A Perception-Influence Model of Innovation Implementation in Project-Based Engineering

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Abstract

Innovation is an imperative in all industry sectors. For those such as construction, which are not considered high-tech and which operate as one-off projects, the uptake and diffusion of new innovations into ongoing practice across projects pose particular problems. The nature of these problems faced at a project level needs to be better understood. This thesis is an exploration of innovation implementation in the context of Project-Based Engineering (PBE). It is an empirical investigation of how new planning technologies are implemented in major infrastructure construction projects and the barriers that prevent such implementations from being effective. The findings of this investigation are used to develop and evaluate a new model of innovation implementation in this context.

The research design is centred on the immersion of a participant-observer in seven live construction projects over a period of 3.5 years. Each project studied was implementing the same innovation: 4D CAD modelling (3D design model + the construction schedule). A wide cross-section of data was gathered in the field including direct observations, documents and other work products from participation, email and other correspondence associated with the 4D CAD implementations, and formal and informal discussions with project-participants. These data were analysed using content analysis software to find patterns.

The research was iterative and involved three phases. The initial phase was a pilot study of implementation in practice using the data from one project. It produced rich descriptions of what transpired and a critical comparison with accounts from the literature. This led to a series of propositions about the influence of project-participant perceptions that were synthesised into a new theoretical model: the initial Perception-Influence model (P-I1

model). The middle research phase then developed this model iteratively using a more-focused data collection and content analysis across four construction project organisations. This was done to provide supporting evidence for the theoretical constructs in the P-I1 model as well as to refine them and add new ones. The outcomes of the middle phase were the P-I2 and P-I3 models. The final research phase analysed the data from the last two project organisations in terms of the P-I model framework with a view to evaluating the model's theoretical significance and practical applications.

The P-I model shows that negative perceptions of value, benefit and usability can cause an innovation implementation to be ineffective as a result of discontinued use or neglect. It provides a map for the progression of an implementation using the perceptions and actions of project-participants as primary constructs. The model proposes that each perception is formed by a number of contributing factors or secondary constructs synthesised from implementation research and user acceptance literature, for example, an opinion or concern about how much an innovation costs (i.e. transaction costs). It also proposes that each perception has both a positive and negative associated action.

The constructs that make up the P-I model are grounded in the empirical data. This is because the actions, opinions and concerns of project-participants observed in live projects are evident in project documentation such as emails. These two sources (i.e. observations and project documentation) provide data sets that were used to triangulate inferences about the perceptions of project-participants and the outcome of each 4D CAD implementation (i.e. effective or otherwise). This aspect of the research was not only important for the recommendation of potential applications for the P-I model but also during its conception, development and evaluation.

The P-I model is a new and important perspective for both implementation research and PBE practitