, would need to be engaged in the new maintenance approach.

The solution that Ledet implemented included the development of a new model; a board game in which Du Pont employees, managers and other stakeholders, could play and experience the consequences of the existing maintenance paradigm as well as the consequences of the new maintenance paradigm. This model was called "The Manufacturing Game" and was subsequently marketed by Ledet to support business improvement in other businesses and industries.
Some of the features of these two models are compared in the table below;

**Table 2.1 A comparison of models used at Du Pont.**

<table>
<thead>
<tr>
<th>Dynamic Model</th>
<th>The Manufacturing Game</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specific about Du Pont’s maintenance systems.</td>
<td>Generic, it could represent any manufacturing plant.</td>
</tr>
<tr>
<td>Provides users with the opportunity to experience the causal relationships between various maintenance policy decisions, and their impact on overall business performance.</td>
<td>Focuses on a few underlying business principles. Successful participants must take a good quality ('zero' defect) approach.</td>
</tr>
<tr>
<td>Targeted at a small group of senior decision makers.</td>
<td>Targeted at all operations and maintenance personnel.</td>
</tr>
<tr>
<td>Tries to capture all relevant business processes and systems, such as human systems and feedback systems.</td>
<td>Many business processes and systems are hidden.</td>
</tr>
</tbody>
</table>

When describing the impact of Ledet’s work, and subsequent work at BP Lima, Sterman seems to intuitively apply a hierarchy to the various models that were used to describe the plants:

1. The highest order is the actual sophisticated model:
   a. Provided the learning arena for Ledet and his team as well as some core managers.
   b. Allowed decision makers to experience the synergy that could occur depending on how various policies were set.

2. Stock and flow diagrams

3. A causal loop diagram

4. The Manufacturing Game

Ledet and Paich\(^3\) (Ledet and Paich, 1994) go further. They make the point that Du Pont had used computer simulations of their maintenance activities before. But these earlier simulations were intended to “mimic” the maintenance functions. That is, the intent was to produce a numeric answer, whereas this new approach was intended to produce models that would “focus on the dynamic causal relationships that generate these variables”. The new model was not intended to give a numeric answer or quantify the output of some aspect of the maintenance function; it was intended to demonstrate some

\(^3\) Paich was the modeller at Du Pont.
quality of the maintenance function. It was intended to allow people to experience the interaction between the various maintenance policy mechanisms. The new understanding was intended to be about these interrelationships.

So we can categorise simulations of business processes and systems as either quantitative or qualitative.

2.4 Some Other Games as Simulations

2.4.1 Deming’s Red Bead Experiment

W. Edwards Deming described the Red Bead experiment in a number of his books (Deming, 1986) and ran the experiment at his seminars. The experiment comprises a container of red and white beads of identical dimension with approximately ten percent of the beads being red and a paddle that will capture 50 beads when it is scooped through the container.

Participants in the experiment are allocated roles such as manager, supervisor, quality inspectors and operators. Red beads represent defective product and white beads represent acceptable product. Operators are tasked to produce good quality – defect free – production runs by scooping beads out of the container with the paddle. Although the participants have no influence over the quality of each run their performance is measured and blame for poor performance is attributed.

There are many lessons about the probabilistic nature of business process outcomes that can be explored using the red bead experiment. However, the lesson that Deming focuses mostly on is a universal business principle, that there are common cause and special cause sources of variation in business processes. The large majority of defects are the result of common cause variation which will require the system to be changed if they are to be reduced or eliminated. It is only management that can change the system and so remove common cause defects. That is, the large majority of defects are not the fault of the workers in the process.

2.4.2 Dice and the EMU 1 Workshop

In his Essential Management Understanding 1 Workshop Barry Newell (2003) uses real dice and computer simulated dice to explore the nature of business processes that have outputs that behave like random variables.

EMU 1 participants start with a real die as a representation of a business task. The participants throw the die many times and become familiar with its behaviour, and with the behaviour of a business task that produces random results between 1 and 6. Participants are required to record the results of running the task several times, both as a time series and as a histogram. Once the participants are familiar with the behaviour of the real-world die as a business task they are introduced to the computer simulation of a die as a business task, and then several dice as a business process. The simulated dice allow the participants to quickly and easily see how the task or process behaves over thousands of process runs.
Participants in the EMU 1 workshop will experience the behaviour of a business process which has output results that behave as a random variable. Based on this experience they gain an understanding of the basic mathematical concepts that are used to describe such variables in business environments including compound measures, the relationship between time series and histograms, properties of the normal distribution and the implications of the central limit effect.

2.4.3 A Die and the Theory of Constraints

In his book “The Goal”, Eli Goldratt (Goldratt, 2003) describes a simulation using a die, a box of matches and some bowls to represent a manufacturing plant process. Each bowl represents a station in a manufacturing process, the matches represent material that flows along the line and is processed at each station. The die provides the random output of each station. Participants are operators of each station and can pass matches through their station, but they can only pass matches to the number shown on the throw of the die. If they have fewer matches than the number shown on the die then they can only pass the matches they have.

In this setup the game represents a balanced production line where each station has exactly the same capacity as all the others. Each station can process at an average rate of 3.5 matches per run. When the game is played some counter intuitive results emerge. Stations further down the line fall increasingly behind the expected production rate.

Goldratt uses this simulation to demonstrate the effects of dependence, statistical fluctuations and covariance in manufacturing plant environments. Other permutations of the game can be used to explore unbalanced production lines and the impacts of bottlenecks.

2.4.4 Beads and Diamonds

As part of a business improvement program at a diamond mine, Aitken and Newell (2007-unpublished) developed a workshop - Sampling and Measurement Errors – using red and white beads. The beads represent ore at various stages of processing in the mine. Participants are able to sample the ore and calculate grade. The participants are able to progressively gain an understanding of key concepts associated with measurement errors and the consequences of varying sample rates and sample sizes from their own experiences with the beads.

2.4.5 The Beer Game

The Beer Game was first developed in the 1960s at the MIT Sloane School of Management. In his book The Fifth Discipline Peter Senge (1993) describes the game and the results that he has observed. The game is a simulation of a production/distribution system for a boutique beer called Lover’s Beer. Participants are assigned roles as a retailer, wholesaler and brewer. Each participant has the task of maximising profit for their position; they may make whatever decisions they deem prudent to achieve this. Decisions are basically
ones of placing orders in response to perceived customer demand and supply issues. The distribution system is constrained by production, administration and delivery delays.

In this simulation participants affect the system output results by the decisions that they make. Their performance at their position is not only affected by their decisions but also by the decisions of the other participants. This type of game has moved from exploring some fundamental physical concept to exploring the socio-technical nature of business processes. For participants to be highly successful in this simulation they must consider their position in the context of the broader system they are operating in. That is they must develop solutions in concert with the other participants. One of the main concepts to emerge from the Beer Game is to take a Dynamic Systems view of the business.

2.4.6 The Big Big Loader (BBL)

The BBL is a toy that has been used in business improvement programs as a simulation of business processes. Several case studies of the BBL used as a business simulation are included in Chapter 5. The BBL was used as a simulation at The Centre for TPM (Total Productive Maintenance) in the early 1990's. In this guise it was primarily used to demonstrate the use of Equipment Effectiveness and Process Effectiveness measures, and it could be considered to be a 'Total Productive Maintenance' (TPM) game. Subsequent to this the BBL has been used at Taribon Pty Ltd in a wide range of broader business simulations that, while maintaining the TPM components of the game, also explore other issues such as business organisation, work of the role\(^4\), team work, visual factory, experience versus training and business improvement strategies.

In BBL simulations participants are allocated roles and are tasked to deliver a specified production output. They are free to make decisions within the boundaries of the role statements they have been given. The BBL is a mechanical toy that participants are usually not experienced in playing. Therefore, issues around interaction of simulation components and participant dexterity or experience also emerge from the simulation. The BBL is another example of a simulation that explores the socio-technical nature of businesses.

2.4.7 The JIT Game

The JIT Game is a simulation of a manufacturing process where the principles of Just-In-Time (JIT) are implemented to solve production problems and improve performance. The JIT game uses Stickle Bricks\(^\text{TM}\) as the components of a product that must be delivered to a customer who places orders of varying quantities but at regular intervals. Participants are allocated roles and can make decisions within the authorities of those roles. Again this simulation explores the socio-technical aspects of business processes. Participants play the game for several production rounds each time implementing improvements. The game is intended to take the participants on a journey from a conventional batch production plant with quality inspected in, to a cellular layout plant and quality

\(^{4}\) Work of the role is a phrase used in Organisation Design which refers to the type of activities implicit in business for particular work levels, or strata. See Requisite Organisation (Jacques, 1998)
built into the process. Achievement of the highest success in the game requires the participants to engage with the customer to the mutual benefit of the plant and the customer. That is, they need to think outside the production facility system.

2.5 Summary

In this chapter a definition of simulations was developed.

**Simulation:** Any activity where a concrete object is used in conjunction with a scenario that supports developing understanding of a target domain (the business) through a mapping from a source domain (the concrete object plus the scenario).

The experiences of Winston Ledet at Du Pont were discussed where it emerged that, for their various purposes, Du Pont developed a range, or hierarchy, of simulations to aide understanding in the company about how maintenance policy settings impacted on company performance.

These simulations ranged from a complex computer simulation to a board game called the Manufacturing Game™. Computer simulations were considered further and it was seen that simulations can be classified into two categories; quantitative simulations and qualitative simulations.

Seven other games that are used as simulations, and that will be referred to in the thesis, were briefly described. A further categorisation emerges from consideration of these simulations. Simulations that use very simple concrete objects, such as dice, demonstrate fundamental principles about the output of business processes but they do not explore in-process characteristics of business processes. Whereas, more complex concrete objects – such as the BBL – demonstrate principles that include the in-process behaviours of a business process including the impact of participant decisions. They are exploring the socio-technical nature of business processes.

The concept of a ‘hierarchy of simulations’ will be developed through the thesis. Characteristics of simulations – such as quantitative or qualitative – will be used to provide guidance for the selection and use of concrete objects as simulations.
Chapter Three

Metaphor

3.1 General

Lakoff and the cognitive scientists that he has worked with have thoroughly demonstrated that metaphor and metonymy are fundamental processes that are involved in the way we understand the world. Furthermore, metaphorical constructions are grounded in our understanding of social systems. It is also the case that the more abstract a metaphor is, the more important it is to understand it.

If this is so in general, then a priori, metaphor could be considered tools that we apply to understanding the world. However, by understanding the role of metaphor in these understandings, and the explicit use of metaphor in simulations, we can construct powerful metaphorically based interventions to help people understand the basics of the businesses and processes they work in, and struggle to manage.

When we use simulations in business environments we understand principles of the business - in forms of metaphorically new. That is, simulations are metaphorically structured. Therefore, simulations can be described, analyzed, and understood using concepts from Lakoff's metaphor theory.

In this chapter aspects of modern metaphor theory that are relevant to the development of these are discussed. In particular, the chapter is focused on the role of metaphor in the basis for the development of understanding. A number of models for metaphor are developed. These models will be incorporated in later chapters to develop a model and theory for simulation metaphor.

- Metaphor: A metaphor is the expression of an understanding of one concept in terms of another concept, where these concepts similarly linked (Lakoff, 1987).

2.2 Metaphorical Mappings

Metaphors are understood in two ways:

1. The instance not the target: Conceptual metaphor is concerned with the target rather than the instance.

2. The instance not the target: Conceptual metaphor is concerned with the instance rather than the target.
“The essence of metaphor is understanding and experiencing one kind of thing in terms of another.” (Lakoff and Johnson, 2003)

3.1 General

George Lakoff, Mark Johnson and Mark Turner provide an excellent summary of the state of modern metaphor theory. This theory gives profound insights into how people develop understanding of the world. In particular, how metaphor is a powerful tool that is often tacit to peoples' cognitive processes, enabling them to develop understanding of new and often abstract concepts.

Lakoff and his colleagues demonstrate that we use metaphor to support the fundamental process of deriving inferences about the world. They show how these metaphorical constructions are grounded in our experiences and cultural systems. It is also the case that the more abstract a concept is the more we rely on metaphor to understand it.

If this is so in general then a priori metaphor must be among the fundamental tools that we apply to understanding our work environments. By understanding the role of metaphor in these environments, and its application in the use of simulations, we can construct powerful metaphorically based interventions to help people understand the nature of the businesses and processes they work in, and struggle to manage.

When we use simulations in business environments we understand one thing - the business - in terms of something else. That is, simulations are metaphorically structured. Therefore, simulations can be described, analysed and understood using concepts from modern metaphor theory.

In this chapter aspects of modern metaphor theory that are germane to the development of the thesis are described. In particular, the chapter is focussed on the use of metaphor as the basis for the development of understanding. A number of models for metaphor are developed. These models will be elaborated in later chapters to develop a model and theory for simulation metaphor.

Metaphor: A metaphor is the expression of an understanding of one concept in terms of another concept, where there is some similarity between the two. (Lakoff, 1987)

3.2 Metaphorical Mappings

Metaphors will be represented in two ways:

1. The metaphor will be written in small capitals as follows - A PURPOSEFUL LIFE IS A JOURNEY. In normal language, when we speak of metaphors, we are talking of something in terms of another thing (such as A PURPOSEFUL LIFE IS A JOURNEY). In this usage we are saying - THE TARGET DOMAIN IS THE SOURCE DOMAIN.
2. An alternative way of describing metaphors is to describe the schema of the metaphor in detail, that is, to detail the metaphorical mapping that is the basis for the metaphor. In this circumstance the metaphor schema will be constructed with the source domain attributes listed on the left and an arrow demonstrating the mapping to the corresponding attribute in the target domain. Such as:

A PURPOSEFUL LIFE IS A JOURNEY

<table>
<thead>
<tr>
<th>Journey</th>
<th>Purposeful Life</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traveller</td>
<td>Person Living a Life</td>
</tr>
<tr>
<td>Destinations</td>
<td>Life Goals</td>
</tr>
<tr>
<td>Itinerary</td>
<td>Life Plan</td>
</tr>
</tbody>
</table>

This schema is to be read as follows;

A PURPOSEFUL LIFE IS A JOURNEY

A Purposeful Life Is a Journey
A Person Living Life Is a Traveller
Life Goals Are Destinations
A Life Plan Is an Itinerary

When this metaphor is applied the experience of journeys is used to understand aspects of a purposeful life. For example, when we embark on a journey we spend some time planning the journey; we determine what destinations we want to reach and what we need to do to successfully complete the journey. We can apply the same concepts to how we might go about leading a purposeful life. Further, we often make this leap tacitly.

Journeys is one of many source domains that we routinely use to describe the world and our relationships in it. Another example is the LOVE IS A JOURNEY metaphor:

LOVE IS A JOURNEY

The Lovers Are Travellers
Their Common Life Goals Are Destinations
The Love Relationship Is a Vehicle
Difficulties Are Impediments to Motion

Again the metaphor can be represented as a source domain (Journey) being mapped to a target domain (Love).

<table>
<thead>
<tr>
<th>Journey</th>
<th>Love</th>
</tr>
</thead>
<tbody>
<tr>
<td>Travellers</td>
<td>Lovers</td>
</tr>
<tr>
<td>Destinations</td>
<td>Common Life Goals</td>
</tr>
<tr>
<td>Vehicle</td>
<td>Love Relationship</td>
</tr>
<tr>
<td>Impediments</td>
<td>Difficulties</td>
</tr>
</tbody>
</table>

In these examples we have two metaphors with the same source domain but two different target domains; and in these examples we have two different
mappings where different aspects of the source domain emerge to be mapped
to the two target domains.

For example, consider the concept of ‘vehicle’:

In the LOVE IS A JOURNEY metaphor it makes sense to consider the relationship
between the lovers as a means for them to progress their love together, just as
the vehicle that two people are travelling in on a journey is the means by which
they move towards their destination. Furthermore, just as the vehicle needs to
be maintained and sometimes repaired so too does the relationship between
the lovers.

It is not obvious how a vehicle would fit into the mapping for A PURPOSEFUL LIFE
IS A JOURNEY. The purposeful life metaphor draws on the deterministic and
planned aspects of a journey. While the vehicle aspect of a journey does not
enhance understanding the road map aspect of the journey certainly does. We
could consider landmarks along the way as short-term life goals that will help us
achieve a purposeful life, or we could talk about alternate paths to consider the
implications of life’s decisions (as in “The Road Not Taken” by Robert Frost).

---

**Figure 3.1 The metaphor model.** The model comprises a source domain, a
target domain and a selective mapping from the source domain to the target
domain. Attributes of the source domain are mapped on a one-to-one basis to
the target domain so that understanding and experience in the source domain
leads to understanding in the target domain. The mapping is defined by the
source domain but is constrained to make sense in the target domain. The
mapping is partial in that not all attributes of the target domain have mappings
from the source domain. In this way some attributes of the target domain are
highlighted and others are hidden.

This suggests a generic model for metaphor (Figure 3.1).

We are consciously choosing a particular source domain to develop
understanding about certain concepts of a target domain. The source domain
provides a set of available attributes by which we can understand certain
attributes of the target domain, and so limits the set of target domain attributes
under consideration. The target domain also constrains the mapping in that the mapping must make sense in the target domain. Therefore, the emergent mapping can be considered to be defined by the relationship between the source domain and the target domain.

Selected aspects of the model are discussed in the sections 3.3.1, 3.3.2 and 3.3.3.

3.3.1 Metaphors are Systematic

Consider the ARGUMENT IS WAR metaphor. Lakoff and Johnson (2003) give a number of examples of its use in everyday speech:

- Your claims are indefensible.
- He attacked every weak point in my argument.
- His criticisms were right on target.
- I demolished his argument.
- I've never won an argument with him.
- You disagree? Okay, shoot!
- If you use that strategy he'll wipe you out.
- He shot down all of my arguments.

We can see from the italicised phrases that there exists a pattern or system to the metaphor ARGUMENT IS WAR. This system draws on many of the aspects of a battle to provide insights into how an argument might be conducted.

Lakoff and Johnson (2003) point out that "The fact that we in part conceptualise arguments in terms of battle systematically influences the shape arguments take and the way we talk about what we do in arguing. Because the metaphorical concept is systematic, the language we use to talk about that aspect of the concept is systematic."

In this sense the source domain (war) is establishing the set of attributes that apply to war by which we can understand some of the attributes of the target domain (argument). On the other hand, our understanding of the nature of argument limits or constrains which attributes of war make sense to consider in the mapping.

This systematicity gives rise to many of the features that make metaphor such a powerful tool in the development of understanding.

3.3.2 Metaphorical Mappings Highlight and Hide

Lakoff and Johnson (2003) point out that the systematic nature of metaphor results in the metaphorical structure highlighting certain aspects of the target domain while hiding others. Consider the ARGUMENT IS WAR metaphor again. While the metaphor enhances our understanding of the win or lose nature of argument, and the various techniques that might be used to win an argument, at the same time it inhibits our understanding of other aspects of an argument, such as, the cooperative aspects where parties are giving their time to participate in the argument.
The source domain we choose determines the features of the target domain that we wish to focus on, at the same time it will hide those aspects that we are not interested in. Consider the concept Love again. We saw through LOVE IS A JOURNEY that there is a rational aspect of love; the lovers have some control over their relationship as they would have control over a journey. For instance, they could choose how fast their relationship progressed as you can choose how fast you drive a vehicle. Now consider the following metaphor:

LOVE IS MADNESS (Lakoff and Johnson, 2003)

I'm crazy about her.
She drives me out of my mind.
He constantly raves about her.
He's gone mad over her.
I'm just wild about Harry.
I'm insane about her.

In this case the source domain (madness) results in highlighting the irrational and lack of personal control nature of love. That is, the concepts about love we are choosing to focus on are diametrically opposed to the more rational aspects of love that the LOVE IS A JOURNEY metaphor evokes. While we are choosing to view love as madness it makes no sense to consider the rational aspects of love. Under this metaphor these aspects of love are hidden from us. So the irrational aspects of love are portrayed in stark relief and are not being cluttered with other aspects of love.

3.3.3 Metaphorical Structuring is Partial

Lakoff and Johnson (2003) demonstrate that systematic metaphor is necessarily partial in nature. Using the metaphor THEORIES ARE BUILDINGS they show that, in the normal lexicon, some parts of buildings are used as source domain attributes in the mapping and others are not. Expressions such as ‘to be without foundation’ or ‘he constructed the theory’ are part of the normal language that we use. Whereas one of the examples Lakoff and Johnson use - "His theory has thousands of little rooms and long, winding corridors" - is not. That is not to say we cannot use this expression, let’s say to demonstrate the theory was very convoluted or overly complex, but this expression is not normally used in everyday language. There are other parts of buildings which do not make sense as attributes to be mapped for this metaphor, such as, ‘his theory is without a window sill’ or ‘he tiled his theory’.

3.3.4 Metaphors are Grounded in Our Experience

"..we claim most of our normal conceptual system is metaphorically structured; that is most concepts are partially understood in terms of other concepts.” (Lakoff and Johnson, 2003)

Lakoff and Johnson show that human spatial concepts such as UP-DOWN, FRONT-BACK, IN-OUT are grounded in our spatial experiences and our cultural presuppositions. These spatial concepts form the basis for, or provide the grounding for, our spatial and perceptual structural metaphors. But more than this, they show that these spatial concepts also provide the grounding for
other more abstract human concepts such as emotions. Consider the example of the structural metaphor HAPPY IS UP; SAD IS DOWN.

Lakoff and Johnson (2003) list many examples where this metaphor is the basis for our normal language, they are included here:

I'm feeling up
That boosted my spirits
My spirits rose
You're in high spirits
Thinking about her always gives me a lift
I'm feeling down
I'm depressed
I fell into a depression
My spirits sank.

These are called ‘orientational metaphors’ where a whole system of concepts are organised with respect to one another.

This grounding of metaphors in our experiences holds for other metaphors as well. Consider the structural metaphor ARGUMENT IS WAR. Lakoff and Johnson (2003) show how even though we may never have even had a fist fight, never the less we still talk about and construct arguments in terms of a battle. They postulate that the experiential basis for this comes from our observations of the animal kingdom; and that from our evolutionary ancestors we have inherited the mechanism of battle to survive but for modern man survival depends on our ability to get our way without physical confrontation. Added to this, from an early age, we observe battle and learn its idiosyncrasies; we learn it in our history lessons, we learn it from television news, we learn it from newspaper reports and we learn it from the cinema. So our concepts of war are ingrained in our cultural system, and our understanding of argument is grounded in these concepts of war.

Lakoff and Turner (1989) propose the following hypothesis for metaphorical grounding. “Generally, metaphorical understanding is grounded in non-metaphorical understanding”. They propose five elements to the hypothesis:

- “Many conventional concepts are semantically autonomous or have aspects that are semantically autonomous.

- Semantically autonomous concepts (or aspects of concepts) are grounded in the habitual and routine bodily and social patterns we experience, and in what we learn of the experience of others.

- Semantically autonomous concepts (or aspects of concepts) are not mind free. They are not somehow given to us directly by the objective world. They are instead grounded in the patterns of experience that we routinely live.

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5 Semantically autonomous concepts are defined by Lakoff and Turner (1989) to be those which can be understood directly from experience. They are not understood on the basis of metaphor or analogy.
• The source domain of a metaphor is characterized in terms of concepts (or aspects of concepts) that are semantically autonomous.

• In this sense, metaphorical understanding is grounded in a semantically autonomous conceptual structure.

3.4 The Great Chain of Being

In *More Than Cool Reason* (Lakoff and Turner, 1989) the structure and use of poetic metaphor is analysed. This analysis provides insights into how metaphor works in general, and provides the basis for discussion in the next chapter about why simulations work in business environments.

In this text proverbs are studied to demonstrate the mechanisms used in metaphor because these mechanisms are in stark relief when used in proverbs. This analysis leads to the development of a theory of metaphor called THE GREAT CHAIN OF BEING.

The theory will be discussed in this chapter and elaborated in the next chapter to develop a theory for simulation metaphor. It will also be the basis for developing the *Hierarchy of Simulations* which will be a fundamental tool in the design and development of business simulations.

The four elements of THE GREAT CHAIN OF BEING are:

• The GENERIC IS SPECIFIC Metaphor

• The Basic Great Chain

• The Nature of Things

• The Maxim of Quantity

The role of each element, and the methods by which they interact to form THE GREAT CHAIN OF BEING metaphor is discussed in the following sections.

3.4.1 The GENERIC IS SPECIFIC Metaphor

Lakoff and Turner (1989) use the analogy of the relation between the biological concepts 'genus' and 'species' to explain what is meant by 'generic' metaphor compared to 'specific' metaphor. Just as a species is one of many species in a genus, so a specific metaphor will be one of a family of specific metaphors that are entailments of a generic metaphor. Similarly, just as the definition of a genus must be much less detailed than the definition of a species, so too, generic metaphors must be much less detailed than a specific metaphor.

They describe 'generic-level metaphors' as those that lack specificity in two respects; they do not have fixed source and target domains and they do not have fixed lists of entities specified in the mapping.

Consider the proverb below:
Blind blames the ditch.

We infer that this statement applies to more than just a blind person. We infer that it applies to people with any incapacity but especially moral, emotional or psychological incapacity. In this sense the proverb is aiding our understanding about how people behave to one another, or how they should behave to one another, through the metaphorical mapping to a physical, and therefore tangible, incapacity. So a particular (specific) tale about a blind man and a ditch tells us something about a whole class of people (generic), people with incapacities. Figure 3.2 is a model of the process that underlies this phenomenon.

**Figure 3.2 The GENERIC IS SPECIFIC metaphor process.** The proverb has a specific-level schema about the actual events described in the proverb. This schema can be mapped to a generic-level schema that generalises the events in the proverb. This generic-level schema can then be applied to any number of similar situations, always highlighting aspects that are in the generic-level schema and hiding aspects that are not. The specific-level schema in the proverb is an instance of the generic-level schema. It is a special instance because it determines the mapping in the generic-level schema.

We can see from Figure 3.2 that this process has two distinct steps. Firstly, within the structure of the proverb, the specific details we are given are mapped to a generic-level schema. The proverb describes a set of events from which we can extract the specific-level schema, as follows:

Specific-Level Schema
• There is a blind man.

• The blind man encounters a ditch which causes him to fall.

• The Blind man blames the ditch for his troubles rather than his blindness.

• The blind man should have blamed himself for not taking appropriate care to compensate for his blindness.

We know the author of the proverb is trying to tell us something more than the tale of the blind man. We can draw the following generic-level information from the proverb, which constitutes the generic-level schema;

**Generic-Level Schema**

• There is a person with some incapacity.

• The person encounters a situation in which the incapacity causes negative consequences.

• The person blames the situation rather than the incapacity for the negative outcome.

• The person should have held themself responsible, not the situation

There is a mapping from the specific case of the blind man’s tale to a generic-level schema - GENERIC IS SPECIFIC – that is implicit in the proverb, as follows:

<table>
<thead>
<tr>
<th>Blind Person</th>
<th>➔</th>
<th>Person with incapacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blindness</td>
<td>➔</td>
<td>Inability to understand its consequences</td>
</tr>
<tr>
<td>Falling into ditch</td>
<td>➔</td>
<td>Committing an impropriety</td>
</tr>
<tr>
<td>Being in the ditch</td>
<td>➔</td>
<td>A negative consequence</td>
</tr>
</tbody>
</table>

The tale about the blind man and the ditch is but one of many instances of this generic-level schema. The second step in this process is to apply this generic-level schema to other specific sets of circumstances to which we want to apply the lessons in the proverb. Lakoff and Turner (1989) offer such an instance; a presidential candidate who commits some impropriety. The press runs the story and his candidacy is withdrawn. He blames the press for his political demise. We say of him ‘Blind blames the ditch’.

**Specific-Level Schema**

• The person is the presidential candidate.

• His incapacity is his inability to understand the consequences of his own improper actions.
- The context he encounters is his knowingly committing an impropriety and the press reporting it.

- The consequence is having his candidacy dashed.

- He blames the press.

- We judge him as being foolish for blaming the press instead of himself.

Lakoff and Turner (1989) state "...GENERIC IS SPECIFIC maps specific-level schemas onto the generic-level metaphors they contain. These are the fewest restrictions possible for a metaphorical mapping, resulting in a metaphorical mapping of extreme generality."

A metaphorical mapping for the above example can be produced, such as:

Person with an incapacity → Candidate

Inability to understand its consequences → Inability to understand consequences of his actions

Committing an impropriety → Committing impropriety and having it reported by the press.

A negative consequence → Losing his candidacy

Although the application of proverbs is a two-step process, as described above, the development of a generic-level schema is usually not apparent to us. We do the mapping subconsciously. The mapping that is more likely to be apparent to us is a SPECIFIC IS SPECIFIC mapping directly from the circumstances in the proverb to the target set of circumstances, such as:

Blind Person → Candidate

Blindness → Inability to understand consequences of actions

Falling into ditch → Committing impropriety and having it reported

Being in the ditch → Losing his candidacy

This example demonstrates that the source domain operates at both a generic-level and a specific-level.

Thus, a proverb simultaneously draws on two very powerful features of metaphor:

- Generic-level schema – Provides the 'generality' that allows the metaphor to be applied to an enormous number of situations.
Specific-level schema – Provides the rich experiences (specifics) that can be used to help understanding of the circumstance of interest.

The mapping from the source domain simultaneously applies these features to the target domain:

- At the same time that we know we are talking about some basic flaw in the character of the presidential candidate, we can understand this character flaw in terms of a physical disability such as blindness.

- And at the same time that we know this character flaw has resulted in the candidate to cause his own downfall, we can understand this outcome in terms of a blind man falling into a ditch.

- And at the same time that we know that a further character flaw will result in the candidate blaming others rather than himself, we can understand this in terms of the blind man blaming the ditch rather than his own careless behaviour.

3.4.2 The Basic Great Chain

Lakoff and Turner (1989) show how proverbs rely on us having a sense of order about the world. We see ourselves at the top of the tree of things. Furthermore, we understand that there is a hierarchy that applies. Human beings are at the top, then animals, then plants, then inanimate objects. This hierarchy is called the Great Chain of Being. This hierarchy also corresponds to “a scale of the properties that characterise forms of being-reason, instinctual behaviour, biological function, physical attributes, and so on.” (Lakoff and Turner, 1989).

We also apply order, or sublevels, within the levels mentioned above; a dog is a higher level than an insect, a tree is a higher level than algae and a piece of furniture is a higher level than a rock.

“The basic Great Chain concerns the relation of human beings to "lower" forms of existence. .....It is largely unconscious and so fundamental to our thinking that we barely notice it.” (Lakoff and Turner, 1989)

Entities are ranked in the Great Chain on the basis of their highest functions. For instance, dogs possess desires (wanting to play), emotions (fear, loyalty) and instinct. Humans also possess these functions but humans also possess “abstract reasoning, aesthetics, morality, communication, highly developed consciousness, and so on. Thus, where a being falls in the scale of beings depends strictly on its highest property.” (Lakoff and Turner, 1989)

It is the Great Chain that allows us to talk about our rat cunning or being as sly as a fox. Each entity on the great chain is defined by its highest property and this highest property will be a generic-level parameter for that entity. Properties that are considered high for a rat is to be cunning and for a fox is to be sly. So our understanding of how rats survive through being cunning or how foxes

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There are two versions of The Great Chain (a) a basic one which has human beings at the top and (b) an extended version which includes god and the universe. This discussion is restricted to the basic version.
survive through being sly provide generic-level attributes that may be applied to other entities - but usually to human beings - to emphasise this generic attribute about the target domain.

"Thus, there is a generic-level characterisation of our implicit unconscious cultural model of the basic Great Chain, a characterisation that does not distinguish among kinds of humans, among kinds of higher animals, among kinds of lower animals, among kinds of plant, and so on. What define a level are the attributes and behaviours distinguishing it from the next level below." (Lakoff and Turner, 1989)

The hierarchical nature of the great chain means the source domain that we choose will determine the generic attributes that are available to be mapped to the target domain. If we consider the examples of cunning rats and sly foxes, the metaphorical constructions we are using are saying something about the way the target domain behaves in certain situations. There is an element of cognitive ability in the sense that to be cunning or sly, the given situation must be analysed and a response devised. But there is more to these mappings. There are additional generic attributes that go to the character of the cognitive processes, that is, the question of the morality or ethics of the chosen response is brought into the mapping.

This would not be the case had we chosen a source domain entity lower down the great chain. We could have used the metaphor HIS MIND IS A COMPUTER. In this case the attributes that are available to be mapped have been reduced. They are limited to consideration of the cognitive ability aspects of the target domain. The morality or ethics of a given response are not brought into play because we see the computer responding to a given problem in an amoral way. We, therefore, do not make judgement about the morality of the response.

There is another feature of the hierarchical nature that needs to be considered. As we move down the great chain the attributes available to us tend to support more fundamental aspects of things. When we talk about a brain behaving like a computer we bring to mind an image of how all brains work. We understand concepts about logic and decision making in terms of computers to imagine how our cognitive processes deal with problems. Whereas, when we talk about someone's rat cunning it is less general. In one set of circumstances someone might exhibit this trait but not in others. Just as some people will tend to exhibit this trait more often than others. It is not telling us something as fundamental as how we make sense of the world.

3.4.3 The Nature of Things

We also have an innate or largely unconscious understanding of 'The Nature of Things'. That is, we have an understanding of the essence of things, they are hard or soft or brittle and so on. Furthermore we understand that this essence will result in "essential physical behaviour". Some attributes we know are essential\(^7\) and others such as hunger or fear are contingent.

\(^7\) Essential attributes and contingent attributes are used in terms of the definitions in philosophy and logic. An essential attribute is required to define an entity whereas a contingent attribute is not. So we could say a dog's sense of smell is an essential attribute but its hunger is a contingent attribute.
"... we have a largely unconscious, automatic, commonplace theory about the nature of things, that is, the relationship between what things are like and how they behave:

- The attributes that a form of being has lead to the way that form of being behaves.
- Essential attributes lead to essential behaviour.
- Contingent attributes lead to contingent behaviour." (Lakoff and Turner, 1989)

### 3.4.4 The Maxim of Quantity

There is a fourth component to the **GREAT CHAIN OF BEING** metaphor; it is the **Maxim of Quantity**. The Maxim of Quantity states; be as informative as required but not more so. The Maxim of Quantity is effectively a “pragmatic principle of communication.” (Lakoff and Turner, 1989)

Consider the proverb discussed in Section 3.4.1 again and the **GENERIC IS SPECIFIC** metaphor process shown in Figure 3.2. The proverb, as the specific-level schema (blue box in Figure 3.2), is also an instance of the generic-level schema (olive box in Figure 3.2) that was derived from it, but it is a unique instance of this schema because it contains all of the detail required to derive this generic-level schema. It is likely to be the only instance that will generate this particular generic-level schema.

We cannot pick up a newspaper and read the story of the presidential candidate and then automatically infer the generic-level schema derived from the blind man’s tale. We cannot automatically generate a mapping back to the tale of a blind man and a ditch from the candidate’s circumstances described in the story.

We cannot do these things because the newspaper story about the candidate will contain much more information about the events than we originally distilled by applying the generic-level schema. The story will contain dates and times, quotations from the candidate and other parties, and probably opinion from third parties.

What we could do is undertake a conscious rational analysis of the candidate’s situation to select the general aspects of his case that we wish to highlight, and so, develop a generic-level schema that contains these aspects. This schema may be different from the one in the blind man’s tale, depending on which aspects of this story we have chosen to highlight. Then, depending on our linguistic ability, we could craft a proverb that would be a specific-level schema of the desired generic-level schema that would provide mappings to many other specific circumstances.

It is this specific-level schema, that we create, that determines which aspects of the presidential candidate’s behaviour are focussed on and which aspects are ignored. The structure of the specifics of the proverb, that is the blind man’s tale, determines what is hidden and what is highlighted.
3.4.5 The Great Chain Metaphor

Figure 3.3 shows how these four components work together to produce a powerful mechanism for human understanding.

The common sense theory of the Nature of Things combines with the Great Chain to form a complex commonsense theory of how things work in the world. Further, it provides a reference system where attributes that will be useful in aiding understanding of some target domain can be sourced. When a source domain is chosen the attributes available to be mapped to the target domain is decided. The GENERIC IS SPECIFIC metaphorical structure provides the mechanism to map these chosen attributes to the target domain, or a plethora of target domains.

Finally, the Maxim of Quantity constrains the Great Chain Metaphor to focus only on the issues of interest. It provides the mechanism to limit the essential and contingent attributes of the source domain that are mapped to the target domain to only those that will support the desired understanding.

Figure 3.3 The Great Chain metaphor. The metaphorical system comprises four components. The Basic Great Chain provides a category of entities based on their highest functions or characteristics, The Nature of Things assigns attributes and behaviours to the entities, The Maxim of Quantity limits the mapping to the attributes of interest and The GENERIC IS SPECIFIC metaphor provides the metaphoric mapping.
Consider the source domain of a thunder storm. The attributes available to us from the Great Chain and The Nature of Things include thunder, lightening, rain, the trembling caused by the shock wave, rolling dark black clouds and so on. All of these attributes of a thunder storm are too many for our purpose. So we need to limit the attributes, in accordance with the Maxim of Quantity, to only those attributes that will serve our purpose. In normal metaphor this is done by the structure of the language that we use. For instance, consider the proverb;

Big thunder
Little rain.

The attributes have been restricted to just two, thunder and rain. It is the role of the GENERIC IS SPECIFIC metaphor to evoke understanding from this four word proverb. Lakoff and Turner (1989) show how the various schema work to achieve this. They are reproduced below.

Source domain specific-level schema;

- A thunder storm contains (at least) two kinds of causally related natural events within it: the thunder and the rain storm.
- The thunder precedes and accompanies the rain.
- Before any occurrence of rain, at least one occurrence of thunder communicates to us that the rain will occur.
- Typically the magnitude of the thunder indicates the magnitude of the rainstorm.

Because of the Maxim of Quantity, and the way the writer constructed the proverb, the above schema is tightly focussed around the relationship between the thunder and rainstorm. Lakoff and Turner then go on to develop the generic level schema that is inferred from this.

Source domain inferred generic-level schema;

- There is a (natural physical occurrence) that contains at least two causally related kinds of (natural events) within it.
- The first precedes and accompanies the second.
- Before any (natural event) of the second kind, at least one (natural event) of the first kind communicates to us that the second type of event will occur.
- The second has the power to affect us.
- Typically the magnitude of the first indicates the magnitude of the second.
- In this case the force of the second is much less than would have been inferred from the force of the first.
There is nothing explicit in this proverb to tell us we should apply this generic-level schema to people but we instinctively assume this to be so. We know the author of the proverb has carefully crafted these words for some purpose and we suspect that purpose is to tell us something about ourselves or people in general. So we can infer that we should apply this to people, and we can do this through the generic is specific metaphor plus the Great Chain. That is, we can infer a generic-level schema for humans from the generic-level schema for natural physical occurrences. Lakoff and Turner develop such a schema.

Target domain (humans) generic-level schema:

- There is a (human behavioural sequence) that contains at least two causally related (human actions) within it.
- The first precedes and accompanies the second.
- Before any (human action) of the second kind, at least one (human action) of the first kind will occur.
- The second has the power to affect us.
- Typically, the magnitude of the first indicates the magnitude of the second.
- In this case, the force of the second is much less than would have been inferred from the force of the first.

We could now develop specific-level schema for many human circumstances that exhibit these generic-level traits, such as when we experience people who boast about what they are going to do but never do it.

We saw above that we instinctively assume that the proverb or mapping applies to humans but this does not have to be the case. We can also be directed on how to apply the proverb by the circumstances in which it is used. Lakoff and Turner talk of two other circumstances where this proverb applies; a dog that is barking at you but is not prepared to physically attack you and an earthquake that causes very little damage.

The earthquake example is of interest because here we are using one natural physical occurrence to understand something about another natural physical occurrence metaphorically. That is we are mapping to a target domain that is at the same level as the source domain in the Great Chain.

3.5 Mental Models and Cognitive Dissonance

"The real voyage of discovery consists not in finding new landscapes but in having new eyes." Marcel Proust.

In his book *The Fifth Discipline*, Senge (1990) devotes a chapter to a discussion about mental models. He includes case studies that illustrate how the prevailing
mental models of a company’s managers impact on the company’s performance and ability to change.

Senge points out that the majority of these models operate at an unconscious level and so become very powerful agents for maintaining the status quo. Because they operate at an unconscious level we cannot easily test their appropriateness, and experiences that do not fit within these models are either ignored or just remain unseen.

**Figure 3.4 The unconscious competence model**. The model depicts the process to become completely competent in a task. The four states are Unconscious Incompetence (I don’t know what I don’t know), Conscious Incompetence (I am well aware that there are things I don’t know), Conscious Competence (I can complete the task with concentration and focus) and Unconscious Competence (The task is second nature to me). Learning can only occur in the conscious states which are to the right of the green line. The orange arrow indicates a shock which generates the cognitive dissonance required to move someone from the unconscious to the conscious side of the green line. The degree of effort required to move someone in the unconscious competent state to the conscious (learning) states is likely to be much greater than that required to move someone from the unconscious incompetent state to the conscious (learning) states.

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8 It is unclear where this model originated, but it is used widely in business training environments. In this version I have added the orange arrow depicting the effect of cognitive dissonance.
Lakoff and Johnson (1999) state “Conscious thought is the tip of an enormous iceberg. It is the rule of thumb among cognitive scientists that unconscious thought is 95% of all thought—and this may be a serious underestimate.”

There is a natural human process at work all the time, determining which of our mental models and cognitive processes move from our conscious to our cognitive unconscious.

Figure 3.4 depicts the path to achieve competence in some activity. If we have no interest in the activity, that is we are not required to complete the activity, then we are likely to be in an unconscious incompetent state. We don’t know what we don’t know, but nor do we need to know it. There is no motivation to learn. If we are required to complete the activity and we have no experience of doing the activity then it is likely we would be in a conscious incompetent state. That is, we are very well aware of our lack of prowess in the activity, we need to seek instruction on how to do it and we must concentrate very closely on many of the tasks in the activity. Our ability to learn at this phase is very high and our motivation to learn is also very high.

Each time we undertake the task we improve our ability to complete it correctly until we reach the point of being competent at the activity. At this point we are in a conscious competent state, that is we still need to concentrate on doing tasks in the activity but we can easily complete the tasks successfully. Opportunity to learn is somewhat reduced because we know how to complete all tasks. However, we may be able to improve the precision with which we complete tasks or the efficiency with which we complete tasks.

After much experience at completing the activity we reach a state where the activity becomes second nature to us. We can complete tasks on auto-pilot. We are in a state of unconscious competence, the cognitive processes required to complete many of the tasks now occur in our cognitive unconscious. Learning is not possible because we are not consciously aware of the actions we are performing to complete the tasks.

Most activities we perform happily proceed at this unconscious competent state. The problem is, while we operate at this state, improvement opportunities will go by unseen. A circuit breaker needs to be introduced to move the activity back to the conscious side of the green line (Figure 3.4) so we can at least be aware of the opportunity. That is, it is necessary to introduce a cognitive dissonance.

Consider for example the process of learning to drive a car. We start off at the unconscious incompetence state, we don’t know what we don’t know, but, also we don’t need to know it until someone hands us the keys. We are then shocked out of this state when we begin to contemplate actually driving the car. So the transition from unconscious incompetence to conscious incompetence is relatively easy to induce.

Compare this with the unconscious competence state. In this case our experiences of driving the car our now largely routine and are managed by our mental models, mainly at the unconscious level. We can no longer easily access the cognitive processes that allow us to drive the car. This does not only
include the mechanical or motor sensory activities in operating the car it can also include navigating the journey. For example, how many people have experienced that after completing a journey they do routinely, when they reflect on the journey, they can't recall any aspect of it. It is as if they slept through the entire journey.

Changing these cognitive processes is no longer a trivial exercise. When we first learnt to drive just handing us the keys was sufficient to 'shock' us into the realisation that there are many things we don’t know about driving the car; we are unfamiliar with the location of instruments, pedals and levers, we are unsure about how to change gears, we have little perspective of the size of the car in relation to the lane sizes and proximity to other vehicles and we need to keep constantly recalling details about the rules of the road. But now we are, at an unconscious level, smug in our knowledge that we know it all. So the energy or shock required to create the realisation that we may not know it all will need to be much greater.

Compare this to the work environment, or any area of activity. We start a new activity such as a new job and immediately begin a rapid learning phase where everything is new and requires our conscious concentration to do the job correctly. However, after we have been doing the job for some time we have become expert at it. At this stage the work activities become routine and we are generally operating in the unconscious mode with powerful mental models that are supporting our behaviour in the status quo. It will require substantial conscious effort for us to accept that there might be a better way to do things. Indeed, it will require us to look at what we are doing with new eyes because our extant eyes are viewing the operation through our current unconscious mental models.

3.6 Summary

In this chapter a number of concepts from modern metaphor theory have been discussed in the context of how these concepts apply to business simulations. These concepts will be developed and elaborated in subsequent chapters to deliver the aim of the thesis.

The first step was to establish the structure of a generic metaphor. It was shown that this structure comprises a source domain, a target domain and a mapping from the source domain to the target domain. It was further shown that this mapping is a selective one-to-one mapping that is defined by the source domain but constrained to make sense in the target domain. That is, it is a product of the relationship between the source and target domains. This structure was developed into a schematic model of metaphor.

Characteristics of metaphor that will enhance understanding of how to best choose, design, develop and deliver business simulations were then discussed. They were; Systematicity, Highlighting and Hiding, The Partial Nature of Metaphorical Structuring and the Grounding Hypothesis.

Special consideration was given to The Great Chain Metaphor and its four components; The GENERIC IS SPECIFIC Metaphor, The Great Chain of Being, The Nature of Things and The Maxim of Quantity. This discussion was largely based
around the structure and use of poetic metaphor and in particular proverbs. The Great Chain Metaphor was a point of focus because the model developed from it will be elaborated to produce a model for business simulations in Chapter 4. Similarly, the hierarchical structure of the great chain metaphor was examined. This concept of hierarchy in source domains and the mechanisms of the great chain metaphor will be applied, in subsequent chapters, to develop design tools for business simulations.

Finally, a discussion around mental models and the need to create cognitive dissonance was included. Consideration of the predominance of human cognition occurring at the unconscious level is critical to the development of effective strategies and approaches to create environments that promote learning.
Chapter 4

Simulations as Metaphors for a Business

In the case of business simulations, we are not only interested in understanding by experiencing, but also in learning. It is when we move from understanding about aspects of the company's key operation to engaging in the simulation source domain. Therefore, the description involves being structured. We use simulations as Metaphors for a Business to explore the relationships that are metaphorically structured and metaphoric in the world that are metaphorically structured.

It is not simply a tool, but a pattern and a set of patterns that are not just metaphorical, but also metaphorically structured. We see an abstraction of a Metaphorical mapping that is present throughout the system. These mappings are related to the metaphorical concepts introduced in Chapter 3.

4.2 Simulation Metaphorical Mappings

In general, metaphor is the link or the conceptual target domain from the systems that we use. When we talk about metaphor, we are talking about the mapping. There is no need to create a tool to do so with a metaphor. We subconsciously understand the terms, because metaphor as an understanding is rooted in the objective cultural systems, the representation or the process in which the target is a journey. Metaphors and metaphoric concepts are fundamental to the way we think about the world around us.

In this sense, it is suggested that there is no need for abstracting the world of systems. They are mental models that do not have to be objective systems. Therefore, many of the mappings between the source and target domains should be in context. This is done by building on the potential concepts of the source domain. That is, the concept is used in a Metaphorical mapping that is the source domain, which is used to understand the source domain. Metaphors may be related to the metaphorical concepts and the metaphoric concept of the source domain, which is a source of the target domain. Praps may be related to the metaphorical concepts of the source domain, which is a source of the target domain.

Consider the case of a tool that uses a metaphor to understand the concept of a business process. The metaphor is not used to create a new business process, but to understand the existing business process. The understanding of the business process is not just about understanding the business process, but also about understanding the process of learning. In short, a specific tool developed that used to learn a specific domain.
...metaphor is not just a matter of language.... on the contrary, human thought processes are largely metaphorical....the human conceptual system is metaphorically structured and defined." (Lakoff and Johnson, 2003)

4.1 General

In the case of business simulations we establish the framework for understanding by experiencing one thing in terms of another. We develop understanding about aspects of the business from experiences we have in the simulation source domain. Therefore, the simulation is metaphorically structured. We use language that is metaphorically structured, we use activities that are metaphorically structured and consequently the concepts are metaphorically structured.

It is not surprising that games and other simulations used as components of a metaphorical mapping have been demonstrated to be powerful tools to enable us to gain insights into how our workplaces really operate. The use of metaphor is innate to our human condition, and how we understand and explain the things around us, that is, to “understand and experience one thing in terms of another”.

These simulations should be able to be understood in terms of many of the attributes of metaphor. In this chapter simulations will be discussed in terms of the metaphorical concepts introduced in Chapter 3.

4.2 Simulation Metaphorical Mappings

In general metaphor we infer the linkages between the source domain and the target domain from the language that we use. When we say ‘their relationship is on the rocks’, there is no need to think what rocks have to do with a relationship. We subconsciously understand the intended meaning. This understanding is rooted in the cognitive cultural systems that have evolved to the point where the LOVE IS A JOURNEY metaphor, and other such metaphors, are fundamental to the way we think about the world around us.

In this thesis it is suggested that this is not the case for simulation metaphors. They are novel metaphors that do not have such a reference system. Therefore, many of the linkages between the source and target domains need to be created. This is done by building on the essential attributes of the concrete object. That is, the concrete object in a simulation does not provide the entire source domain. Something more is needed. A narrative is developed that describes components and characteristics of the source domain in terms of the target domain. Props may be added to the concrete object to enhance these linkages. In short, a scenario is developed that completes the source domain.

Consider the use of a die as the concrete object in a simulation of the variable nature of a business task outcome. If a participant is given the die to throw, without any context about why he is throwing it, there is very little likelihood that the participant will infer anything about a business task. In fact, at this stage the die is not a metaphor for the business task, it is simply a die. For the die to become a metaphor for a business task it needs to be placed into the context of the business task. The facilitator needs to describe aspects about the die in terms of a business task, and the participants need to be given an exercise they
must complete using the die to represent the business task. That is, a scenario must be developed that creates the context for the metaphor \textit{DOING A BUSINESS TASK IS THROWING A DIE.}

Consider a dynamic system model of a business process. Other than for those in the business who have been intimately involved in developing the model, it is likely that running the model as the business will require the modeller to provide significant explanation of the mappings from the source domain to the target domain; assumptions built into the model will need to be explained, input data needs to be explained and its source specified. The modeller’s stylisation of process components needs to be made clear.

Both for the die and the dynamic model the extant relationship between the source domain and the target domain is insufficient to totally specify the mapping between these domains. A narrative must accompany the simulation to fill in the gaps and to explain the subtleties of the relationship between the two domains. This is the case for simulations generally.

\begin{figure}
\centering
\includegraphics[width=\textwidth]{fig4.1.png}
\caption{The mapping for the simulation metaphor as proposed in this work. This diagram shows a source domain mapping to a target domain. The source domain is a composition of the concrete object and the components of the scenario that describe the concrete object in terms of the target domain.}
\end{figure}

A simulation metaphor model can be derived from an elaboration of the model for metaphor (Figure 3.1). The model comprises three components; the concrete object, the scenario and the target domain. The concrete object is not a stand-alone source domain. It can only be a component of the source domain. It only becomes a component of the source domain once it has been given context by the scenario, that is, once the concrete object is overtly classified as a representation of components in the target domain.

Thus, the source domain comprises both the concrete object and the component of the scenario that gives the concrete object context in terms of the
target domain. This component of the scenario extends the metaphorical mapping beyond the essential attributes of the concrete object. It creates a set of contingent attributes that elaborate the concrete object to become a source domain that has sufficient characteristics to support a mapping that will achieve the simulation aims.

Can we understand some aspects of the source domain in terms of the target domain? Let us consider a die again. When used by Newell (2003) or Goldratt (2003) throwing the die is taken to represent the result of running some business process. It can be shown to have a range of results (integers from 1 to 6 for a standard die), it can be shown to be reproducible within this set of outcomes and it can be shown to behave like many typical business process outcomes. For instance, the scores obtained when a die is thrown repeatedly will wander around some average value. We can see many parallels between the behaviour of a die and the behaviour of a business process. So when the score on the die is spoken of as the output of a business task or process, it is plausible for the participants to view it as such. They can build upon the parallels between a die’s behaviour and a business process’s behaviour to see the die as being representative of the outcome from a business process.

The case of a die is a relatively simple one, but nevertheless, this part of the simulation process is important. The aim is to draw on the historical experiences people have had with a die and with dice, and augment this with experiences in the simulation to understand something about business processes. So the concrete object, in this case a die, must be seen as a way to credibly represent a business process.

What about concrete objects that are more complex than a die?

In the case of “The Manufacturing Game” the game (its hardware and rules) has been designed to represent a manufacturing process. Therefore, it has many attributes that provide mappings or linkages to manufacturing plants. However, the lessons that can be drawn from “The Manufacturing Game” are focused on maintenance of plant equipment and, in particular, defect avoidance. These understandings generally will not arise if people just play the game. The game is a facilitated exercise with the facilitator providing much of the context for the game, and developing many of the mappings from source domain to target domain. That is, describing the concrete object in terms of the target domain and creating attributes of the game that are not obvious from the game hardware alone.

In the case of a quantitative computer simulation of a processing plant, the aim of the modeller is to mimic the plants operation, so there are many mappings to the plant. The simulation will be designed to replicate results from the plant for various configurations of the plant. However, the simulation is not the plant. In order for the plant engineers to develop confidence in the simulation they will likely require information on the assumptions that underpin the simulation, and information on how the simulation is able to act as a model of certain plant functions. That is, they require information on how mappings are created from the model to the plant. Furthermore, these mappings are very specific in nature. The modeller will answer many of these questions by describing the model in terms of the plant (THE MODEL IS THE PLANT metaphor).
4.3 Simulation Metaphors are Systematic

We saw in Chapter 3 that a metaphor is, in general, part of a system of metaphors. The metaphorical construct ARGUMENT IS WAR was discussed and we saw that there exists a system to metaphorical concepts. For example, we can talk about argument in terms such as:

- Attack a position
- Indefensible
- Strategy
- New line of attack
- Win
- Gain ground, etc.

These components of the mapping form a systematic way of talking about the battling aspects of argument.

Similarly, when we simulate business processes there is a pattern or system about the metaphorical concept (and language). For example, we can talk about the BBL (The Big Big Loader—see Figure 5.1) in terms such as:

- Equipment availability
- Efficiency
- Performance rate
- Losses and lost time
- Cycle time
- Training
- Going for tonnes (production or output)
- Productivity

Thus, when we talk about the concrete object as a component of a simulation of the business, we talk about it in terms of a metaphorical system where there are very broad and direct parallels between the concrete object as we describe it in the simulation and the business (both specifically and generically). That is, we talk in a language that is specific to whole categories of business.

How can we do this?

When we first establish the metaphorical mapping THE BUSINESS IS THE BBL we do so in terms of the language of the business. If this process is going to truly support the metaphorical mapping it must be plausible. That is, the participants must be able to take the description on board. Considering the BBL, which is a relatively simple mechanical device, it is plausible for us to talk about production, production losses, cycle time and lost time because the participants can experience all of these phenomena in the game.

This would not be the case for simulations like Deming's red bead experiment or the EMU 1 workshop. In these cases, the essential attributes of the concrete objects are much more limited than the BBL. The metaphorical mapping is constrained to these attributes and some contingent attributes which can be contrived about dice or beads (and which make sense). This results in the language comprising a smaller group of much more fundamental concepts. For
instance, in these two examples important concepts to be evoked by these metaphors are the impact of variation in the measurement of process outcomes and (in the case of EMU 1) the escalation of this impact as the process becomes more complex, that is, we have more than 1 die (task). Even though there are fewer concepts discussed, these metaphors are still systematic. We can talk about concepts such as:

Average
Standard Deviation
Distribution Functions

While these concepts are more fundamental than the concepts highlighted by the BBL, and while they are fewer in number they are also universal. That is, they are applicable to all businesses or any activity where measurements are taken. As we go lower in the Great Chain for a concrete object (and subsequent source domain), the essential attributes of the concrete object relate to increasingly fundamental physical concepts about business processes and consequently the metaphorical mappings are more fundamental, they are about universal concepts or principles. The metaphorical mapping is consequently increasingly simpler and the GENERIC IS SPECIFIC component of the mapping is increasingly generic. This is a very important phenomenon. It goes to the crux of selecting concrete objects that will support understanding of the concepts of interest.

4.4 Simulation Metaphorical Structure is Partial

Consider a die as a concrete object. There are attributes of a die that make sense to include in the metaphorical mapping and there are attributes that do not. Attributes that would be in the metaphoric mapping include; the die has six sides, the die will produce a result of 1 to 6, the result will be random and the result of each throw is independent of other throws. Attributes that would be excluded in this example include; the colour of the die, the edges of the die are rounded and the style of the markings on the die (spots or numbers).

Similarly, if we consider a quantitative computer simulation of a business process there are many attributes of the concrete object that are excluded from the mapping. For instance, the computer itself and the projector used to display outputs of the model are not part of the metaphorical mapping.

4.5 Simulation Metaphors Highlight and Hide

When we use games as concrete objects to understand some of the basic physics of our workplaces, the concrete object that is used and the scenario that is established, will create a metaphorical system that will build understanding about particular aspects of the workplace, that is, highlight those aspects while hiding other aspects.

We saw earlier that throwing a six sided die to represent running a business process highlights the probabilistic nature of business processes, and supports the development of insights and understanding about the impacts of variation.
This understanding encompasses one of the most fundamental aspects of the physics of a business process. So the use of a die is an excellent tool to promote important understanding about a particular physical aspect of a business process. However, the metaphorical mapping **RUNNING A BUSINESS PROCESS IS THROWING A DIE** hides many other aspects about business processes, including those that contribute to the variation in the process measurement. For example, the competence of operators, or equipment that is set-up incorrectly. These, and many other issues, are important to understand at some point. However, if we choose another concrete object, with a much larger set of essential attributes (such as the BBL), the fundamental lesson about the impact of variation in process outcomes could well be lost on the participants.

When we use a die as the concrete object there is no role for the operator other than throwing the die, and there is no equipment to set-up, so these attributes of business processes cannot be part of a plausible metaphorical mapping from a source domain based on a die to the business process target domain. In this way the metaphorical mapping is hiding many aspects of the business process that we do not wish to focus on at this time. This hiding feature puts the target concepts into stark relief.

More generally, when we use a particular metaphor the resultant focus will be on quite specific aspects of a business process. We are able to focus on those aspects that are highlighted by the systematicity of the metaphor while not confusing the issues by hiding other aspects (usually more complex aspects) of the business process, again by the systematicity of the metaphor.

In business simulations the systematicity is an outcome of the choice of concrete object and the content of the scenario (the CONCRETE OBJECT IS THE TARGET DOMAIN component of the scenario); that is, the source domain.

### 4.6 Simulation Metaphors are Grounded in Our Experience

When using simulations, such as **THE BUSINESS PROCESS IS THROWING A DIE** or The Manufacturing Game, the first stage is to allow the participants to become familiar with the operation of the concrete object. This may be done while referring to components of the concrete object as components of the target domain (business or process), and so commence establishing the metaphor. In this way valuable time is not spent discussing the pros and cons of the concrete object, rather, this time is spent discussing issues that emerge from the simulation that can be mapped back to the workplace, and are on the list of target concepts.

Participants can observe the entire simulation; nothing is physically hidden or intangible about the simulation. So before the use of the metaphor is applied in earnest, that is, exploration of concepts about the business, participants are *grounded* in a non metaphorical understanding of the simulation. The process of achieving the grounding is relatively quick (depending on the complexity of the concrete object) and effective.

Most participants have at some stage in their lives played with dice or games that are similar to the concrete object. Perhaps the grounding goes beyond the
immediate experience of the simulation back to participants experiences as children playing with similar games, or experiences they have had playing with games with their own children. This could be why games seem to be very successful tools for this purpose.

In Chapter 3 (Section 3.2) we discussed the Grounding Hypothesis proposed by Lakoff and Johnson (2003). Their hypothesis states “Generally, metaphorical understanding is grounded in non metaphorical understanding.” They conclude “… metaphorical understanding is grounded in semantically autonomous conceptual structure”.

A semantically autonomous expression is one that is meaningful completely on its own terms. That is, it does not derive any of its meaning from metaphor.

The concrete objects discussed above (dice, The Manufacturing Game and similar games) are meaningful on their own terms. That is, we understand them directly. Even more complex concrete objects, such as quantitative or qualitative computer simulations, are still meaningful on their own terms. It may take more time, concentration and perhaps coaching to develop a satisfactory understanding of them, but we can run them and understand the outputs they produce as stand-alone entities. They are semantically autonomous.

4.7 The GREAT CHAIN METAPHOR and Simulations

4.7.1 The Simulation Great Chain Model

We saw in Chapter 3 how the GREAT CHAIN METAPHOR can help us build a powerful metaphorically-structured system to develop understanding. The metaphorical system has four components:

- The Basic Great Chain
- The Nature of Things
- The GENERIC IS SPECIFIC Metaphor
- The Maxim of Quantity

The same mechanisms can be used to design very powerful business simulations that are targeted to the business’s specific needs. This leads to the development of a model for THE SIMULATION METAPHOR (Figure 4.2).

The model has a similar structure to the model for The Great Chain Metaphor (Figure 3.2), however, there are some significant differences which are discussed in the following sections.

4.7.2 The Concrete Object

We saw in Chapter 3 that the Great Chain of Being provides us with a reference system that we tacitly apply in metaphors to provide the functions, characteristics, attributes and behaviours of the source domain that are available for the metaphor to use, to aid understanding in the target domain.
This is also the case for concrete objects in simulations; they are physical entities that have their position on the Great Chain. But a concrete object is not a source domain, it is one component of a source domain, it must be complimented by a scenario that gives it context regarding the target domain (Section 4.2).

![Diagram of the simulation metaphor](image)

**Figure 4.2 The structure of the simulation metaphor.** The proposed model comprises four elements. The concrete object provides the essential attributes of the source domain, the scenario of THE CONCRETE OBJECT IS THE BUSINESS provides the contingent attributes of the source domain and the Maxim of Quantity provides limitations on the mapping from source to target domain. The 'GENERIC IS SPECIFIC' mechanism allows the specific case of this source domain to be mapped to many business instances.

Concrete objects provide the essential attributes available to us from the source domain. For example, a die provides a concrete object that can be thrown and will produce one of six different outcomes displayed on the topmost surface (that is the numbers 1 to 6). Further, for a fair die, these outcomes have equal probability of occurring. These are some the essential attributes of a die as a concrete object.

Source domains based on the same concrete object may move up and down the Great Chain, depending on the nature of the scenario. But this movement
will be constrained by the set of essential attributes that are provided by the concrete object.

So the concrete object sets the range of positions its source domains can occupy on the Great Chain. The scenario creates the source domains contingent attributes that determine where in this range a specific source domain sits.

In the model (Figure 4.2) concrete objects are shown as providing the essential attributes of source domains. We can place the die at the bottom of the list in terms of functionality and complexity, and we could consider a quantitative business simulation as being at the top of this list, in terms of functionality and complexity. All other simulations lie somewhere in between these two.

### 4.7.3 The Role of the Scenario

#### 4.7.3.1 Scenario Part 1: Contingent Attributes

The scenario provides context for the concrete object by creating a set of contingent attributes that, in conjunction with the essential attributes of the concrete object, complete the source domain (Section 4.2).

In our die example we saw that the die by itself offers no inferred information or understanding of the business task. It is only once the outcome of throwing the die is spoken of as the outcome of the process that it has relevance to the process. It is the process that gives the die context, and it is the die that demonstrates the nature of the variable output of the process.

![Figure 4.3 A die as a concrete object.](image)

Our experiences of a die provide us with a set of functions and characteristics that can be incorporated into the simulation metaphor. We know we can roll the die and we will get a score $S$ between 1 and 6. We also know that for a fair die each result has an equal probability of occurring.\(^9\)

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\(^9\) This diagram is from Newell, 2003. *EMU I Describing and Measuring Variation.*
domain that the concrete object becomes the basis of a source domain in a metaphorical mapping.

The development of the source domain is metaphorically structured itself. But the structure has the process of interest as the source domain and the concrete object as the target domain – THE CONCRETE OBJECT IS THE TARGET DOMAIN.

4.7.3.2 Scenario Part 2: Target Concepts and the Maxim of Quantity

The purpose of a simulation-based workshop is to aid learning. This suggests that there is a set of target concepts that warrant exploration. The second component of the scenario is the narrative and props that are introduced to explore these concepts.

Column three of Table 4.1 specifies whether the concrete objects in the table can or cannot be tuned. That is, can the participants change parameters in the simulation, or alter how the simulation responds. The behaviour of simulations that are tuneable can be varied over time. That is, a progression of simulation responses can be planned, so that participants can be taken on a journey of discovery. This journey can result in one concept providing the basis for an understanding of the next concept, or participants can drill down into an already understood concept to generate deeper understanding.

Tuneable simulations are excellent tools, which can be used in workshops to explore business processes and concepts. To do this the scenario needs to be constructed to support the use of this characteristic of the concrete object.

When constructing this aspect of the scenario the purpose is to establish a way of altering the focal attributes of the source domain, so that different target concepts are progressively exposed during the workshop. The extension of the scenario in this manner allows new concepts to be explored.

But this expansion must be only enough to deliver the aims of the workshop, and be restricted to exposing only the desired sequence of target concepts. That is, consideration of the Maxim of Quantity is important during the development of this part of the scenario.

In the general metaphor model the Maxim of Quantity is produced by both the specific language used in the metaphor and the nuances and cultural triggers that the form of language implies to us. In the case of simulation metaphor it is not usual for any of this information to be implicit from the concrete object. There may be many functions and characteristics of the concrete object that go well beyond the set of concepts of interest in the simulation metaphor. The scenario must be carefully crafted to provide just enough (but no more) information about the concrete object (in the context of the business domain) so that the aims of the simulation are attained.

A scenario must be developed that will establish the metaphor THE TARGET DOMAIN IS THE SOURCE DOMAIN. This is done by way of an ongoing narrative. We talk about the source domain as if it is the business; we create in the source domain the requirements in the simulation, such as, the roles we give to
participants in the simulation, the tasks that we require participants to complete, the procedures we provide, the measurements that we require to be recorded, and so on.

4.7.3.3 Scenario Part 3: Cognitive Dissonance

In section 3.6 the presence of mental models and how they inhibit learning was discussed; along with using cognitive dissonance as a technique to overcome them.

Simulations can be designed so that they create cognitive dissonance. The simulation needs to generate a dilemma, or a series of dilemmas, for participants. These dilemmas need to be chosen and designed so that addressing issues around the target concept will resolve them.

4.7.3.4 Definition of the Scenario

This discussion leads to the following definition of the "scenario";

**Scenario:** The component of the simulation which:

- Creates a context for the concrete object in terms of the target domain by creating a set of contingent attributes. 'THE CONCRETE OBJECT IS THE TARGET DOMAIN'.

- Augments the source domain so that all target concepts are highlighted by running the simulation, while concepts that are not of interest are hidden. 'The Maxim of Quantity'

- Promotes learning and understanding in the simulation by challenging existing mental models. 'Cognitive Dissonance'.

The scenario will include the banter that the facilitator uses to talk about the concrete object and the target domain as well as any exercises that form part of the simulation including measurement sheets, spreadsheets and the like.

4.7.4 The GENERIC IS SPECIFIC Metaphor

The fourth component of The Simulation Metaphor model is the GENERIC IS SPECIFIC METAPHOR. This component works in exactly the same way as it does in the general metaphor model. That is, the combination of the source domain and the Maxim of Quantity provide a specific set of circumstances that highlight a set of concepts and at the same time hide other concepts. These highlighted aspects can then be mapped to a generic-level schema. This generic-level schema can then be mapped to innumerable other specific-level schemas including the business target domain that is subject to the exercise in question.

Let's now consider some examples of this process.
With what we know about the functionality of a die we could develop a specific-level schema for a die as follows;

**Specific Level Schema of a Die**

- There is a six sided cubic die.
- Each side has a number from 1 to 6.
- Each time we run the process of rolling the die one number will appear on the upward facing side of the die; this number is the process outcome from rolling the die.
- Each number from 1 to 6 has equal probability of being the process outcome.
- Each result is independent of all previous results.
- There is a probability distribution function that tells us what the chances of a particular process run outcome might be.

![Figure 4.4 A die as the concrete object in a simulation for a business process.](image)

**Figure 4.4 A die as the concrete object in a simulation for a business process.** The act of rolling the die is representative of running the process (or task). The score $S$ is representative of a measurement of the outcome of a process run. $S$ can vary from 1 to 6 with equal probability. The simulation is representative of a process that delivers an outcome that behaves as a random variable.\(^{10}\)

What is the generic-level, or highest level of information that the die can refer to us? The die is telling us something about the output of a process or task. Although we talk about the process of rolling the die, this process gives us

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\(^{10}\) This diagram is from Newell, 2003, *EMU 1 Describing and Measuring Variation.*
absolutely no insight about what might be going on in some business process or task in terms of the interaction of equipment and materials. Also, the die does not tell us anything about the involvement of people in the process or task, what decisions they make or their level of training and experience.

What can we learn from such a concrete object?

Newell (2003) has used dice and the THROWING A DIE IS RUNNING A TASK metaphor to demonstrate the typical behaviours of the random variables that we measure while trying to manage and control business processes. The metaphor is extended to the THROWING SEVERAL DICE IS RUNNING A BUSINESS PROCESS metaphor to demonstrate mathematical concepts such as compound measures, the Normal Distribution and the Central Limit Effect. Aitken and Newell (2006) have extended the use of this metaphor to explore control charts and the basis for decision making with random variables. Similarly Goldratt (2003) has used dice to demonstrate when process components are not balanced. He demonstrates the impact of bottlenecks, and explores the concepts of the Theory of Constraints.

How is this done?

As we saw earlier, the die is at the lower end of concrete objects in the Great Chain. As such, the die as a concrete object brings a relatively small number of functions and characteristics - essential attributes - into play in a simulation. These characteristics are described in the specific level-schema of a die (above).

If we run a scenario where, while rolling the die, we describe it as some business process we can augment our understanding of the behaviour of a die with our understanding of the behaviour of business tasks and processes.

This new understanding of the die, as a business process, could lead to the metaphor THROWING A DIE IS RUNNING A BUSINESS PROCESS which has the following generic level schema;

Generic-Level Schema

- There is a business process.
- Each time the business process is run it produces an outcome bounded by some upper and lower limit.
- Each time we run the process we can measure the outcome from that process run.
- We cannot predict what a particular process run outcome will be.
- Each process run outcome is independent of all previous process run outcomes.
- There is a probability distribution function that tells us what the chances of a particular process run outcome might be.
We can see from this metaphor that the specific circumstance of the die has enabled us to develop generic-schema that can be instantiated by any business process we choose to consider. In fact, it can be instantiated by any activity that produces measureable outcomes, and that exhibit the characteristics of a random variable. So we can now explore those behaviours of random variables that our die, or dice, exhibits and apply the understanding we elicit from the die to any business process we are interested in.

4.8 Some Other Concrete Objects

The discussion, so far, has mainly focussed on games as concrete objects for simulations. There are many other, more sophisticated, concrete objects that are higher up the Great Chain. Some examples that have been mentioned so far are quantitative computer models, qualitative computer models, causal loop diagrams and stock and flow diagrams. In the following discussion four more concrete objects will be discussed as examples of these higher order concrete objects. The first two are a block diagram and a circuit schematic of the same electronic circuit.

4.8.1 The Circuit Block Diagram

A real world electronic circuit will contain resistors, capacitors, integrated circuits, inductors, switches, LEDs (Light Emitting Diodes), input and output sockets and so on. All mounted on a circuit board. It may also contain elements such as MCUs (Micro Controller Units) and microprocessors that have been programmed for a specific purpose in the circuit.

How would we describe the circuit to potential customers that are interested in the facilities such a circuit would provide for them, or to support staff who need a rudimentary knowledge about how such an electronic device works (such as sales or customer service staff)? We would typically use a block diagram that depicted the circuit in terms of its major functional components. The block diagram would be used to describe the circuit in terms of the causal relationships between these functional components. It is a high level representation of the circuit where much of the detail is hidden from view, notionally inside the blocks of the block diagram. A well constructed block diagram should only show sufficient detail to meet the purpose of aiding in developing the required level of understanding in the target audience ('enough information but not more than enough').

Consider the example of the Circuit Block Diagram (Figure 4.4). This block diagram represents an electronic circuit which has the purpose of enabling the connection of a POTS (Plain Old Telephone Service) or analogue device to a digital telecommunication network such as ISDN (Integrated Services Digital Network). We can see that this is a very simplified diagram of what we might expect such a circuit to be like. How can a person with only a rudimentary knowledge of such a circuit make any sense of this diagram?

There are two possibilities that come to mind. We could have an expert explain to us what each block in the diagram does, and how it interacts with other
blocks in the diagram, and what the whole circuit is doing. Or we could study the notes in the document supporting the diagram, and develop our understanding accordingly.

Either way, the diagram is not a standalone thing. We need a supporting narrative, either oral or written, to help us make the connection between the blocks and the real world circuit. We need to understand the block diagram in terms of the real world circuit.

We might expect such a narrative to be along the following lines:

The phone is connected to the Telco Network through the Relay and SLIC (Subscribers Line Interface Card) at the exchange. The SLIC will manage call statistics for billing purposes etc. These pieces of equipment are dedicated to this phone line.

The CODEC (Code/Decode) will facilitate routing the call through the network by accessing a DTMF (Dual Tone Multiple Frequency) device, which will convert the keypad phone tones into the destination telephone number. This number is sent to the MCU (micro controller) to enable it to route the call through the network.

The MCU will also initiate a ring signal to the phone if an incoming call is detected.

The CODEC also converts the analogue (voice) signals from the phone conversation into a digital signal, and vice versa for the incoming data stream.

There are other functions that support these primary functions, to manage the call. They are the DC-to-DC Converter (Direct Current-to-Direct Current) which provides power at the appropriate voltage to the SLIC, the Ring Control Logic which responds to the phone handset being lifted by engaging the MCU, or to incoming calls by initiating the ring generator which cause the phone to ring, and the Off-Hook Detector which monitors the phone for any request (lift the handset) to make a call. The later three components are dedicated to this phone line.

We can develop a specific-level schema for our example circuit as follows:

Specific-Level Schema

- There is an analogue phone and a digital network.
- A circuit is required to enable the analogue phone to be able to use the digital network.
- There is dedicated equipment associated with the phone. Some of this equipment manages call statistics and charging, other equipment is necessary to manage the actual calls.
- There is common equipment that is shared by other phone users.

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• Some of the shared equipment (CODEC and DTMF) are required to convert analogue information to digital information, and vice versa.

• The MCU manages the end to end call set up including interpretation of local and distant signalling, and call routing.

If we consider our model for simulation metaphor (Figure 4.1), and apply it to the example circuit block diagram, we can see that all components of the model are present. First and foremost, we can see that we are developing understanding of a real world electronic device in terms of something else, in this case, a representative diagram. Furthermore, we have a concrete object in the form of the block diagram, and it is supported by a scenario in the form of an oral or written narrative of how each block functions and interacts with the other blocks.

Figure 4.5 Example of a circuit block diagram (Morgan, 1997).
Our rudimentary understanding of how the electronic circuit works is based on a metaphorical structure, and uses metaphor properties to aid that understanding. The block diagram representation helps us understand the function of the circuitry, as much by what is not shown as by what is shown. We are encouraged to think about the circuitry in terms of big blocks of components. These blocks provide higher order functions that, we can easily see, are important to the functionality of the entire circuit. This is based on the highlighting and hiding property of metaphor.

However, the metaphorical structure for the block diagram is primarily SPECIFIC IS SPECIFIC. The components of the block diagram are mapped to specific sections of the circuitry and circuit board. Those complex combinations of electronic components are understood as combined units that perform the functions attributed to the blocks in the block diagram. These blocks do not represent any other function other than the function attributed to them. We cannot infer some universal generic principle from this block diagram.

4.8.2 The Circuit Schematic Diagram

Now let's consider a more detailed diagram of the same circuit (Figure 4.5). This diagram may be used by a maintenance technician or engineer debugging some operational problem.

First let's consider whether this is a metaphorical representation of the real world circuit or is it equivalent to the real world circuit. The circuit schematic can be considered a concrete object in that it is representative of many of the attributes of the real world circuit, but not all attributes. The technician will not rely on the circuit schematic alone. He will likely need to refer to specification sheets for many of the components in the schematic. He may need to determine how certain parameters have been set for this circuit in data tables, he may need to refer to and measure signals within the circuitry, and look for timing conflicts. In short, understanding the circuit schematic at this detailed level requires a significant narrative about how this diagram represents the real world circuit. That is, there is a significant scenario required to support understanding of the real world circuit using the schematic as a concrete object. The schematic can be thought of as providing the topography of the real world circuit and the supporting specifications provides the detail on how the elements in this topography interact with each other.

The circuit schematic fits the model for the simulation metaphor (Figure 4.1). It is a concrete object that is supported by a scenario that both (a) defines aspects of the source domain in terms of the target domain and (b) defines the mappings from the source domain to the target domain. The significant difference with this level of concrete object is that it attempts to map all significant attributes from the source domain to the target domain. It does this because the intention is to completely represent the target domain.

But the schematic is not equivalent to the real world circuit. For practical purposes it will be arranged to minimise clutter, and there will likely be production and operational considerations in the real world circuit that do not need to be considered in the schematic. For instance, in the above example the
documentation includes a cautionary note for the printed circuit board layout to provide a ground plane because of the presence of both analogue and digital signals in the circuitry.

In the above examples we saw two metaphorical representations of the same real world electronic circuit. Each has its own purpose and features, and both have some fundamental features in common. The two representations need to be considered in the context of the intended audiences and their purpose.

In the case of the block diagram the audience is technically relatively unsophisticated, and is likely to be only interested in how the circuitry functions to deliver the required result; access to a digital network by an analogue phone. As a consequence, the metaphor - THE REAL WORLD CIRCUIT IS THE BLOCK DIAGRAM - lies at a level in the Great Chain that exposes the functional aspects of the circuitry that are of interest. This is achieved by the block diagram retaining a significant level of abstraction from the real world circuit.
In the case of the schematic diagram the audience is technically sophisticated and, while they have a good knowledge of how the circuitry functions, they are particularly interested in the interactions within the circuitry at a component to component or structural level. That is, the prime purpose of the metaphor is to support understanding at a structural level. The metaphoric structure is clearly SPECIFIC IS SPECIFIC. This concrete object cannot be construed as anything else but a representation of this real world circuit. The circuit schematic is intended to remove as much abstraction as possible, as a representation of the real world circuit.

The word abstraction is used here to mean the generalisation of a concept, phenomena or thing by reducing the information content provided about the concept, phenomena or thing. The result is the thinking about a concept, phenomena or thing being distanced from the concept, phenomena or thing.

In the case of the block diagram the aim is to enable thinking about the real-world circuit in terms of the functions of sub-systems within it. In the case of the circuit schematic the aim is to enable thinking about the real-world circuit as the physical real world circuit. A fundamental difference between the block diagram and schematic is the intended level of abstraction moves in opposite directions; towards zero for the circuit schematic and towards some level deemed appropriate to achieve the desired purpose for the block diagram.

4.8.3 The Quantitative Computer Simulation

Let us consider a quantitative computer simulation of an underground copper mine. Here we have a very complex set of interactions between a variety of fleets of equipment, as well as, the physics of the mine and the behaviour of the people in the process. Each element has its own set of complexities and inherent variation.

The simulation allows managers, engineers and scientists to test a range of assumptions and scenarios about the mine, and the interaction of the equipment. In many instances the model will confirm existing views about performance, but in other circumstances will confront well entrenched theories and opinions about how the system will behave. It provides a rich set of model outputs that will support decision making about how to proceed.

The model can be an invaluable tool in aiding managers to make good decisions about how to go forward in very complex dynamic environments. However, the insights provided are extremely specific in that a model run only evokes understanding about one specific mine, at one period of time for one set of assumptions.

The outcomes of such a simulation can, realistically, only be applied to the process that was modelled. This is due to the level of detail about that process implicit in such a model. The inputs for the various scenarios are generally estimates of actual variables within the process that was modelled, and the value of those inputs will have some relationship to the actual values recorded in the business operation.
While this outcome will serve a valuable purpose for those few people in the business whose roles can use the results to support their decision making, the outcomes will generally only provide insights to variants on how the current process is operated.

That is no to say that this type of simulation does not have its place, quite the contrary. This type of simulation can be the catalyst for the process or system experts to re-evaluate their assumptions about the modelled process. That is, to raise decision making back to the conscious level ('cognitive dissonance').

How does the quantitative model compare to the previous two examples?

The quantitative simulation’s primary purpose is to produce results that the mine would produce if it were set up as per the assumptions in the simulation, and it produces these results to support decision makers deciding on a course of action. The reason for using the simulation is to provide this information in an environment of reduced time, space, cost and risk.

The modeller’s task is to produce a simulation that behaves as closely as possible to how the mine would behave for each assumption set; the modeller’s aim is to make the simulation as much like the mine as possible. Therefore, the simulation must be as small an abstraction of the mine as possible. This intent is the same as for the circuit schematic; to move the level of abstraction towards zero.

There is a fundamental difference between simulations such as the circuit schematic and the quantitative computer simulation of the mine. The circuit diagram cannot be tuned. It is what it is, and only produces one static output. In comparison, the quantitative simulation can be run for a number of assumption sets. The output of these runs can provide decision makers with a rich pool of data to support their decisions.

4.8.4 The Flight Simulator

Compare the quantitative simulation of the mine to a simple model (simple from the point of view of the user, not necessarily in terms of the modelling) that is used as the basis of a 'management flight simulator' to show how queue-server systems are affected by random arrivals.

The simulator is designed to help managers to develop understanding of the impact of variation on their business processes. In this circumstance the model is universal to the extent that it applies to any business activity that can be characterised as a queue-server relationship. Such relationships cover an extraordinarily large range of business and organizational circumstances.

In this case the flight simulator evokes understanding about the basic physics of queue-server systems, and is quite generic, as well as timeless. The flight simulator is comparable to dice and beads as a concrete object. It is exploring the effects of a fundamental principle, queuing theory, on a broad range of business process circumstances.
This example is included to demonstrate the point that it is not the complexity of the concrete object that is important when making these comparisons. It is the essential attributes that the concrete object provides that is important.

Both of these computer simulations were developed with the same software package, the Extend™ discrete event simulation package. Both simulations provide the opportunity to run 'what if' scenarios based on assumption sets. But they have quite different purposes. Therefore, the modellers have designed them to give the audience quite different experiences.

In the case of the quantitative simulation to provide discrete numeric answers to specific questions about a specific mine, and in the case of the flight simulator to allow the audience to experience the ephemeral nature of queues. The modellers have done this through the essential attributes they have provided for the audience, including; the way the audience interacts with the simulation, the types of questions and information the audience can supply and request, and the way the outcome information is conveyed to the audience.

4.9 The Hierarchy of Simulations

In this section definitions are developed for four simulation categories based on the types of concrete objects they contain. These categories are then used as the basis for developing a hierarchical table of simulations, using simulations that have been discussed in this thesis as representative of all simulations.

Earlier in this thesis (Section 4.6.2) the important role that the scenario plays in the development of a source domain was discussed. So, why is the hierarchy of simulations based on concrete objects alone? It is the concrete object, and its essential attributes, which sets the range of characteristics simulations can have. Therefore, the concrete object determines the extent of the mappings to a target domain that are possible. The scenario can establish a variety of source domains based on the concrete object, but they must be credible, so they are limited within some range that makes sense for a particular concrete object.

In Section 4.6 we considered the use of a die as a concrete object and saw that it has a GENERIC IS SPECIFIC metaphorical structure. We also saw that the die was characterised by being limited to mapping information about the output of a task or process. It doesn’t provide representation of in-process characteristics of the target domain; it doesn’t provide representation of the interactions between equipment and materials, it doesn’t provide representation of people interacting with the equipment and materials, and it doesn’t provide representation of the impacts of their decisions. It is a Category 1 concrete object.

Compare this with some of the other games that have been discussed as concrete objects. When playing 'The Manufacturing Game', 'The Beer Game' or 'The BBL' participants are assigned roles; they are required to make decisions which affect their performance and the performance of others, they are given production and profit targets they are required to meet, and, in the BBL case, the equipment is prone to failure and variable performance. While these concrete objects are the basis for GENERIC IS SPECIFIC metaphors – there are a multitude of business examples that can instantiate them – they are more complex than the die example.
Category 1: Simulations based on concrete objects such as dice or beads, where the metaphorical structure is GENERIC IS SPECIFIC, and the concrete object is such that the attributes and characteristics it brings to the metaphor only allow us to infer things about the outputs, or external interactions, of tasks and processes. These simulations shed no insight into what is happening inside the process. However, because they are so generic in nature, they provide fundamental source domains to explore concepts that apply to all processes in business environments, or indeed, human endeavours. In this sense they can be considered universal in their application. Simulations based on these concrete objects can be classified as Generic-Universal.

Category 2: Simulations based on concrete objects such as the BBL and The Manufacturing Game™. In these cases we saw that the metaphorical structure was still GENERIC IS SPECIFIC but these simulations provide insights into what happens inside the processes that we are trying to manage. They allow us to explore the socio-technical systems at play as various components of systems and processes interact. In this sense their application is focussed on the functionality of the process components and the process in its entirety. Category 2 simulations can be classified as Generic-Functional.

Category 3: Simulations based on concrete objects such as block diagrams, flow charts and qualitative computer simulations. In this case the metaphorical structure is SPECIFIC IS SPECIFIC. The simulations provide insights into how specific components within the entity function and interact with each other. They allow us to explore input and output behaviours of subsets of the entire entity or process. These simulations can be classified as Specific-Functional.

Category 4: Simulations based on concrete objects such as circuit schematics and quantitative computer models. In this case the metaphorical structure is SPECIFIC IS SPECIFIC. The simulation supports the development of predictions on outputs in the target domain by endeavouring to replicate the target domain structure and therefore the level of abstraction is driven to the lowest practical level. These simulations can be classified as Specific-Structural.

This category would encompass interactive computer simulations where participants’ decisions influence outcomes of the simulation (such as computer games like Sim City and Civilisation). They provide representations of in-process behaviour, and they allow us to build mappings that explore concepts associated with in-process behaviours, or the functionality of processes. They are examples of Category 2 concrete objects.
The Du Pont experience (Section 2.3) was the first example of a category 3 simulation that was discussed. It was a qualitative computer simulation that explored the business consequences of various settings of maintenance policies. It was not intended to provide an answer, but to demonstrate the interaction between the various policy options. It was the genesis of the evolution of Du Pont's simulation activity that resulted in the development of The Manufacturing Game. Another example that was discussed was the block diagram representation of a circuit diagram.

Quantitative computer simulations of business processes are exemplar category 4 simulations. In Section 4.7.3 such a simulation of a copper mine was discussed and compared to other simulations. Simulations in this category are different to the other three categories because these simulations' primary purpose is to provide quantified answers to specific questions. As a consequence abstraction works against the desired outcome; anything that creates doubt about the answer reduces the effectiveness of the simulation. The other three categories of simulation use abstraction to support their primary purpose, to aid understanding of concepts, phenomena and things.

Category 4 simulations will always have a level of abstraction. A zero level of abstraction would be reality; it is the target domain. Abstraction in these simulations is about practicalities and efficiency. It is a cost benefit equation between being able to simulate the real world and confidence in the result of these simulations, that is, the value of the simulation.

Just as the circuit schematic is not really the real-world circuit, so too, the quantitative simulation is not the real-world process. It contains mathematical models of real world phenomena and is based on assumptions at the data collection, process definition and modelling stages. It has a degree of abstraction, but the abstraction is there to make simulating the process practical, not to aid understanding.

In Table 4.1 Column 2, thirteen concrete objects are listed, and grouped into the four simulation categories discussed above. Seven criteria are also listed in the table, and each category is rated against these criteria. It needs to be noted that beads and dice each appear twice in the table. Although the simulations draw on the same essential attributes (of a die or beads), when they are combined with the different scenarios very different conclusions emerge. For instance, in the case of dice used by Newell participants are learning something fundamental about any random variable or compound measure, whereas, when Goldratt uses dice, participants are learning about aspects about processes and combinations of processes, such as unbalanced processes and the emergence of bottlenecks.

The table could equally include a number of other scenarios based on concrete objects that are in the table, particularly the BBL, but the purpose is to list exemplar concrete objects that are the basis for typical business simulations. In the case of the BBL, various scenarios could move the concrete object along, what might be considered a continuum of source domains and simulations either up or down the table, but it will not move very far and it will remain in Category 2.
Table 4.1 is intended to be used as a support tool for making decisions about what type of concrete objects are most appropriate for particular business circumstances. As such, it will be one of the key tools discussed in the latter chapter on Designing and Developing Simulation Based Workshops.

The seven criteria listed in the table are;

**Can Be Tuned:** In column 3 the ability to change the concrete objects response is defined as either they can be (yes) or they can’t be (no). Computer simulations are generally designed so that the audience can change parameters and so get different responses from the simulation. The, diagrammatic simulations generally cannot be changed by the audience, but the modeller can produce different versions of these simulations that can represent different simulation responses.

Category 4 diagrammatic simulations are a special case where any different versions would only contain ‘cosmetic’ changes and the simulation response remains static.

The ‘game’ type simulations will generally be presented in workshops where the simulation scenario evolves to produce different and evolving responses by the simulation, so the audience participates in different simulation set-ups and responses.

**Metaphor Schema:** In column 4, the 4 categories are rated regarding their degree of GENERIC IS SPECIFIC characteristic. We have seen in the previous discussion that those concrete objects towards the lower end of the Great Chain will tend to be more generic in nature, and as we go up the Great Chain concrete objects will tend towards being specific.

**Typical Concepts:** In column 5 examples of typical concepts that would be explored in the four categories are listed. It can be seen from these examples that the concepts for Category 1 are fundamental, and support principles that could apply to all business endeavours. In Category 2 concepts address conceptual principles and concepts about operating businesses. In Category 3 concepts about causal relationships within specific business contexts are explored. In Category 4 the concepts are typically specific with quantified results about specific areas of interest.

**Reliance on Scenario:** In column 6 the four categories are rated from low to very high, regarding the extent to which the simulation metaphor is dependent on the scenario. The highest reliance is for Category 1, concrete objects that have few, if any, explicit features that would lead a participant to infer a relationship to a business process. In the case of Category 4 the concrete objects are created with very specific and strong references to the target domain business process. Categories 2 and 3 have a reliance on the scenario that is between these two circumstances.

**Level of Abstraction:** In column 7 the four categories are rated regarding the level of abstraction involved in drawing inferences about the target domain from the source domain. In the case of Category 1 concrete objects there is a very high level of abstraction involved. While the concrete object exhibits a particular
behaviour of interest, such as a die behaving like a random variable, there is very limited, if any, explicit relationship between the die and the business process. Compared to Category 4 concrete objects where the concrete object has been designed to be as like the business process as practical. In this case there are many explicit and inferred direct relationships between the concrete object and the target domain business process.

Mapping Detail: Column 8 is a rating of the degree of detail required in the mapping. It follows from the previous column that as the level of abstraction decreases then the level of detail in the mapping from the source domain to the target domain will increase. A Category 1 concrete object is intended to draw out those few behaviours we experience in the target domain that are evident in the source domain. Because the source domain concrete object is low on the Great Chain, the number of features that can be mapped is necessarily small. Whereas, in the case of a Category 4 concrete objects, that are high on the Great Chain, the opportunities to map features from the source domain to the target domain is much greater. The key is to only map those features necessary for the aims of the simulation ('give enough information but no more than enough').

Typical Purpose: In column 9 some examples from experience are listed. The examples give an indication of the typical purposes for concrete objects in the various categories. In the case of Category 1 they are typically used to give insights into fundamental theoretical, physical or mathematical concepts that have the broadest application in business environments. In Category 2 the simulations are typically intended to give insights into operational principles or approaches to managing businesses and business processes. In Category 3 the simulations typically give insights into how components of complex systems interact with each other and how these interactions affect the entire system. In Category 4 the simulations are intended to give insights into specific questions in specific business environments.

4.10 Summary

In this chapter it was shown that a concrete object, by itself, does not serve as a source domain for a metaphoric mapping in a business simulation. When it is overtly classified as being representative of components of the target domain it becomes a component of a source domain in a metaphoric mapping. The other component of the source domain is the scenario that provides this overt classification.

Once it was established that business simulations are metaphoric, concepts from metaphor theory were analysed with regard to how they work in business simulations. This analysis was limited to those concepts that will aid in the design and development of effective business simulations, and workshops using simulations.

This analysis resulted in the development of the structure of the scenario, and a definition of the scenario. It was shown that there are three components of the scenario, they are;
• A mapping from the target domain to the concrete object which creates contingent attributes that classify the concrete object as being representative of components of the target domain.

• A mapping from the source domain to the target domain to augment the source domain with attributes and circumstances required to deliver the aims of the simulation. That is, which develop the emergence of the target concepts, but limit the emergence of other concepts – The Maxim of Quantity.

• A narrative that creates a dilemma in the scenario that will assist learning by introducing cognitive dissonance into the simulation.

Two other key outcomes from the chapter are:

• The development of a proposed SIMULATION GREAT CHAIN metaphor.

• The proposed Hierarchy of Simulations.

They will be key tools used in later chapters on the design and development of effective business simulations.
<table>
<thead>
<tr>
<th>Category</th>
<th>Concrete Object</th>
<th>Can Be Tuned</th>
<th>Metaphor Scheme</th>
<th>Typical Concepts</th>
<th>Reliance on Scenario</th>
<th>Level of Abstraction</th>
<th>Mapping Detail</th>
<th>Typical Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 Specific-Structural</td>
<td>Quantitative Computer Model</td>
<td>Yes</td>
<td>Specific</td>
<td>NPV, Production Capacity Debugging</td>
<td>Very Low</td>
<td>As Low As Is Practical</td>
<td>Very High</td>
<td>Investment or Configuration Decisions</td>
</tr>
<tr>
<td></td>
<td>Circuit Schematic</td>
<td>No</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 Specific-Functional</td>
<td>Qualitative Computer Model</td>
<td>Yes</td>
<td>Primarily Specific</td>
<td>Interactions within the system</td>
<td>Moderate</td>
<td>Moderate</td>
<td>High</td>
<td>Complex Operational Interactions</td>
</tr>
<tr>
<td></td>
<td>Circuit Block Diagram</td>
<td>No</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Causal Loop Diagrams</td>
<td>No</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Stock and Flow Diagrams</td>
<td>No</td>
<td></td>
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<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Flow Charts</td>
<td>No</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 Generic-Functional</td>
<td>The Manufacturing Game</td>
<td>Yes</td>
<td>Primarily Generic</td>
<td>Zero defects Maint. Policies</td>
<td>High</td>
<td>High</td>
<td>Moderate</td>
<td>Operational Principles</td>
</tr>
<tr>
<td></td>
<td>The Beer Game</td>
<td>Yes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>The JIT game</td>
<td>Yes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>The BBL</td>
<td>Yes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 Generic-Universal</td>
<td>Beads (Aitken &amp; Newell)</td>
<td>Yes</td>
<td>Generic</td>
<td>Meas. &amp; Sampling Errors, Sampling</td>
<td>Very High</td>
<td>Very High</td>
<td>Low</td>
<td>Fundamental Principles</td>
</tr>
<tr>
<td></td>
<td>Dice (Goldratt)</td>
<td>Yes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Beads (Deming)</td>
<td>Yes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Dice (Newell)</td>
<td>Yes</td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

Table 4.1 The Hierarchy of Simulations.
Chapter 5

The Anatomy of a Source Domain: The BBL

There are several features of the BBL, some of which are visual clues. For instance, there is a Thomas' engine body, and the lorry should be placed in the right. (This is usually an essential attribute of the BBL, that demonstrates the use of the lorry.)
Figure 5.1 The Big Big Loader (BBL). The physical components of the BBL are: 1. The motorised chassis powered by an AA battery; 2. The Thomas engine body; 3. The lorry; 4. The spiral; 5. The elevator; 6. The crane; 7. A and B transfer ramps; 8. The loading station; 9. Rail sections to connect the parts; A. the turnaround area; B. 10 black plastic balls; C. The lower delivery shoot; D. The spiral bin; E. The base of the loading station; F. Decals that show how to place the lorry and Thomas engine body on the transfer ramps.

There are decals on the BBL, some of which give visual clues on how the Thomas engine body and the lorry should be placed in the BBL. These decals are essential attributes of the BBL that demonstrate the use of visual controls.
5.1 General

In Chapter 4 a simulation theory was developed, together with a model of the structure of the simulation metaphor (Figure 4.2). In this chapter the model is applied to a specific concrete object; the Big Big Loader (BBL). BBL simulations can be dissected and explained in terms of the model. An understanding of how the model is applied to the BBL will facilitate understanding of how it should be applied to simulations in general.

Three workshops that were developed around BBL simulations are discussed in this chapter. The first is a simulation of a chemical processing plant that produces Zirconium Basic Sulphide (ZBS). The discussion of the ZBS plant is used to elaborate the metaphor structure of simulations. This discussion is presented in sections 5.2 to 5.7. The second is a simulation of an open pit mine. It is discussed as case study 1 in section 5.8 where it is used to describe (a) why the BBL was chosen as the concrete object, (b) how a scenario is developed during a BBL simulation and (c) why various aspects of the scenario are developed. The third is a simulation of an underground mine. It is discussed as case study 2 in section 5.9. This discussion demonstrates how the scenario needs to be altered to deliver a different set of target concepts for a different audience when, the physical process is very similar.

5.2 The Concrete Object

When the BBL is used as a concrete object, its components provide the essential physical attributes that can be used as source domain attributes in the simulation. But these physical characteristics are not the total set of essential attributes provided by the BBL. Others are derived from the intrinsic behaviour of the BBL. When you think about it, these same behaviours can be discerned in business processes. The behaviours include:

- The components of the BBL perform a series of actions that occur in the same sequence every time the BBL completes a circuit. These actions constitute a set of behaviours that can be mapped onto behaviours in the target domain.

- Material, in the form of small plastic balls, is conveyed around the BBL circuit. Furthermore, the material changes state as it moves around the circuit. It is randomly placed when it is found at the base of the loading station, when the lorry scoops up and into the loading station the material is gathered together and raised in readiness to load into the Thomas engine body; it is conveyed by the Thomas engine body, it is raised further by the elevator, it is separated and lowered through the spiral, it is raised by the crane and it is randomly dispersed (back at the base of the loading station) by the lower delivery shoot.

- The cycle time for the BBL to complete a circuit is not constant. The most prominent impact on cycle time is the battery type and life, but other characteristics (such as tyre wear) can also affect the performance of the BBL.
• The BBL can exhibit many random and unintended events that affect its operation. For example, balls can fall out of the circuit and components can malfunction.

• The extent of these malfunctions is usually exacerbated when participants interfere with the operation of the BBL. This effect depends critically on the dexterity and the level of experience of the participants.

We can recognise these essential attributes of the BBL as being similar to characteristics exhibited by many business processes, even those from businesses other than manufacturing or mining. For instance, the BBL has been used in service industries, including telecommunications and vending machine service applications. In these industries the BBL was used to simulate activities such as work-dispatching processes and field maintenance activities.

5.3 The Scenario Part 1: Contingent Attributes

While it is true that the BBL has essential attributes that can be mapped to matching attributes in most business processes, it is also the case that running the BBL as a stand-alone game will not be very instructive for the participants. The participants may learn to operate the BBL more efficiently, but by doing so they are unlikely to learn anything important about their business processes. By itself the concrete object (the BBL) lacks context. To act as a source domain for a useful metaphor it must be clearly placed within such a context.

The process of doing this involves creating a mapping from the concrete object to the target domain within the narrative about the concrete object (Sections 4.2 and 4.6.3.1, Figure 4.2). This mapping augments the essential attributes of the concrete object with additional contingent attributes that will make the concrete object a plausible representation of the target domain. This mapping is most commonly constructed by describing aspects of the concrete objects as their matching aspects in the target domain. In the case of the BBL:

1. It is described as the target domain business process.

2. Tasks are created in the BBL that are identified with tasks in the business process.

3. Participants are allocated roles in the BBL that match roles in the business process.

The set of contingent attributes augment the characteristics of the BBL so that it becomes a rich source domain which will allow experience and understanding developed while running the BBL to be applied to the target domain business process.

The mapping below is an example of how this correspondence was constructed for the simulation used in the ZBS (Zirconium Basic Sulphate) workshop. The mapping is developed by talking about the BBL as if it were the ZBS plant. The plastic balls are described as product and the time that the BBL is run is described as a shift or several shifts. The BBL is given a context by target production quotas, role descriptions, measurement sheets and additional tools.
(props such as ball extraction tools). This allows the participants *old* understanding to flow from the ZBS activity into the BBL.

### THE BBL IS THE ZBS PLANT

<table>
<thead>
<tr>
<th>ZBS Plant Domain</th>
<th>BBL Domain</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1 Tonnes of Product</td>
<td>1 Ball</td>
</tr>
<tr>
<td>Operator</td>
<td>Operator</td>
</tr>
<tr>
<td>Maintainer</td>
<td>Maintainer</td>
</tr>
<tr>
<td>Supervisor</td>
<td>Supervisor</td>
</tr>
<tr>
<td>1 Shift</td>
<td>3 Minutes</td>
</tr>
<tr>
<td>Production Target</td>
<td>Production Target</td>
</tr>
<tr>
<td>(4 Tonnes/Shift)</td>
<td>40 Balls/Shift</td>
</tr>
<tr>
<td>Production Target</td>
<td>Production Target</td>
</tr>
<tr>
<td>(12 Tonnes/Day)</td>
<td>(120 Balls/Day)</td>
</tr>
<tr>
<td>Collect Sand</td>
<td>Lorry at Loader Gate</td>
</tr>
<tr>
<td>Convey</td>
<td>Thomas Engine Body</td>
</tr>
<tr>
<td>Dry &amp; Leach</td>
<td>Elevator</td>
</tr>
<tr>
<td>Precipitate &amp; Dewater</td>
<td>Spiral Tank</td>
</tr>
<tr>
<td>Filter &amp; Bag</td>
<td>Spiral</td>
</tr>
</tbody>
</table>

In this mapping the source domain is the BBL and the target domain is the ZBS plant. This part of the simulation development establishes the metaphor **THE BBL IS THE ZBS PLANT**.

The choice of concrete object, and the essential attributes it provides, will limit the range of contingent attributes that can be plausibly built into the source domain. A well chosen concrete object will tend to provide the bounding of the target domain to highlight only the concepts of interest. The use of the scenario to establish contingent attributes is not intended to extend the boundary of the target domain; it is intended to enhance the plausibility of the source domain as a representation of the target domain. There is an element of risk that a too elaborate scenario will increase the complexity of the target domain and cause the target concepts to be diluted in the simulation. The Maxim of Quantity needs to be kept in mind while constructing this aspect of the scenario.
5.4 The Scenario Part 2: Target Concepts and The Maxim of Quantity

Once the workshop commences and participants are running the BBL as a representation of the business process, the mapping described in section 5.3 is reversed. The nature of the narrative has changed. The change is subtle but profound. While the BBL is still spoken of in terms of the business process new understandings flow to the ZBS plant from activity that happens in the BBL domain. That is, the metaphorical structure is THE ZBS PLANT IS THE BBL.

### BBL Domain vs ZBS Plant Domain

<table>
<thead>
<tr>
<th>BBL Domain</th>
<th>ZBS Plant Domain</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Ball</td>
<td>0.1 Tonnes of Product</td>
</tr>
<tr>
<td>Operator</td>
<td>Operator</td>
</tr>
<tr>
<td>Maintainer</td>
<td>Maintainer</td>
</tr>
<tr>
<td>Supervisor</td>
<td>Supervisor</td>
</tr>
<tr>
<td>3 Minutes</td>
<td>1 Shift</td>
</tr>
<tr>
<td>Production Target</td>
<td>Production Target</td>
</tr>
<tr>
<td>(40 Balls/Shift)</td>
<td>(4 Tonnes/Shift)</td>
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<td>Production Target</td>
<td>Production Target</td>
</tr>
<tr>
<td>(120 Balls/Day)</td>
<td>(12 Tonnes/Day)</td>
</tr>
<tr>
<td>Lorry at Loader Gate</td>
<td>Collect Sand</td>
</tr>
<tr>
<td>Thomas Engine</td>
<td>Convey</td>
</tr>
<tr>
<td>Elevator</td>
<td>Dry &amp; Leach</td>
</tr>
<tr>
<td>Spiral Tank</td>
<td>Precipitate &amp; Dewater</td>
</tr>
<tr>
<td>Spiral</td>
<td>Filter &amp; Bag</td>
</tr>
</tbody>
</table>

In section 4.6.3.2 the tuneable nature of some concrete objects was discussed. The BBL is a good example of such a concrete object. The scenario for the BBL simulation can be developed during the workshop so that concepts on the target list can be highlighted as behaviours that occur in the BBL. These concepts can then be explored in the BBL. In this way, the workshop can be designed so that learning evolves in a logical and planned way.

For example, as shown below, the mapping above can be augmented with concepts about OPE (Overall Process Effectiveness) and Losses. These concepts can now be explored in the BBL but the understanding is explicitly about the ZBS plant and, more generally, about any process plant.
The participants are required to use the BBL to do exercises that are directly related to the ZBS plant. For example, they are required to measure the OPE for the BBL, they are required to break the OPE down to its three components (availability, rate, and quality), they are required to explore losses that they are able to record and they are required to compare these results with the OPE results that they measured earlier.

During these exercises the participants are exploring the new concepts (OPE and Losses) in the 'bounded' environment of the BBL. The circumstances are constrained by the set of essential and contingent attributes that have been developed in the BBL source domain.

The ZBS workshop included a series of simulation runs. Each time the simulation was run the narrative was augmented so that the scenario contained more attributes that would either provide deeper understanding of the target concepts, or introduce new concepts from the target list. For example, in later runs the participants were required to implement changes that would improve OPE performance. These improvements involved additional control being applied to the simulation, such as visual controls and pre-shift inspections.

The example of the ZBS plant demonstrates how each element of simulation metaphor (Figure 4.2) is applied:

- The BBL was chosen as the concrete object because its set of essential attributes will give rise to events that demonstrate losses in the BBL. The losses can be stylised so that they match the losses that will occur in process plants in general and in the ZBS plant in particular.

- Once the BBL was chosen as the concrete object contingent attributes were added to the mapping so that it was seen as a plausible representation of the ZBS plant. That is, the ZBS plant provided the detail that was used to construct a specific-level schema the ZBS plant is the BBL (see above).

- Additional attributes were progressively added to the simulation to support the exploration of the target concepts in the BBL. For example, the concepts of OPE and Losses were introduced into the simulation.

- When the losses in the BBL are recorded they can be shown to have three origins (availability of the equipment, the rate at which the BBL runs and the process quality). These three components can then be shown to be the elements of the Overall Process Effectiveness (OPE) measure.

Other versions of this simulation were developed for the ZBS plant. For example, the BBL was used to explore planning and scheduling issues. In this scenario the mapping presented in Section 5.4 above was augmented with customers A, B and C. Each customer required different quantities of ZBS, each customer required ZBS with different product specifications and each of
the different products was sold for a different price and margin. The participants' task was to maximise profit.

Clearly a scenario could have been developed that included both of the scenarios above. However, there were compelling reasons why doing so would be counterproductive:

- The target groups for each workshop were different.
- The complexity added to each workshop would have diluted the key messages
- The increase in workshop time would tax participants' concentration.

The basic rule adopted was that the component of the scenario that establishes THE BUSINESS PROCESS IS THE BBL metaphor must be confined to only the information that is necessary to develop the source domain as a plausible representation of the target domain and support participants' understanding of the target concepts. "Be as informative as required, but not more so", that is, apply The Maxim of Quantity.

5.5 The Scenario Part 3: Cognitive Dissonance

Sections 5.3 and 5.4 are concerned with the metaphorical structure of simulations and how the scenario (narrative and props) used in the simulation supports the development of this metaphorical structure. The present section is concerned with the style of the scenario, the nuances and degrees of difficulty required to aid effective learning.

In Section 3.5 the impact of existing mental models and the need to generate cognitive dissonance to support learning were discussed. Cognitive dissonance arises in workshops provided (a) the participants have some difficulty achieving the desired outcomes, or (b) the simulation produces some counter intuitive outcomes, or (c) both.

If cognitive dissonance is to be used deliberately to prompt learning, then the scenario must be designed so that the participants encounter a dilemma in the simulation. This dilemma must relate to the target concepts. Furthermore, it is important that participants can resolve the dilemma only by changing their own world view and, so, their own behaviour. If the scenario is well designed, then there will be a good chance that this experience will be mapped back into the work environment by the participants.

The trick is to create a dilemma sufficiently challenging that it will require considerable resourcefulness and imagination to resolve, but is not so daunting that participants can't resolve it. In the latter case participants will disengage from the simulation. If the participants are required to work together in a team, they will be encouraged to share the challenge and so minimise the chance of failure. Also, team work will help participants to share the development of new insights with each other, and so reinforce any new learning.
In the case of the BBL simulations, cognitive dissonance can be generated in a variety of ways:

- The primary method of producing a challenge is to set the production targets close to the limit of the capability of the BBL. A typical set-up is to make the shift duration 3 minutes and require each shift to produce 40 balls per shift. The BBL circulates at about 43 seconds per cycle, so, while this target is theoretically possible everything would need to go perfectly to achieve the target. When the added complexity of shift changes, multiple participants with different roles and refuelling are brought into the scenario then the target becomes unattainable. However, improvement during the period of the workshop will enable participants to approach the target.

- Second, the participants’ inexperience with the BBL can be used to create dissonance. A typical approach is to prevent the participants from physically running the BBL until they are tasked to produce product. This means the ‘learning the simulation’ phase is done by the facilitator demonstrating the simulation. Participants will typically struggle to get simple things right, such as, locating the motorised chassis correctly on the track. The frustration that this situation causes can lead to a fruitful discussion about assigning tasks, and the need for training and experience.

- Third, participants can be given specific challenges that they must resolve by changing the way the BBL is run, or changing the way the shift teams are organised. This is usually done by having the workshop participants form into ‘cross functional’ or ‘cross shift’ teams that are given the improvement tasks.

5.5.1 An Example of Cognitive Dissonance

The BBL has a particular essential attribute that can be used to demonstrate the effect of an existing mental model. In this case the automatic response of individuals when they are confronted by an arrow. There is a natural tendency to see the arrow as dictating the direction the motorised chassis must face.

The motorised chassis has an arrow on its top side (Figure 5.2). If it is placed in the turnaround area with the arrow pointing away from the main body of the BBL the chassis will head towards the lorry, and if it is placed with the arrow pointing towards the main body of the BBL the chassis will head towards the Thomas engine body. If the balls are placed in the loading station at the start of day, a 10 second improvement in production can be achieved by having the motorised chassis start by heading towards the Thomas engine body. These 10 seconds represents a 5.5% improvement in the capacity to complete the production target of four cycles in the first shift. Furthermore, shift teams can use this knowledge to generate further productivity improvements by developing decision criteria for the operators; that is, operators can choose to send the motorised chassis in the direction that will give the best production outcome, depending on where the most balls are when they restart the motorised chassis.
The problem is that this solution requires the motorised chassis to be started heading against the direction of the arrow. Experience has shown that 'improvement teams' in the simulation find it difficult to discover this counter-intuitive solution, and some only do so when given clues from the facilitator. Exploring this attribute of the BBL can lead to a fruitful discussion about 'arrows' and mental models. The discussion starts when the facilitator asks why the improvement team felt they took so long to turn the motorised chassis around and what part did the direction of the arrow play. The discussion concludes when the facilitator asks participants how many 'arrows' they think they pass every day in their workplaces.

Figure 5.2 Starting the BBL. The simulation is set-up with the safety rule that the motorised chassis can only be stopped (other than breakdowns) at the turnaround area, and it can only ever be started at the turn around area. At the start of the first shift the balls are always placed in the loading station (see Figure 5.1). If the motorised chassis is placed as shown here, with the arrow on top of the motorised chassis pointing out of the BBL, it will head towards the lorry and away from the balls. Generally, participants are unaware that they can start the motorised chassis with the arrow facing the other way (lugs on the tracks will reverse the motor). If the motorised chassis is started with the arrow pointing towards the main body of the BBL it will head towards the Thomas engine body and the balls, saving about 10 seconds on the initial cycle.

Finally, a word of warning. For effective learning to occur it is best if participants have a positive experience in the workshop. That is, they must at least feel that they have significantly improved the performance of the simulation. It is the facilitator's responsibility to ensure this can happen. I have observed the BBL simulation being run where the chosen scenario resulted in the participants having no chance of success. The reaction of participants was varied, but included people believing that they were set up to fail, and the exercise was a waste of their time and the company's money.
5.6  The GENERIC IS SPECIFIC metaphor

In section 5.3 the BBL was mapped to the ZBS plant. That is, the BBL simulation was run as a SPECIFIC IS SPECIFIC metaphor. This was done because the participants in question worked in the ZBS plant, and the target concepts related to their experiences in the plant. The context was taken from the workplace because the aim was to draw on their experiences at work and challenge their existing mental models about work-related target concepts.

These concepts could have been equally well explored within the BBL itself.

Consider the BBL scenario as a specific-level schema.

**Specific-Level Schema of the BBL**

- There is a toy called the Big Big Loader (BBL).
- The BBL comprises a motorised chassis powered by an AA battery, a Thomas Engine body, a lorry, a spiral, an elevator, a crane, A and B...
transfer ramps, a loading station, rail sections to connect the parts and 10 black balls.

• The BBL produces product in the form of black balls when they are deposited in the Spiral.

• The BBL is run for 3 shifts each of 3 minutes.

• The target for each shift is to produce 40 black balls.

• Each shift is manned by a Supervisor, an operator, a maintainer, and a process engineer.

• Each role has a job description, work procedures and safety procedures.

A generic-level schema can be derived from this specific-level schema:

**Generic-Level Schema of the BBL**

- There is a serial and cyclic business process.

- The process is comprised of many components that interact during a process run.

- The process produces product.

- The process is run for a number of shifts each shift with its own crew.

- Each shift has a shift production target.

- There are also daily production targets.

- Each shift is manned by participants who have specified roles, responsibilities and accountabilities that include decision making requirements.

- There are a set of safety and operating procedures.

While drawing on the richness of the participants' workplace experiences in the ZBS plant – the metaphor is underpinned by a generic-level schema. Such a generic-level schema can be applied to virtually any business process. There are innumerable business circumstances that instantiate this schema, the THE ZBS PLANT IS THE BBL metaphor is but one.

This is a GENERIC IS SPECIFIC metaphorical structure. Just as in Chapter 3, where we saw that the lessons of the blind man and the ditch could be applied to innumerable human episodes, so too, the lessons in simulations such as the BBL can be applied to innumerable business process circumstances (Figure 5.3). Also, just as we saw a consideration of the innumerable human episodes is bounded by the elements of the blind man's predicament in the ditch, so to, the consideration of the ZBS plant, or any other instantiation of the BBL generic-
level schema, is bounded by the essential and contingent attributes of the BBL simulation.

5.7 Grounding and the BBL

In Section 3.2 the Grounding Hypothesis proposed by Lakoff and Johnson (2003) was discussed. Their hypothesis states “Generally, metaphorical understanding is grounded in non metaphorical understanding.”

The BBL is semantically autonomous, that is, it is completely meaningful in its own terms. It can be understood on the basis of direct experience. Our understanding of the BBL is grounded in the habitual and routine bodily and social patterns we experience while playing the BBL. That is, the concepts we use to think about and understand the BBL are semantically autonomous, they are not derived from metaphor. Therefore, any understanding of the business process that is derived from experience with the BBL simulation is grounded in the semantically autonomous conceptual structure of the BBL.

Participants experience the application, or effects, of the target concepts while running the BBL simulation. This experience is grounded in the real world through the BBL. The metaphorical mapping is constructed from the essential and contingent attributes of the BBL source domain being linked to the ZBS target domain. This mapping provides the mechanism for participants to project experiences in the BBL simulation into their real-world work place, in this case, the ZBS plant.

5.8 Case Study 1: The Business Process Improvement Team

5.8.1 Context

The case study is of a BBL simulation that was designed to support a major business improvement program at an open pit diamond mine. The operation at the mine comprised mining of ore and overburden, processing the ore and liberating uncut diamonds. The program intent was to move the operation to a paradigm based on ‘Lean Production’ principles.

The initial round of the improvement program comprised three improvement projects carried out by separate improvement teams;

1. **Team 1 - Interface Project.** This project covered the processes for the ore run-of-mine (ROM) from the shovel, through the initial crushing stage and to the primary stockpile. The Lean Production conceptual driver for this team was *flow* of the ore. This required the team to consider production line balance, identify a drum beat, define the purpose of the stockpile and develop measurement parameters for the process.

2. **Team 2 - Processing Plant Capable and In Control Project.** This project covered processing operations from the primary stockpile through to the Heavy Media Separation (HMS) stockpile. The Lean Production conceptual driver for this team was *First Pass Yield.*
3. **Team 3 - The Drill and Blast Project.** This project covered mining operations from mine planning through to shovel effectiveness for both the ore and overburden processes. The Lean Production conceptual driver for this team was *Cycle Time Reduction*.

Each team was established for a twelve week period. Team members were seconded to the team on a full time basis. The teams had four main tasks:

1. Design the operating philosophy for the processes within their scope, based on the lean production conceptual driver.

2. Identify the component of the system that was the rate determining step and significantly improve its performance, and so, improve the system performance.

3. Trial and then implement their proposed solutions.

4. Identify quick wins along the way, and either fix them or refer them to the responsible areas.

The teams were given challenging targets, typically a 25% improvement in a key business measure. This was done to ensure that the team focus was on fundamental system change rather than incremental change. The teams were provided with a process improvement tool kit from the six-sigma\(^\text{11}\) methodology.

Teams comprised 8 to 10 people selected from various departments, with a balance of skills and experiences. All teams had experts from the area being targeted, but they also had members with little knowledge or experience in the area. The latter members were included to provide balance and a healthy scepticism about proposed solutions.

Each Team started with a three day kick-off workshop where the team task was formally assigned by the mine General Manager. The workshops comprised various activities and sessions to explore the task assignment and the way ahead. Each kick-off included a 4 hour simulation-based workshop using the BBL.

### 5.8.2 Aims of the Simulation

The simulation was intended to support learning by:

- Taking the team through a series of exercises that would allow them to experience improvement of a process that applied *Lean* principles, such as (a) process effectiveness measures, (b) viewing the process through the lens of time, and (c) visual controls.

\(^{11}\) The six sigma methodology is a business improvement approach based on statistical tools and a systematic approach. It was developed and popularised first by Motorola PL and then GEC (Pande and Holpp 2002).
• Allowing the teams to experience the socio-technical nature of typical business processes.

• Allowing team members to experience the effects of relying on traditional data sources, and to explore alternate data sources.

• Allowing the team to experience the proposed improvement approach for their improvement task. This included (a) exploring the various forms of data they would need, (b) development of a hypothesis, (c) testing the hypothesis, (d) develop the proposed solution, (e) implement the proposed solution, and (d) lock in the gains.

5.8.3 Why Use the BBL?

If we consider the four project aims (Section 5.8.2) we can see they are generic issues for business process improvement activities. Furthermore, the business improvement activity is intended to be a journey of discovery. The BBL can meet these needs, as follows:

• It is a tuneable source domain. A scenario can be constructed where the simulation is varied over time to progressively explore the lean production concepts of interest.

• Participants can be given improvement tasks during the workshop, which will allow them to experience the application of the lean production principles in the BBL simulation.

• The BBL not only behaves like a business process with a series of tasks, it also provides workshop participants with the opportunity to interact with the BBL equipment, and the procedures and processes that have been established to run the BBL. For example, an inexperienced operator is likely to have some difficulty in placing the motorised chassis on the tracks correctly, participants need to make decisions about whether to stop the simulation to retrieve balls that have escaped the circuit, and participants need to decide how often the batteries should be replaced.

These decisions are similar to those that the participants need to make when they are back in their work places. Business simulations like the BBL are not constrained to lie within the complex inanimate range of entities of the basic great chain; they provide source domains that encourage a rich exploration of how people function in response to the external environment. In particular, they allow participants to explore the socio-technical nature of operating business processes.

• A scenario for the simulation can be constructed around aspects of the OPE measure. The BBL operation can be assessed within this measurement structure so that participants can explore the multi-dimensional nature of the OPE measure.
Generally, understanding of the OPE measurement structure is supported by a strong cognitive dissonance in the workshop. A prevailing mental model in many businesses is that production losses are predominately caused by availability losses in the process. The OPE performance can be calculated on the basis of production data. When this result is compared to the losses that team members record in the BBL simulation, the participants are confronted with a significant gap. The OPE measure will indicate that the losses in the process are much greater than the losses that participants were able to measure. This is because the team is, initially, only measuring availability losses. It is only when the team considers how rate and quality affect the OPE performance that the gap between the OPE calculation and their loss measurements can be resolved.

The participants cannot achieve the required production level in the BBL unless they collect data other than the traditional output or production measures. They must closely observe the performance of the equipment, and gather in-process data to support good decisions about process improvement.

- The simulation scenario can be designed so that participants work through a number of structured improvement activities. One of the activities has participants form into three improvement teams. Each team is given a task assignment for their improvement task. The three improvement teams are then taken through a mini version of the improvement process that they will undertake over a typical twelve-week project.

It can be seen from this discussion how the BBL, as a concrete object, can be used as the basis for a simulation that will deliver against the aims stated in section 5.8.2. But, the BBL provides additional useful features.

The improvement targets for the three improvement teams are set so high that the teams cannot be successful by delivering only incremental improvements; they must discover a breakthrough improvement solution. Therefore, it is desirable that they meet the improvement concepts in a context that differs from their real-world business context. This can be done with a simulation provided the concrete object that we choose provides a plausible representation of the business.

The BBL fulfils these criteria. It patently is not the real-world process. Yet, when we consider the BBL generic-level schema (Section 5.6) we can see that it has many of the characteristics of the real world process.

As noted above, it is necessary to establish similarities with the workplace so that participants can map lessons and understanding from the simulation back to the workplace. However, this similarity to the real world workplace needs to be considered carefully. While enough information needs to be provided to make the source domain plausible the Maxim of Quantity still needs to apply. This means that just enough information should be provided and no more.
While it is important to make the mappings to the workplace plausible, it may also be important that these mappings have limited detail. This will keep the participants experimenting and exploring in the domain of the simulation and encourage them to use their creative imagination. If they are working in an environment that too closely mirrors the real world workplace their creativity may be hindered by existing mental models; models that are resistant to change because they have been constructed from experience over many years.

If we consider the aims of the simulation in this case study we can see that the target concepts are generic principles about how businesses operate. They are Category 2 simulations, Generic-Functional (Table 4.1). Table 4.1 also shows that the simulations for these types of concepts have characteristics such as - they are primarily generic, they have a high reliance on the scenario, they have a high level of abstraction and they have a moderate level of detail in the mapping between the source domain and the target domain.

Figure 5.4 The BBL at work. Here the BBL is being used at the kick-off workshop for a 12 week full time improvement team at a diamond mine. Participants have been allocated roles and are measuring the performance of the mine (BBL) to the criteria set out in the simulation scenario.

The source domain, comprising the BBL and an appropriate scenario, provides these characteristics. In section 5.2 the essential attributes of the BBL were described, and it was seen that they supported a generic-level schema that could be applied to virtually any business process. We can see from the scenarios discussed in this chapter that an appropriate scenario can augment these essential attributes with contingent attributes that can make a particular
target domain an instantiation of this generic-level schema. But the underlying schema remains generic. With an appropriate scenario this generic schema can be further augmented. This additional augmentation should only be to the degree that the mappings to the target domain support exploration of the target concepts. Such a source domain will exhibit the characteristics of a Category 2 source domain.

The BBL simulation also has a number of features that support effective learning, they include;

- It provides an interactive environment where participants can be grouped into teams, and where team synergy can enhance the learning and understanding experience.

- The learning environment is 'hands on' where participants experience the effect of the concepts that are intended to be explored. Experience suggests that participants from operational environments prefer this learning environment far more than a class-room setting.

- Although the scenarios are designed to provide plausible links to the operational environment, the simulation remains a metaphor for the operational environment. The workshop process aims to tap into the participants' creative imagination to support learning.

- Participants are free to experiment without the risk of any serious consequences.

- Almost universally, participants have fun.

Further to this, in this case study, the workshop is part of the team-forming process. An activity that allows team members to have a bit of fun while exploring some new concepts is a bonus that flows from using concrete objects like the BBL

### 5.8.4 Structure of the Simulation

The BBL simulation in this case study had a basic design structure designed to support learning. The basic structure was the same for all three improvement team workshops. However, in each workshop the scenario was established to refer to parts of the business that each individual team was investigating. Specific comments in the following discussion will refer to the simulation used for the Drill and Blast team workshop. The basic structure comprised four components;

- Establish the metaphor; scenarios were developed around the BBL so that strong similarities were established with the operational environment. In essence major components of the BBL were described in terms of both the physical and process aspects of the target domain process.
The BBL was allowed to run while the facilitator talked through the process. Participants were allowed to watch the simulation so that they could learn how it should run and they could see that the process was basically capable of producing the target production.

- Establish cognitive dissonance; participants were given a target that is at the margin of the BBL process capability. They were not, however, given all of the information they needed. In particular, aspects about target concepts to be explored were initially left vague or were not disclosed at all.

The participants were divided into 3 shift teams made up of 3 or 4 members. Members were given a role different to their normal work role; this was to provide opportunity for participants to ‘see’ the environment from a new perspective. The facilitator ensured that the shift teams had a basic competency to run the simulation, so that the target concepts could be explored without other issues deflecting attention.

Participants were given the rules of the simulation, and were allowed to run it. At this point they either floundered or performed significantly worse than the apparent capability demonstrated by the facilitator. Any improvement suggestions offered by individual participants were glossed over by the facilitator, and were generally ignored by other participants. Their suggestions were just noise in the background of the hurly-burly to produce tonnes. This supported the intent that improvement teams established during the simulation would resolve how to improve performance.

- Developing competence and delivering improvement – LEARNING; the teams were required to run the BBL simulation in accordance with set rules. They were to record data and deliver reports. At the end of each run a period of review by the teams was required. These review periods were carefully designed to ensure that the desired target concepts were exposed. The methods that were used varied from spending some time developing general improvement strategies -to forming improvement teams focused on specific issues. The improvement teams could be cross-functional or single-discipline; they could remain in their shift teams or be made up across shifts. The team structure was chosen to support delivery of the desired understanding.

The facilitator kept a balance between having the teams working hard to develop understanding and not having them flounder.

The facilitator needed to be alert to serendipitous learning by the team. Often teams will gain insight into an issue that is not on the target list. These opportunities must be captured because they will often be the most rewarding and profound revelations for the teams.

The facilitator continued to reinforce the production target to maintain the cognitive dissonance, and keep the teams a little off balance.
• Reinforce the things learnt and reflect: the teams continued to run the simulation and hold review sessions. The facilitator ensured that improvements and insights were brought together so that the teams performed significantly better than they did at the start of the workshop. Things learnt throughout the workshop were captured and written prominently on a board so that all participants could see them. Discussion was focused on the target concepts but teams were allowed to emphasise outcomes they saw as major achievements.

During these discussions the facilitator’s focus was on the level of improvement and how it was achieved, rather than how close they came to the target. The facilitator also tried to tap into the participants emotions about the simulation by encouraging them to speak about how they felt at various stages. This was reinforced by discussion of sensory experiences:

What did it sound like? (Loud to quiet)

What did it look like? (Chaos to order)

5.8.5 Running the Simulation

The following resources were provided for the workshop:

• The Big Big Loader (BBL)
• Oversize balls
• Blockage removal tools (X 3)
• Workshop Agenda
• Mine Simulation Instructions
• Excel Spreadsheets
• Data recording sheet
• Stopwatches

The initial workshop task was to establish the BBL as a simulation of the mining operation. This was achieved by the facilitator running the game and, as the motorised chassis was going through the various components of the BBL, describing the circuit using language taken from the mining operation.

Some features of the BBL lent themselves to fairly direct comparisons, such as the Lorry in the BBL being referred to as the shovel in the mine and the Thomas Engine Body in the BBL being referred to as a haul truck in the mine. Other direct comparisons revolved around production targets with the simulation output scaled to correspond to a production capability of 30k tonnes per day (30 KTPD), which is the target rate for the mine.
During the description of the simulation other idiosyncratic language-use taken from the mine was thrown into the mix. The words and phrases used were gleaned from activities such as ride-ons with operators and maintainers, or from observations while walking around the mine operations. For example, as material was going down the spiral in the BBL (Primary Crusher) the facilitator might refer to the implications of a blockage here on the ‘choke feed at the secondary crusher’.

Elements of the BBL were described as elements of the mine, as shown in the mapping below:

<table>
<thead>
<tr>
<th>Mine Domain</th>
<th>BBL Domain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ore Shovel</td>
<td>Lorry</td>
</tr>
<tr>
<td>Haul Truck</td>
<td>Thomas Engine Body</td>
</tr>
<tr>
<td>Blasted Material in the Pit</td>
<td>Material in base of Load Station</td>
</tr>
<tr>
<td>Ore Ramp</td>
<td>Elevator</td>
</tr>
<tr>
<td>Primary Crusher</td>
<td>Spiral</td>
</tr>
<tr>
<td>250 Tonnes</td>
<td>1 Ball</td>
</tr>
<tr>
<td>1 X 8 Hour Shift</td>
<td>3 minutes</td>
</tr>
<tr>
<td>Shift Target</td>
<td>Shift Target</td>
</tr>
<tr>
<td>10k tonnes</td>
<td>40 Balls</td>
</tr>
<tr>
<td>Supervisor(s)</td>
<td>Supervisor(s)</td>
</tr>
<tr>
<td>Operator</td>
<td>Operator</td>
</tr>
<tr>
<td>Maintainer</td>
<td>Maintainer</td>
</tr>
<tr>
<td>Planner</td>
<td>Planner</td>
</tr>
</tbody>
</table>

While the facilitator was establishing the simulation scenario, it was also an opportunity to develop a level of competence for the participants to run the simulation. The aims of the simulation were to explore issues around roles in the business, not an exercise to test how quickly they could learn how to operate the BBL. However, there needed to be a careful balance here. On the one hand, knowledge of how the game operates is important, on the other hand, the level of expertise the participants develop to actually run the simulation needed to be kept to a level that would support the emergence of issues around the target concepts in the simulation. In this case study the facilitator demonstrated running the simulation several times, but participants were only permitted to handle the BBL when the first round of the simulation
commenced. At the same time a plausible relationship between the game and the workplace was established so that participants could map the issues raised, and understandings that emerged, back into their workplaces.

The simulation was based on a realistic operational scenario with certain aspects revealed while others were assumed. The scenario was set around a 3 shift by 8 hour operation. The mine operates on a 2 by 2 hour shift basis with four panels. The 3 shift scenario was used in the simulation to accentuate the complexities around shift changes and communication between shifts.

The workshop participants were divided into the 3 shifts. The facilitator appointed a supervisor for each shift. These supervisors were selected from workshop participants who were either operators or maintainers in the workplace. Each supervisor was handed the ‘The Mine Simulation Instructions’ sheet. Supervisors were now asked to assign roles to their team members such that team members were performing tasks other than their normal workplace roles. The three roles were;

- Operator
- Maintainer
- Planner or Process Engineer

As soon as the roles had been assigned the facilitator brought the participants back around the BBL and pointed out that the work was behind time and “we need to get a move on”.

The facilitator gave the shift teams a cursory description of the operation, demonstrating several cycles in a shift, and answering some questions on the run. At this stage some supervisors watched the demonstration while others were reading the instructions.

The following discussion gives an insight into how and why some of the key aspects of the scenario, mostly contingent attributes of the scenario, were developed during the simulation. The italicised text is the facilitator’s banter, while the text in parenthesis describes the corresponding BBL activity.

As you can see, Acme Mining has, at great expense, developed this working model of the mine. You can see the shovel collecting the broken ore from the drill and blast ready to be loaded in a haul-truck (the BBL lorry places the balls in the Load Station); the haul-truck now takes the ore up the ore ramp- (The Thomas engine body collects the balls at the load station and proceeds up the elevator); now the haul-truck queues at the primary crusher and tips into the ROM bin (the Thomas engine body tips the balls into the bin at the top of the spiral); finally the ore goes through the crusher and is conveyed onto the primary stockpile (the balls go through the spiral to the base of the load station and the Thomas engine body heads back to repeat this cycle).

During this demonstration problems with the BBL may arise. This is particularly likely if a quality problem has been introduced into the simulation. In the case of the Drill and Blast team an oversize ball was introduced into the simulation.
Events such as a blockage can enhance the metaphorical mapping by referring to them in terms of common problems in the mine. A good example is when the oversize ball causes a blockage at the spiral. An oversized rock has been placed in the ROM bin and will need to be broken up. This could result in the secondary crusher losing choke feed and over-size material going through to the primary stockpile.

Elements of the scenario expressed in this way are important because they often go to the core issues that the improvement team must consider. In this example, the Drill and Blast team experienced some of the negative consequences of a poor quality blast. Even if this event didn’t happen during the demonstration it will happen sometime during the workshop, as long as the oversize ball remains in the simulation.

Although the demonstration was cursory some aspects were dwelt on because they were included in the scenario to support the emergence of target concepts. In this simulation a number of the rules were highlighted because they would go to the socio-technical nature of the simulation, and they would create complexity which puts production at risk, they include;

- The procedure for battery change and isolation
- The rules around shift change
- The rules around the use of blockage removal tools
- The 10 KTPD target for each shift is frequently referred to, whereas, the 30 KTPD is only mentioned at the introduction of the session. The purpose being to accentuate the small team (shift) target, and so raise the competitive nature that often exists between shifts. This issue was to be explored later in the workshop.

One of the target concepts explored during the simulation was the socio-technical nature of business processes, and therefore, the need to consider more than just technical fixes as the basis for improvement. Aspects of business processes involving training, experience, task assignment, driving on output targets and coaching all have a social dimension. The impact on process performance from ineffective management of these social dimensions was explored during the workshop.

During the first run of this simulation participants are likely to experience problems associated with some of these issues, but the BBL has an essential attribute that can be manipulated to accentuate these issues. The motorised chassis has two pins that must be located in the groove on the track to keep it on the track. An adept facilitator can start and stop the BBL several times, each time removing and replacing the motorised chassis on the track, and have the BBL run smoothly each time. Then, while the first shift team is under pressure to produce the target tonnes, the facilitator closes the pins as he hands the motorised chassis to the operator for the first shift, at the same time starting the stopwatch so the simulation production time begins counting down.
It usually takes the operator several goes at placing the motorised chassis back on tracks before someone will stop the shift and study the relationship between the motorised chassis and the tracks. Using this essential attribute in this way provides a physical and sometimes emotional method of producing cognitive dissonance.

Figure 5.5 The Motorised Chassis. The photo shows the chassis on the left with the pins that locate into the track in the down position. The chassis on the right has the pins retracted. During the simulation operators sometimes inadvertently retract the pins, usually causing a major breakdown. Alternatively, the facilitator can hand the chassis to an operator with the pins retracted. The first time this occurs is a good opportunity to discuss training issues; subsequent events highlight a lack of experience. Also note the white switch on the bottom of the chassis. It is this switch that interacts with lugs on the tracks to reverse the direction of the chassis.

After the first simulation run (one day’s production) had been completed, the simulation and its results were reviewed. Production was very low, yet the team members that had been tasked with recording losses and defects did not record significant losses. Losses that were recognised included the trouble with the motorised chassis at the start of the simulation, shift change losses and some spillage of balls.

The problems with the motorised chassis at the start of the simulation created confusion and some frustration, few participants were concentrating on their assigned tasks, and consequently the data they collected was poor. These experiences formed the basis for a rich discussion about some of the target concepts for the workshop. The topics that were covered included:
• Task assignment-
  o How effective had the task assignment been from the shift team leaders?
  o Did everyone know their role and other team members’ roles?
  o Have they ever been given a task, or, indeed, have they ever issued a task, with lack of clarity in the real-world mine?

• Training-
  o How well did shift team members feel the workshop facilitator trained them in the operation of the BBL?
  o Have they ever been given a task in the real world mine with insufficient training?

• Experience-
  o Was it reasonable to expect them to produce 30 KTPD in the BBL the first time that they had an opportunity to run it?
  o Have they ever been given new tasks in the real-world mine and been expected to perform at the rate of well-experienced personnel?

• Output Targets as the Driver-
  o How focussed were shift team members on achieving 10 KT in their shift?
  o Did this influence their behaviour in dealing with problems, such as the motorised chassis running off the tracks at the start of day?
  o What are the most important measures of performance in the real world mine, output targets (such as tonnes) or in-process performance?

Before the next round of the simulation the shift teams were asked to list all the problems they observed. The three shift teams were then asked to nominate two problems which could be addressed before the next simulation run. However, they could not alter the basic rules of the simulation process.

This led to a discussion about which two of the listed problems should have the top priority. This discussion made it clear that the teams did not have much data about the performance of the BBL, and the data that they did have was not very useful because they doubted its validity. This introduced three more concepts on the target list;

• effectiveness measures
- losses
- the nature of historic measurements

In the absence of good data the workshop members were encouraged to opt for the removal of the oversized ball and the opportunity to receive more training and experience on the BBL, outside of production time.

Before they commenced simulation round two, the participants were given information about an effectiveness-measurement view of the simulation process, and a losses-view of performance.

If the BBL is performing at its optimum then it could complete four cycles per shift for three shifts with each cycle delivering 2,500 tonnes of ore onto the primary stockpile. If a shift produces 10 KT it can be considered 100% effective. Thus, if 3 shifts (a day) produce 30 KT they can be considered 100% effective. Any reduction in production from these targets must be equal to the losses in the process, which the team members can record.

A facilitated discussion concerning the categories of the losses that could observed resulted in an agreed list of categories. The shift teams were given measurement sheets and asked to record production and losses for round two of the simulation.

### The Big Big Loader Simulation-Drill and Blast Score Sheet

<table>
<thead>
<tr>
<th>Shift</th>
<th>Cycle</th>
<th>Tonnes</th>
<th>Plan Time</th>
<th>Lost Time</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Plan Tonnes</td>
<td>Actual Tonnes</td>
<td>Shift</td>
</tr>
<tr>
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<td>1</td>
<td>2,500.00</td>
<td>2,500.00</td>
<td>45.00</td>
</tr>
<tr>
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<td>2</td>
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<td>2,500.00</td>
<td>45.00</td>
</tr>
<tr>
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<td>3</td>
<td>2,500.00</td>
<td>-</td>
<td>45.00</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>2,500.00</td>
<td>-</td>
<td>45.00</td>
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<tr>
<td>2</td>
<td>1</td>
<td>2,500.00</td>
<td>-</td>
<td>45.00</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>2,500.00</td>
<td>2,500.00</td>
<td>45.00</td>
</tr>
<tr>
<td></td>
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<td>45.00</td>
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<tr>
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<tr>
<td>3</td>
<td>1</td>
<td>2,500.00</td>
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<td>45.00</td>
</tr>
<tr>
<td></td>
<td>2</td>
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<td>Grand Total</td>
<td>30,000.00</td>
<td>14,600.00</td>
<td>540.00</td>
</tr>
</tbody>
</table>

**Table 5.1 Second round BBL simulation result.** The table shows the tonnes recorded for each cycle of each shift in column 4. The tonnes are totalled for each shift and for the day. The five columns to the right show the losses, measured in seconds, under the 5 categories of loss defined by the workshop.
After the second round the shift teams’ data was entered into an excel spreadsheet to calculate the process effectiveness and losses (Table 5.1 and Graph 5.1). The discussion around these results helped to clarify and elaborate the target concepts concerning measures. The first discussion point was that over the three shifts the OPE was only 47%. That is, 53% of available production capacity was lost. Furthermore, it was found there was a total of 11% production capacity lost with no recorded data concerning the nature of those losses. The discussion raised the following issues:

- The only measurement tools the shift teams had were stop watches, and therefore, they could only easily measure lost time.
- There were observations of balls falling out of the simulation circuit for a number of cycles. Once out of the circuit these balls were not contributing to production for those cycles. This was considered to be a problem with the quality of the process.

Graph 5.1. Pareto analysis of the second round results. The Pareto chart shows the results of the Drill and Blast teams second run of the simulation. The graph displays the outcome for each shift, and for the combined shifts to give the days outcome. Blue columns correspond to the percent of tonnes produced compared to the optimum tonnes, and is the Overall Process Effectiveness (OPE) performance—from a time perspective this represents productive time for the process. The maroon columns correspond to the losses recorded in Table 5.1. This is the down time measured by the shift teams as a percentage of total available time. The yellow columns correspond to the difference between the total available time and the sum of the productive time and recorded lost time. That is, the unrecorded losses as a percentage of total available time.

- There were still further losses that could not be accounted for, although the workshop participants agreed they did not know the history of the batteries powering the BBL, and the actual time it was taking for the BBL
to complete a cycle (this cycle time was specified as 43 seconds at the introduction of the simulation). This was considered to be a potential rate loss.

- The discussion led to a definition of effectiveness;

\[ \text{OPE} = \text{Availability} \times \text{Rate} \times \text{Quality} \]

Before the shift teams commenced the third round of the simulation the scenario was further extended to address several more concepts on the target list. The group was given three improvement tasks to complete:

- The three team leaders were tasked to review shift change processes to develop a new process that would focus on delivering the best performance for the day, rather than for the shift.

- A cross-shift team was set up to conduct an experiment to determine which set of batteries (at least two) would produce the best rate performance.

- A cross-shift team was set up to identify a cycle time reduction of at least 5% in the first shift of the day, and to develop visual controls that would enable a new operator to always deliver this cycle time reduction, as well as making optimum decisions during the shifts.

This part of the scenario was designed to introduce further concepts to the group:

- The groups were formed into small teams to resolve specific problems. Much of their work in the project would involve this type of activity. It required them to share the workload amongst the workshop team, as well as within the three smaller teams. The simulation was no longer just a metaphor for the mine, a second metaphorical structure - THE BBL SIMULATION IS THE IMPROVEMENT PROJECT - was introduced.

- The first and third tasks were largely about social processes, and so, they reinforced the earlier point about the socio-technical nature of business processes. The first task also introduced the concept of organising work for the success of the BIG team (the day) rather than the LITTLE teams (each shift). Up until this point the behaviour of the shift teams was very competitive.

- The third task introduced concepts about visual controls, simplifying tasks and fool proofing tasks.

A further concept was introduced when the three improvement teams had completed their work. They were invited to immediately start the next run. While some were keen to get the simulation under way others were reticent, until someone suggested the three teams explain their solutions to the wider group. This led to a discussion about the communication and socialisation actions they would need to institute during their real-world project.
The shift teams were then asked to run the simulation for the last time. Their results are in Table 5.2 and Graph 5.2. The results showed dramatic performance improvement over their initial and second simulation runs.

**Figure 5.6 Use of visual controls.** One improvement team was tasked to develop a procedure for operators that would assist them to make the best decision when starting the BBL. They were required to develop visual controls to support the procedure. The butcher’s paper has two arrows drawn on it, if the operator places the motorised chassis with the arrow in the direction shown by the drawn arrow on the left then the chassis will head towards the haul truck (Thomas engine body), if the motorised chassis is placed with the arrow in the direction shown by the drawn arrow on the right it will head towards the loader (lorry). The team developed additional visual controls to address problems they had experienced in the simulation; notes at the chassis and lorry to make sure pins are correctly located in track slots; a guide at the chassis on where to place it so that it doesn’t get stuck on a track lug, and they traced the track on to the butcher’s paper to assist maintainors to do a pre-start check that the track was not misaligned.
### Table 5.2 Final round BBL simulation results.

The team applied a strategy of not recovery balls until at least three were out of the circuit. This resulted in a quality loss of 2,250t or 7.5% however they completed a total of 10 cycles.

### Graph 5.2 Pareto analysis of the final round results.

Achieved an OPE of 76% with availability losses of 13%, quality losses of 7.5% and other losses of 3.5%.
Figure 5.7 The six big losses. The Drill and Blast team were able to use their data from the BBL to apply the model to their simulation experience. In this model losses in the three components of OPE are broken down into six common occurrences in business processes.

Figure 5.8 The lens of time. In this model losses are viewed as the equivalent amount of time that the equipment is prevented from operating. This view includes rate losses and quality losses.
The results from the final run still showed unrecorded losses of 3.5%, some of these losses could have been rate losses, but the improvement team on batteries were confident that the two batteries being used were good, and that the BBL was cycling under the 43 second rate specification. This result was used to introduce two other concepts on the target list, a 'Loss Model' for typical business process (Figure 5.7), and a time view of process performance (Figure 5.8).

5.9 Case Study Two: The Supervisor Workshop

An underground copper mine company was conducting a series of workshops to address leadership issues for supervisors. This work was being done in conjunction with an improvement intervention called IPMS (Integrated Process Management System). Issues for the leadership workshops were identified by observation of individuals' behaviour during the IPMS initiatives. These issues were used as themes for the next leadership workshop, and were usually the basis for a task assignment for participants at the workshop. It was decided to base the next leadership workshop around a BBL simulation.

The theme for the BBL workshop was the role of the supervisor. The way supervisors manage organisational and process boundary issues was of particular interest. The simulation scenario was designed to raise role-related issues for supervisors at the workshop, including the following target concepts:

- Allocation and specification of tasks within the team
- Prioritise the work requirements
- Planning the next shift
- Production versus safety
- Production and sub optimal shift behaviours
- The role of visual controls
- The importance of change management

The structure of the simulation was basically the same as for Case Study 1. Both case studies are in mining, so the processes and structures of the two businesses are similar. There were some superficial changes in terminology, such as, haul trucks in Case Study 1 become load haul and dump trucks (LHDs) in case study two. The major difference between the case studies was in the elements of the scenarios that bring out the target concepts. For example, while it was important to keep the drive for tonnes in the simulation to generate the desired cognitive dissonance, the focus on measurement and losses was reduced, whereas other work roles for supervisors were highlighted, including safety, task assignment, planning and change management.
The roles in the simulation were also different, they were:

- Operations Shift Supervisor
- Crusher/Conveyor Supervisor
- Shaft Supervisor
- Mobile Equipment Maintenance Supervisor

The workshop theme is the role of the supervisor, so a number of activities that are typical accountabilities for mine supervisors were built into the scenario. A specific issue targeted for exploration was the management of accountabilities at organisational and sub-process boundaries. The participants were allocated roles for the simulation; individuals' roles were other than their normal roles and all the roles were at the supervisor level. Although the participants were running the simulation the intention was for them to view the game from a position of responsibility for compliance to procedures and process. The Operation Supervisors were given a relatively long list of accountabilities:

- Record production in tonnes (count the balls as they go down the auto mill – that is, the BBL spiral).
- Record lost production time and the reasons for it.
- Record lost time incidents and safety issues, and report by end of the following shift.
- Calculate OPE
- Ensure compliance with CBPs (Current Best Practices). These were:
  - Engine must be refuelled. Fuel capacity is 55 seconds.
  - Engine must be refuelled at start of the day.
  - The refuelling cycle time is 5 seconds.
  - The process cycle time is 43 seconds.
  - No work, such as recovery of material, or repair of the tracks can occur while the motorised chassis is going. This includes refuelling.
  - Isolation of the motorised chassis can only be done in the Turnaround area.
  - Crusher hang ups can only be released using red explosives (demonstrate the use of the red paddle pop stick).
• Draw point hang ups can only be released using blue explosives (demonstrate the use of the blue paddle pop stick).

• Safety
  o SMATs (Safety observations)
  o HIRAs (Risk Assessments)

• Implement improvement work.
  o Suggest equipment, system and cost reduction improvements.
  o Participation in the implementation of improvements.

• Cost control
  o Effective operation of the equipment.
  o Maximise availability of the equipment.
  o Compliance with original equipment manufacturer (OEM) standards.

The first simulation run could be described as chaotic with many breaches of procedure, and some participants unsure of their roles. After the first simulation run the teams were asked to gather their data and report back. All teams reported on production performance with some recording of major failures and ball spillage. The day’s performance was; OPE 34%, down time 38% and quality losses 28%. There was no mention made of any of the other accountabilities. All shift teams reported a lack of experience in running the BBL, and a lack of training in how the BBL actually works (particularly the motorised chassis). The teams were offered two quality improvements, which were removal of the oversized balls and a training session on the operation of the BBL.

Before the next simulation run the workshop discussed the following topics, both in relation to the BBL simulation and the real world mine;

• The Supervisor’s Role in:
  o Task Assignment
  o Training
  o Coaching
  o Planning the shift

After this the teams reassembled and were given ten minutes to prepare for the next simulation run.
During the next simulation run the environment was notably more ordered and less frenetic. The facilitator recorded safety breaches on a white board as the teams completed the simulation run. After the simulation run the facilitator advised the teams that the safety performance was appalling for all shifts, but it was particularly poor for shift two, which had managed to injure every member of the shift. So while they were improving production – OPE 69%, down time 6.5%, quality losses 13%; and other losses 11.5%- safety performance was unacceptable. These simulation results formed the basis of a discussion around:

- The Supervisor's Role in:
  - Quality
  - HIRAs (Risk assessments)
  - SMATs (Safety observations)
  - Ensuring that high production did not result in poor safety.

A session of safety role-plays were conducted in the workshop, where the Maintenance Manager and Superintendent provided coaching to the supervisors.

The workshop was divided into three improvement teams with the following tasks;

- Operations Supervisors were to develop improved shift change processes to ensure that overall production was maximised and safety was improved. They were told to focus on the big team (the day) performance rather than the little team (the shift) performance.
- A cross-shift team was set up to conduct an experiment that would determine which set of batteries (at least two) would produce the best rate performance.
- A cross-shift team was set up to identify a cycle time reduction of at least 5% in the first shift of the day, and to develop visual controls that would enable a new operator to always deliver this cycle time reduction, as well as making optimum decisions during the shifts.

The three improvement teams implemented their solutions, and the simulation was run again. The environment was now calm and the noise level had reduced dramatically compared to the earlier simulation runs. Performance had improved again – OPE 86.5%, quality losses 5.5% and other losses 8% - and there were no safety incidents. The next discussion with the workshop covered the following issues;

- The Supervisor's Role in;
  - Improvement
In this chapter three source domains that were all based on the same concrete object, the BBL, were analysed. It was demonstrated how the concrete object and the scenario combine to form the source domain. The ZBS simulation was analysed against each component of the simulation theory that was developed in chapter 4. It was shown how the ZBS PLANT IS THE BBL simulation was constructed, and that it comprised the following features:

- A concrete object that provided a set of essential attributes. The Hierarchy of Simulations.

- These essential attributes were augmented by a set of contingent attributes that were designed to make the source domain a plausible representation of the target domain. They include the props introduced into the simulation and that part of the scenario that describes the BBL as components of the target domain. The contingent attributes were kept to the minimum required to achieve this outcome. The source domain comprises the concrete object and the scenario.

- The essential and contingent attributes were further augmented throughout the simulation workshop with additional attributes that would support the emergence of issues around the target set of concepts for the workshop. These additional attributes were limited to only those that support the emergence of the target concepts. The Maxim of Quantity.

- The development of understanding during the workshop was supported by the introduction of dilemmas for participants. Cognitive Dissonance.

- The mapping from the source domain to the target domain was provided by the essential and contingent attributes of the source domain. This mapping was tenuous enough that the source domain could represent a generic-level schema of which the ZBS plant is only one instantiation. The GENERIC IS SPECIFIC metaphor.

- The BBL is semantically autonomous so that understanding developed during the simulation workshop is from direct experience in the simulation runs. Grounding and the BBL.

Two further case studies were also discussed in the chapter. The first, THE BBL IS THE DIAMOND MINE, was described in some detail. This description demonstrated the following aspects about designing a simulation:

- The choice of the concrete object is determined by its ability to be a plausible representation of the target domain, and that its essential attributes will support the development of a scenario that will deliver the aims of the simulation.
The Hierarchy of Simulations (Table 4.1) was used to show why the BBL was an appropriate choice for the aims of this simulation.

The description of the approach taken to develop case-study workshops is instructive on how to design and develop similar workshops.

A further case study, **THE BBL IS THE COPPER MINE**, was described briefly. In this case study the scenario for the contingent attributes was very similar to that for the diamond mine. This makes sense because the operations are very similar. However, the aim of this workshop was quite different. In the case of the diamond mine the aim was to develop concepts about business improvement tasks, in the case of the copper mine the aim was to explore issues about leadership and the role of the supervisor. The discussion of the copper mine workshop focused on aspects where it was significantly different to the diamond mine workshop.

A comparison of the three workshops – the ZBS plant, the Diamond Mine and the Copper Mine – is instructive. In terms of complexity the ZBS workshop can be considered the least complex. While the workshop was about process improvement, the environment was one where the equipment is contained in a processing plant, and the process is determined by chemistry. In the Diamond Mine workshop the complexity is higher, the process is not constrained in the plant, and there are several processes operating that are sometimes interdependent but at other times are independent. In the Copper Mine workshop the complexity is higher still. This is because decisions that are made are more complex, they more directly influence the social aspects of the business, and they have a longer time horizon.

So, using the same concrete object (the BBL), it is possible to develop simulations that are designed to operate through a range of complexities. That is, simulations based on a particular concrete object may move up or down the Hierarchy of Simulations, depending on the aims they are designed to address, and the scenario that is developed to establish the mapping between the source domain and the target domain.

These issues, as well as other design and development considerations, will be discussed in Chapter 6.
Chapter Six

Guidelines for the Design of Simulations

Both real-world and virtual situations provide us with real opportunities to be conceived and built. The advantages of virtual simulations over traditional methods is that they can help to think about situations more quickly and at less cost. For instance, the use of the virtual reality (VR) can be used to represent different mental models of the business environment, allowing everyone to experience different aspects of the business environment.

Consider the following examples of using the BBL for a case study:

Typical issues isolated using the BBL technique focused on multiple perspectives:

- Equipment effectiveness
- Role of management
- Role of training
- Variation and random events
- Graphs and charts

Typical issues isolated using a virtual environment focused on single perspectives:

- Competition between shifts
- Aligning devices to the big data or fully integrated system
- Role of leadership - superintendents, foremen, operators
- Performance measurement

Typical issues isolated using a VR technique focused on single perspectives:

- Training versus safety performance
- SWAT's and HiRAT
- Training

However, the VR technique is present in many cases, but the way the BBL technique is implemented enables the workshops to be more or less at a particular stage of the business environment, while at the same time, changing the business expectations, which helps in reducing the complexity of the situation by the understanding of the business environment.
"Human purposes typically require us to impose artificial boundaries that make physical phenomena discrete just as we are entities bounded by a surface." (Lakoff and Johnson, 1980)

6.1 General

Business simulations provide us with one way of improving understandability of our world. They impose useful boundaries around business operations and so help to focus our attention on discrete aspects of business phenomena. For instance, the Big Big Loader (BBL) can be used to help participants to establish different mental models of the business process, allowing them to focus on different aspects of the business experience.

Consider the following examples all using the BBL at a copper mine.

Typical issues isolated using the THE BBL IS A MACHINE metaphor:

- Equipment effectiveness
- Role of precision
- Role of training
- Variation and random events
- Graphs and charting

Typical issues isolated using a BBL scenario focused on the shift-change issue:

- Competition between shifts
- Aligning activities to the big team or little team objectives
- Role of leadership – supervisors/superintendents
- Performance measurement

Typical issues isolated using a BBL scenario focused on safety:

- Tonnes versus safety performance
- SMATs and HIRAs
- Training

How the BBL scenario is presented, and the way the BBL session is facilitated, enables the workshop participants to focus on particular aspects of the business experience while at the same time ‘bounding’ the business experience, and so by reducing the complexity of the situation to be understood, assist participants to ‘make sense’ of those aspects of the business experience.
Similarly, as we saw in Section 2.3, Du Pont used computer simulations of the maintenance function for two quite different purposes. The quantitative models were designed to give specific answers to specific questions, while the qualitative model was designed to demonstrate the interrelationship between various policies. Each type of model 'bounded' the maintenance function so that the appropriate business phenomenon was more clearly visible.

This is the essence of why we use simulations in business. The issue that must be resolved, in any attempt to design an effective simulation-based workshop, is how to 'bound' the business to make the phenomena of interest clearly visible.

This question is dealt with in this chapter. A model for the design and development of simulations is proposed, and each element of the model is discussed.

6.2 The Workshop Design Model

6.2.1 Aims of the Workshop

Understanding the aims of the workshop is critical in the development of effective simulations. The aims need to be clear, and agreed, between the workshop developer and the customers for the workshop. While in many circumstances the aims may seem obvious, nevertheless, it is essential to test the assumption that all parties share these aims. This is especially the case for workshops that are based on simulations in either Category 3 or 4 of The Hierarchy of Simulations (Table 4.1).

We can see from the table that simulations in Category 4 utilise mappings that are highly detailed, and that are very low in abstraction. This emerges from their purpose. Such simulations are generally intended to provide understanding of what the real-world target domain can potentially produce. The simulation is designed to achieve this understanding as efficiently as possible, that is, in a much reduced timeframe, space and cost than can be achieved in the real-world target domain.

When designing Category 4 simulations, the developer’s challenge is one of cost benefit. How much detail is enough for (a) the developer to be confident the simulation is giving usefully detailed results concerning the behaviour of the real-world target domain, and (b) the customers to be confident that they can rely on the simulation results?

Even though all simulations will necessarily hide some phenomena and highlight other phenomena this is not the primary purpose of bounding for Category 4 simulations. In this case, the primary purpose is to generate understanding in an efficient manner.

The simulation developer’s challenge is quite different for Category 3 simulations compared to Category 4 simulations. The purpose in Category 3 simulations is to highlight those concepts that are of interest while hiding those that are not, and to generate sufficient cognitive dissonance to challenge the prevailing mental models.
Figure 6.1 The workshop design model. This proposed model for the design and development of simulations is based on the metaphorical structure of simulations, as discussed in Chapter 4. The model depicts the process flow and major considerations that need to be addressed when designing effective simulations, and simulation-based workshops. In the case of simulation-based workshops the 3 boxes that represent part 2 of the scenario are indicating that the simulation will change over time as the workshop progresses. This change in the simulation is produced by the interactive development of the scenario during the workshop.

For example, we saw in Section 2.3, that Du Pont developed a dynamic model of the maintenance function. The purpose was not to replicate the performance of the maintenance function - it was to challenge existing mental models about maintenance policy and the maintenance function. The simulation was intended
to generate cognitive dissonance about maintenance, and to generate a view of some possible new states of the business.

This is also the case for Category 1 and 2 simulations. These simulations are patently not designed to give outcomes that could be construed as reproducing outcomes in the real-world target domain. This is not always the case for Category 3 simulations which may appear very similar to Category 4 simulations—they may be developed with the same software, they will refer to many of the same elements of the target domain, and they may produce similar outputs.

This circumstance can lead to confusion among the customers for simulation-based workshops. All parties need to know clearly what the purpose of the exercise is if this confusion is to be avoided.

If the simulation is to be the basis of a workshop then the aims of the workshop must be clearly understood. The simulation will need to be designed so that all target concepts for the workshop can emerge from experience with the simulation. It also needs to have an appropriate concrete object—that is, one that can support the progressive emergence of the target concepts.

6.2.2 Define the Target Concepts

Once the aims of the simulation have been determined the nature of the concepts that might be explored will become clear.

Careful consideration of the aims will assist in defining the target concepts. Table 4.1 lists a number of concepts that are typically explored in simulations from the four categories. Definition of the target concepts then enables a suitable concrete object to be chosen, and an appropriate scenario to be developed to support the desired learnings.

When designing a simulation the first question to be answered is whether the simulation should be able to be tuned. That is, do the aims require the simulation to change overtime as the workshop progresses? This change could be needed to run a number of ‘what if’ scenarios of a quantitative model, or to build understanding over the course of a workshop (Sections 4.7.3.2 and 5.4).

Second, are the aims to generate understanding about specific aspects of a specific process, or is it intended to deliver understanding about some generic principles that can be applied to many, or all, processes?

Third, if the principles are generic are they related to the function of a business process, or are they universal principles that are applicable beyond business processes?

Consideration of these issues is important. They underpin the selection of the concrete object and, therefore, the set of essential attributes that will determine the range of ‘bounding’ that can be applied by the simulation. A quantitative model of a process could be used to show the impact of variation in the process that it models, but dice very elegantly display the fundamental physics of a random variable—a concept of universal importance in attempts to understand
the nature and impact of process variation. If the aim is to show the impact of variation on the specific process then use the quantitative model, if the aim is to generate understanding about variation and random variables then use the dice.

These decisions are about the GENERIC IS SPECIFIC nature of the simulation that is chosen. The quantitative model can be used to explore the variation in a specific process, but the understanding that is gleaned from the exercise may be limited because the audience understands it to be a feature of this specific process, whereas, if dice are used as the concrete object there can be no misunderstanding that the principles being considered are universal to all things that we measure. As the target concepts move from being specific about a particular process towards more generic principles, then the simulation should also move down the categories of Table 4.1 increasingly based on concrete objects that will increase the GENERIC IS SPECIFIC nature of the simulation.

Table 4.1 can be used as a guide to the type of concrete object that might be chosen. Consideration of the aims of the simulation should lead to a decision about the category of the simulation. The simulation may be developed as a version of one of the examples listed in the table, or the developer can use the example concrete objects as the basis for a simulation. Alternatively the examples may provide clues that will lead the developer to identifying other, more appropriate concrete objects.

6.2.3 Choosing a Concrete Object

Once the target concepts have been determined the concrete object can be chosen. The chosen concrete object needs to have the following features;

- It must be able to plausibly represent the target domain.
- It must allow participants to experience the target concepts within the source domain (concrete object plus scenario).
- It must have a set of essential attributes that ‘bound’ the target concepts.

The plausibility of the concrete object is a function of its essential attributes and the concept being explored. For instance, as long as the target concepts include variation and random outcomes, then dice will always be a plausible representation of the target domain.

Similarly, as long as a target domain exhibits a sequential series of tasks or processes that produce some product, and exhibits losses and poor performance, and as long as the concepts being discussed are around performance in such target domains, then the BBL will be a plausible representation of the target domain.
At the most generic level we can conceive of entire classes of businesses in terms of the operation of the BBL\(^\text{12}\). The BBL is versatile, in the sense of being an appropriate choice of concrete object, because it can be run in a way that is essentially the same for many business operations. Thus, we can conceive of a specific business in terms of the BBL, we can conceive of sections of the specific business in terms of the BBL, and we can conceive of specific processes within the business in terms of the BBL. We can even conceive of individual pieces of equipment in terms of the BBL (Figure 6.2)

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**Figure 6.2 The BUSINESS IS THE BBL tree.** The tree demonstrates the scalability of simulations that are very generic. The scalability is derived from the simplicity, or limited set of essential attributes, of the concrete object. This limited set means the simulation must be bound tightly around a small set of concepts or principles that emerge from running the concrete object in the simulation.

BBL simulations can be considered to be representative of businesses in general, but they can also be considered to be representative of classes of businesses such as mines and processing plants. Further, they can be considered representative of types of businesses within these classes, such as a diamond mine. They can also be considered to be representative of sections within the business types, and processes within these sections, such as a crushing circuit in a diamond mine processing plant.

If we first consider the metaphor THE BUSINESS IS THE BBL then we have a very general view. When we move down the tree (Figure 6.2) through to, say, THE DIAMOND MINE IS THE BBL, we can see that the concepts will be applied much more specifically. This is the case even though the concepts maintain their

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\(^{12}\) The Centre for TPM (CTPM) has run BBL simulations in this context at public workshops. In this context the audience are from very diverse businesses yet the games are run at the generic business level and so have relevance to this broad audience.
generic nature. This needs to be carefully considered. A balance needs to be struck between (a) creating a metaphor that facilitates people learning from the BBL operation, and applying those learnings to their operation, and (b) limiting the understanding to such an extent that people will not see its wider application.

Here it is suggested that the following rule be applied:

1. Determine the target process and the key generic concepts to be explored.

2. Construct the metaphor at a business complexity level that is at least one level greater than the process of interest.

This will require participants to consider the process of interest in terms of the BBL, but will ensure that they continue to be aware of the complex in which the process of interest operates. In this way participants will apply the concepts to their own process and yet will still see the business level of which their process is but a part. They will view the new understanding within a broader context than they might otherwise do.

Concrete objects, such as dice and the BBL, are underpinned by a GENERIC IS SPECIFIC metaphorical structure. When choosing a concrete object it is necessary to consider the degree to which the target concepts are generic. Lack of complexity in the concrete object will deliver a small set of essential attributes which will 'bound' the target concepts tightly, and will support only a generic metaphorical structure. If the target concepts are generic then the concrete object needs to be simple, and the scenario needs to maintain this simplicity.

6.2.4 Develop the Scenario

Now that the target concepts have been decided, and a concrete object has been chosen, it is necessary to develop a scenario linking the concrete object to the target concepts.

The Workshop Design Model (Figure 6.1) calls for a scenario that consists of three parts that are shown as parallel processes. The essential and contingent attributes that make up the underlying source domain will be established up front. However, where the simulation changes over time (for example, when it is tuned in a workshop environment) the components of the scenario that augment the source domain to support the emergence of further target concepts, and that create cognitive dissonance, are developed together over time. As each new concept from the target list is introduced, understanding is usually developed by building on previous concepts. The narrative of the simulation must, therefore, develop as the workshop progresses.

6.2.4.1 Scenario Part 1: Contingent Attributes

Lakoff's model for general metaphor is based on the premise that humans naturally use metaphor as a cognitive strategy to aid understanding. The metaphorical systems that are the basis for this process are fundamental to our
cultural and linguistic systems. So there is no need to have a mapping from the target domain to the source domain that creates the metaphorical schema. In the case of novel metaphors, such as those used in poetry, the author generally does not necessarily want the reader to see the metaphorical structure at first glance. So again there is no need for an explicit mapping from target to source domain. Also, in the case of these novel metaphors the understanding is often provided by third parties—scholars who analyse and interpret the poetic work. So the metaphorical structure is discussed over a long period of time.

Simulations, especially category 1 and 2 simulations, are based on novel metaphorical structure, and so they do not draw on the metaphorical systems that are present in our cultural and linguistic systems. Also, when we are running a simulation it is usually a one-off exercise for the participants, therefore, there is no opportunity for a discussion over an extended period of time. Consequently it is important that the metaphorical structure of the workshop is clear in the minds of the participants from the word go. An effective method of achieving this is to start the workshop with a reverse mapping where the concrete object is described in terms of the target domain. In so doing, contingent attributes are created in the source domain that will support the aims of the workshop.

This issue has been discussed above in Chapter 4. The information given in Table 4.1 will provide guidance on how to construct the simulation scenario. The first component of the scenario must create a set of contingent attributes that augment the essential attributes of the concrete object to ensure that the source domain is a plausible representation of the target domain (see section 4.7.2).

We can see from Column 6 in Table 4.1 that this is particularly the case for Categories 1 and 2 simulations. There is an essential difference between the Category 3 and 4 simulations. In the case of simulations from Categories 3 and 4, the concrete object has been designed to be a more detailed representation of specific features of the target domain. In the case of Categories 1 and 2 simulations, on the other hand, the concrete objects are chosen because they exhibit characteristics that are clearly instantiations of the target concepts. They will usually have no, or very limited, inherent physical mappings to the target domain.

This component of the scenario must include sufficient mappings between the source and target domains to allow participants to project their experiences in the source domain back into the target domain. That is, to experience the target concept in the source domain, and then to understand how the concept applies to the target domain.

This is typically achieved through a narrative that links the concrete object to components of the target domain. The components that are chosen should be carefully considered in the context of how well they will support the process of mapping the experiences in the source domain back to the target domain.
6.2.4.2 Scenario Part 2: Target Concepts and The Maxim of Quantity

The second component of the scenario comprises the narrative that supports the emergence of the target concepts, and the supporting props that enable participants to experience the target concepts in the simulation.

Its design must deliver two outcomes;

- All concepts on the target list emerge from running the simulation
- These target concepts are held in stark relief by the simulation

That is, phenomena that occur within the target domain are represented in the simulation in such a way that participants can focus on and experience those phenomena without distractions from other phenomena. The target concepts from the target domain are ‘bounded’ by the simulation. The clutter and hurly-burly of the real-world target domain are stripped back to just those aspects that will support experiential learning about the target concepts.

Also, it is this component of the scenario that delivers the development of the simulation (for tuneable simulations) over time. It needs to be carefully constructed so that it supports this development logically, and in a way that maximises the potential for learning. Issues that should be considered when designing this component include:

- The sequence in which the target concepts are introduced.
- The depth of precursor understanding required for each target concept.

6.2.4.3 Scenario Part 3: Cognitive Dissonance

This component of the scenario comprises the events that cause participants to question their existing mental models of the target concepts (see section 3.5). The most powerful events are those that produce counterintuitive outcomes for the participants. The intent is to challenge the participants existing mental models, giving them a jolt sufficient to bring their subconscious thinking about the concepts up to the conscious level.

The freedom to create cognitive dissonance is an important consideration when selecting the concrete object. The freedom is a function of the essential attributes of the concrete object and the creativity of the simulation designer.

The simulation designer needs to focus on three principles:

- The simulation designer must have a profound knowledge of the concrete object, and how it behaves.
- The simulation designer must understand the target domain in depth. In particular, he or she must know how the target concepts present themselves in the target domain. This knowledge will provide insight into
how the concrete object might be manipulated so that a dilemma, around the target concepts, can be created.

- The simulation designer must practice. He or she must continue to design and develop simulations with the intent of using cognitive dissonance as an aide to effective learning. The designer should take an action research approach by assessing the effectiveness of each simulation and adjust his or her approaches accordingly.

6.2.5 Test and Review

Once the simulation has been designed and developed it is important that it be tested, reviewed and where appropriate amended.

The questions that must be answered include:

First, have the aims of the simulation been achieved? That is, does the workshop provide insight and help participants to develop understanding of the target concepts.

Second, does the workshop deliver this outcome in a clear and unambiguous way? If concepts and principles, other than the targeted ones, are emerging from the simulation the aims may be diluted or confused.

If the answer to either of these questions is ‘No’ then the simulation needs to be revised. As shown in Figure 6.1, this revision may involve review of the methods used to (a) define the target concepts, (b) select the concrete object and (c) develop the scenario. Regarding (a), if the list of target concepts is seen to be incomplete or too extensive then a pragmatic decision must be made about what really needs to be in the list. If the list is changed, then the concrete object should also be reconsidered as to whether it is still appropriate. Does it match the new list of target concepts?

If the simulation is seen to significantly miss the target list then the problem is likely to lie with the choice of concrete object.

If the problem is that too many extraneous issues are arising during the simulation then the concrete object is probably too complex - it is not providing for a tightly bound source domain around the target list of concepts.

If some of the target concepts are not emerging from the simulation, then the concrete object probably does not exhibit the behaviours associated with the target concepts. In this last case, the solution is to consider if the concrete object can be further augmented with additional props. If not, a different concrete object needs to be used.

If there is only a slight gap between the target list of concepts and those that are grasped by workshop participants, then the problem can probably be fixed by revising selected aspects of the scenario.
6.3 Case Study 3: Underground Mine Maintenance

The events in this case study occurred before the development of the simulation theory and models that are described in this thesis. The development and use of this simulation was carried out intuitively, as events unfolded. It was on reflection about this simulation, and other simulations being developed for clients, that a pattern in the development of simulations began to be seen. Furthermore, the elements of this pattern were common to all simulations, whether they were quantitative computer simulations, or dice being used to represent process variation.

6.3.1 Aims of the Simulation

The mine in question was still being developed, and a major business improvement initiative was underway. The mine production was 12 KTPD (kilo tonnes per day), and the improvement initiatives were aimed at moving production to 30 KTPD. As the operation improved and production increased maintenance performance began to emerge as critical issues that could prevent success.

On several occasions the maintenance manager was offered support to undertake a reengineering effort in the maintenance area. He avoided the help offered and was not prepared to address the issue. The cause for this reluctance was eventually enunciated. He explained that he was already working very long hours, he felt he needed to get on top of things as they were, and the reengineering effort would just create more work for him.

It was decided that a simulation was needed to challenge the maintenance manager’s current mental models of how the future would pan out as the mine moved towards 30 KTPD. That is, to give him ‘new eyes’ to view the future state of the mine and the maintenance function.

The intended outcome was to lead the maintenance manager to the realisation that he could not keep operating within his current paradigm, and expect to achieve success in reaching 30 KTPD. This change of perception was to be encouraged by exposing the maintenance manager to a simulation that would help him to ‘experience’ this future state at first hand.

6.3.2 Define the Target Concepts

The underlying concept that needed to emerge from the simulation was the dynamic (time varying) nature of the maintenance function. That is, the effect of the complex feedback loops that drive behaviour in the maintenance arena, and the realisation that complexity was only going to increase as the mine moved towards 30 KTPD. It was decided that 3 concepts needed to emerge from the simulation workshop:

- The behaviour of a maintenance operation is driven by strong feedback loops.
- Some of these feedback loops are obvious; others are not.
• The level of 'dynamic complexity' (Senge 1980) will increase as mine production increases.

6.3.3 Select a Concrete Object

First, it was decided that the simulation needed to be presented as being specifically about the maintenance function at this mine. That is, the mine manager needed to see that he had a personal interest in this – the simulation needed to be presented as a SPECIFIC IS SPECIFIC metaphorical structure. Concrete objects in Categories 3 and 4 from Table 4.1 are most suitable for this metaphorical structure because they contain essential attributes that allow strong specific mappings to the target domain.

Second, it was decided that a quantitative computer simulation of the maintenance function at the mine would be an appropriate Category 4 concrete object. Nevertheless, the time it would take to develop such a simulation precluded this option.

It was decided that a concrete object from Category 3, that would support the exploration of the maintenance function from a system dynamics perspective, was appropriate.

It was decided to use a Causal Loop Diagram (CLD) as the concrete object. Although the CLD is a non-tuneable model it was appropriate in this circumstance. It was used as the focus of a discussion with the participants.

6.3.4 Develop the Scenario

6.3.4.1 Scenario Part 1: Contingent Attributes

We can see from Table 4.1 that category 3 source domains have a high level of mapping detail in the mapping from the source domain to the target domain. Much of this detail is contained in the essential attributes of the concrete objects.

A CLD of the maintenance function of an underground mine (Figure 6.3) will be a fairly obvious representation of the maintenance function at a mine, and would readily be seen as such by people who work in mining. However, the detail in the diagram will bring issues to the surface that might otherwise be taken for granted or overlooked. So, the CLD had many essential attributes that were specific mappings to the underground mine maintenance function. This was augmented by specific features of this mine being included in the narrative for the simulation; the number and types of trucks, the increase in production from 12 KTPD to 30ktpd and the architecture of the mine.

6.3.4.2 Scenario Part 2: Target Concepts and the Maxim of Quantity

The dynamic system characteristics of processes, and the complexity they cause, are fundamental essential attributes of CLD s. They are a feedback-
loop-centric view of systems. These concepts did not need to be augmented in the scenario because they are a fundamental component of the simulation concrete object.

Figure 6.3 A causal loop diagram (CLD) of maintenance for an underground mine. The CLD was developed before the simulation session. It was used by the facilitator as a template to lead a discussion with the maintenance and mine managers. The managers were encouraged to develop their version of the CLD. Once they developed their diagram it was used as the basis of a discussion about the consequences of moving from a 12 KTPD mine to a 30 KTPD mine.

While designing the simulation, an extensive list of possible variables was considered before the CLD was produced. This list was carefully assessed to ensure the balance was right in terms of the complexity of the diagram and the ability to have the target concepts emerge from the simulation. It was decided to restrict the diagram to just two causal loop drivers; tonnes and the number of machines. These drivers were patently interrelated - as the mine developed more machines would be introduced and the tonnage would increase. Conversely, as demand for tonnage increased more machines would be added. The other causal loops, such as those involving spare parts, space and contractors, would then be discussed at the end of the simulation to accentuate the potential complexity in the future state – all in accordance with The Maxim of Quantity.

Attributes designed to support a discussion of a 30 KTPD future state did need to be built into the scenario. Accordingly a narrative was developed that would engage the maintenance manager in a discussion of the differences between
the current state and a 30 KTPD future state (when all the interactions shown in the CLD were considered).

6.3.4.3 Scenario Part 3: Cognitive Dissonance

Cognitive dissonance was introduced in three ways.

First, a peer of the maintenance manager, the mine manager, was asked to attend the simulation. This meant that the maintenance manager's participation was framed by the expectations of his major customer. The intent was that he would have to participate, conscious of his responsibilities to provide appropriate service to the mine manager.

Second, it was decided to use the CLD (Figure 6.3) as a template to facilitate a session where the two managers developed their own shared version of the CLD. It was felt that this would encourage the 2 managers to think deeply about the relationships between the various variables, and the processes that influenced these variables (rather than the having facilitator describe the template CLD to the managers).

Third, once the causal loop was developed on the white board the managers were asked to explain what would happen in the various loops as tonnes increased, and as the number of machines increased. It was this discussion that provided some quantification to the challenge that faced the maintenance manager, and so, generated the realisation that the status quo would not deliver the required outcomes.

6.3.5 The Results

At the end of the simulation both managers agreed that the maintenance function had to be improved. The maintenance manager accepted the assistance he had been offered, and left the session with the intention of reengineering the maintenance processes.

On the 30th August 2003, some 9 months after the workshop, the mine produced over 30 KT—the first time such a result had been achieved in a single day.

6.4 Summary

This chapter is intended to provide guidance to those intending to design simulation-based workshops. It is a conceptual guide to the structure of effective simulations, based on the present author's metaphor theory.

The Figure 6.1 shows the fundamental steps required developing an effective simulation-based workshop, when the simulation is linked metaphorically to a business process. Discussion presented in the present chapter, draws on the models from Chapter 4 for simulation metaphors and The Hierarchy of Simulations (Table 4.1).

The following paragraphs are offered as further advice to simulation designers.
First, develop a profound understanding of how the concrete object works. This will arm you with a plethora of options that can be used to create the unexpected, or facilitate the exposure of a particular point using the simulation. It will also open your mind to ways to introduce foreign materials that can enhance metaphorical mappings to actual operations, and ways to build plausible scenarios.

Second, spend the time and effort necessary to understand the target domain. It is desirable to ride with operatives in the operation. This will give you insight into some of the language, stories and idiosyncrasies of the target domain, which can be built into the scenario, and which can be referred to casually during the simulation workshop. Banter between the facilitator and the workshop participants, in the language of the operators, is a powerful mechanism to build and reinforce similarities between the target and source domains. Such banter can underpin the metaphor in the minds of the participants, without reducing the generic structure of the source domain.

Third, listen to the participants, and within the basic structure of the workshop, respond to the dynamics of each individual workshop.

Fourth, stay on message. Be careful about allowing the simulation to expand beyond the design list of target concepts. While serendipitous learning by participants should be highlighted and encouraged, it is still important that the Maxim of Quantity is observed. This will maximize the chance that participants develop an understanding of the target concepts.
Chapter Seven

Discussion and Conclusions

The first step was a review of the current situation regarding the use of simulations in business (Chapter 5). Based on this review, and personal experience in developing and using simulations in business improvement strategies, a number of characteristics of simulations were isolated. In this chapter:

1. A definition of business simulation was developed.

Simulations: Any activity where a concrete object is used in conjunction with a scenario that supports developing understanding of a target domain (the business) through a mapping from a source domain (the concrete object plus the scenario).

2. The experiences of Du Pont, and elsewhere, were reviewed. This review showed that simulations are hierarchic; they range from complex quantitative computer models to simple toys used as models to demonstrate principles that underpin business processes. This discussion led to the first characterisation of simulations, that they can be either (a) quantitative, where they result in a quantified estimate of process outcomes, or (b) they can be qualitative, where they demonstrate qualities, or underlying features, of business processes.

3. Consideration of other simulations used in business led to a further characterisation of simulations. They can either:

(a) Allow the participant to have a decision making role, such as in board games, or a qualitative model. Such simulations demonstrate in-process behaviours, and the socio-technical nature of business processes.

(b) Demonstrate only output behaviours of processes—examples include dice and qualitative models (although quantitative models can be manipulated and run with different parameter settings according to the user's choice).

The concept of a 'hierarchy of simulations' was identified as a major theme of the thesis.

Simulations fulfill metaphoric. They are a vehicle for understanding the behaviours of one thing, a business process, in terms of the behaviour of another, a concrete object. In Chapter 3, aspects of modern metaphoric theory that are germane to understanding how simulations work were described and
7.1 Discussion and Conclusions

As outlined in Chapter 1, the aim of the work presented in this thesis was to address a gap in the business-simulation literature - namely, the lack of guidelines for the conceptual design and development of simulation-based workshops. In order to meet this aim it was necessary to understand the metaphorical nature of simulation.

The first step was a review of the current situation regarding the use of simulations in business (Chapter 2). Based on this review, and personal experience in developing and using simulations in business improvement settings, a number of characteristics of simulations were isolated. In this chapter:

1. A definition of business simulation was developed.

**Simulation:** Any activity where a concrete object is used in conjunction with a scenario that supports developing understanding of a target domain (the business) through a mapping from a source domain (the concrete object plus the scenario).

2. The experiences at Du Pont, and elsewhere, were reviewed. This review showed that simulations are hierarchical; they range from complex quantitative computer models to simple toys used as models to demonstrate principles that underpin business processes. This discussion led to the first characterisation of simulations, that they can be either (a) quantitative, where they result in a quantified estimate of process outcomes, or (b) they can be qualitative, where they demonstrate qualities, or underlying features, of business processes.

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(a) Allow the participants to have a decision making role, such as board games or a qualitative model. Such simulations demonstrate in-process behaviours, and the socio-technical nature of business processes.

(b) Demonstrate only output behaviours of processes—examples include dice and quantitative models (although, quantitative models can be manipulated and run with different parameter settings according to the user’s choice).

The concept of a ‘hierarchy of simulations’ was identified as a major theme of the thesis.

Simulations utilise metaphors. They are a vehicle for understanding the behaviours of one thing, a business process, in terms of the behaviour of another, a concrete object. In Chapter 3, aspects of modern metaphor theory, that are germane to understanding how simulations work, were described and
discussed. This discussion provided a framework for developing a simulation theory that would support development of simulation-design guidelines. Selected concepts from modern metaphor theory were developed into schematic models (Figures 3.1, 3.2 and 3.3). These models express the structure of metaphor and how metaphors work. The key concepts identified from metaphor theory were:

- A generic metaphor structure comprises a source domain, a target domain and a mapping from the source domain to the target domain. Furthermore, this mapping is a selective one-to-one mapping that is defined by the source domain but constrained to make sense in the target domain. That is, it is a product of the relationship between the source and target domains.

- The hierarchical structure of the great chain metaphor and the consequent hierarchy of source domains have strong parallels to the hierarchical nature of business simulations.

Cognitive science tells us that some 95% or more of human decisions are made in the cognitive unconscious, so people are unaware that they are making these decisions. This means that it is difficult for people to see the limitations of the mental models of cause-and-effect that underlie their decisions. Simulations can be designed to address this human condition by generating cognitive dissonance. A model for cognitive dissonance was described in Chapter 3 (section 3.5).

At this point in the thesis the building blocks from (a) experience with business simulations, (b) metaphor theory and (c) cognitive dissonance had been assembled.

The development of a simulation theory was described in Chapter 4. Schematic models of the theory were developed (Figures 4.1 and 4.2).

Simulations are novel metaphors. They do not draw inference from the cultural and linguistic systems in the manner of general metaphors. Consequently, metaphor theory needs to be adapted to develop a general simulation theory.

First, a concrete object, by itself, does not serve as a source domain for a metaphoric mapping in a business simulation. It needs to be overtly classified as being representative of components of the target domain before it can become a component of a source domain in a metaphoric mapping. The other component of the source domain is, therefore, the scenario that creates the contingent attributes which provide this overt classification.

Second, simulations are used either as (a) stand-alone representations of how some process or thing works, or (b) as a component of a workshop to demonstrate some concepts or principles. Attributes that support the emergence of these target concepts may not be automatically inferred from the source domain. They must be generated through a narrative and additional props that, together with the fundamental source domain, ensure the concepts emerge. This narrative, along with the essential attributes of the concrete object, must also satisfy the Maxim of Quantity.
Third, in order to encourage learning it is useful to generate cognitive dissonance. The possibility of creating cognitive dissonance must also be built into the scenario.

As defined here a scenario has three components, they are:

- A mapping from the target domain to the concrete object to classify the concrete object as being representative of components of the target domain. The mapping establishes the contingent attributes of the source domain.

- A mapping from the source domain to the target domain to ensure the target concepts are highlighted in the simulation, and extraneous concepts are hidden. This mapping must satisfy The Maxim of Quantity.

- A certain level of indeterminacy that will cause dilemmas to emerge during the workshop, in order to generate cognitive dissonance. This dissonance will encourage learning.

Two other discussions in this chapter concern:

- The development of a proposed SIMULATION GREAT CHAIN metaphor.

- The proposed Hierarchy of Simulations.

The hierarchical nature of simulations was explored through a study of business simulations. This study resulted in the definition of four categories of business simulations (Section 4.9), they are:

1. Generic-Universal
2.Generic-Functional
3. Specific-Functional
4. Specific-Structural

These categories were used as the basis for developing a Hierarchy of Simulations (Table 4.1). In this hierarchy characteristics of the simulations are described against eight criteria.

In Chapter 5 the simulation theory was applied to develop a theory of business simulations. This was done by analysing simulation workshops that had already been developed and run by the author. The first workshops discussed concerned a plant producing zirconium basic sulphide (ZBS).

Three source domains were analysed. These were all based on the same concrete object, the Big Big Loader (BBL). The discussion of the ZBS simulation described how each element of the simulation theory applied to this simulation.
Two further BBL simulations were discussed as case studies. The first case study was a simulation of a diamond mine. It was used to explore the issues that need to be addressed when designing a simulation. The discussion covered the following issues:

- Choosing a concrete object.
- Using The Hierarchy of Simulations (Table 4.1).
- Developing a scenario.

A further case study, a simulation of a copper mine, was described briefly. In this case study the scenario for the contingent attributes was very similar to that for the diamond mine. This makes sense because the operations are very similar. However, the aims of this simulation were quite different. The case study was used to demonstrate how the scenario must be developed in the context provided by the aims of the workshop.

The guidelines for designing simulations are presented in Chapter 6.

Figure 6.1 shows the fundamental steps required for designing and developing an effective simulation, or a simulation-based workshop, that is linked metaphorically to a business process. Each element of the design process is described in Chapter 6, along with guidance on how it should be implemented. Chapter 6 also includes some practical advice for facilitating simulation-based workshops.

The guidelines are intended to be used with the models from Chapter 4 and the practical considerations contained in Chapter 5. Together, they constitute ‘a practical guide for business improvement practitioners on how they should go about choosing, designing and using a business simulation that will meet their specific needs’.

Chapter 4 provides the underlying simulation theory. The theory establishes the rules for the construction of business simulations. Chapter 5 develops this simulation theory showing how it is applied in a number of case studies. The case studies show the approaches required to design and develop simulation-based business workshops. In Chapter 6 the design and development process for business simulations is presented as a flow chart (Figure 6.1), based on the metaphorical structure of simulations. Figure 6.1 is used as the basis for describing how to go about designing and developing effective simulation-based workshops.

7.2 Further Work

The theoretical basis for this work largely comes from modern metaphor theory. However, other areas of study have significant parallels to the principles of modern metaphor theory and have been drawn upon in this work. In particular, the work of Seymour Papert (1993) in the field of early education, and his use of microworlds, and work in system dynamics by people such as Senge (1990) and Sterman (2000). While these sources have been used to develop the
simulation metaphor theory presented here, there is scope to further integrate aspects of modern metaphor theory, learning theory and system dynamics.

The work presented in this thesis could be described as Applied Cognitive Science. This suggests two possible avenues of further work.

Firstly, while the present discussion is focussed on simulations of business processes, the underlying metaphor theory is applicable to any field of human endeavour. Particularly where there is a need to develop understanding of relatively abstract concepts. It follows that the work presented here has broader application than just business simulations.

Certainly there is a strong tradition of using concrete objects in educational environments. A review of their use, in the context of the work presented here, could result in a more 'scientific' approach to the design, development and use of such concrete objects; and perhaps much more consistent educational outcomes from their use.

This work could also have broader application in management environments. The simulation theory and models developed in this work were based on work that was done in production process improvement environments. But managers have broader responsibilities than just improving production performance. They should be improving all aspects of their business, and therefore, need to develop the understanding of all aspects of their businesses. The approach presented could be applied in these other areas of businesses.

Furthermore, it is not just businesses that people endeavour to manage. We endeavour to manage our relationships, our families, our communities, our environment and other systems that we encounter as a society. Managing these systems also requires the development of understanding, and the development of effective models (or simulations) to express this understanding. The approach described in this thesis could assist in all such endeavours.

Secondly, cognitive science includes many subjects other than metaphor theory. The approach taken in this present work could be applied to other fields from cognitive science. That is, the cognitive theory could be analysed and understood in the context of some human endeavour in order to codify how the science is applied. Then, using this knowledge, develop practical guidelines on how the science can be applied in many other circumstances.
References


Morgan, Dennis., 1997, “Providing a POTS Phone in an ISDN or Similar Environment”, Motorola Inc. 1997.


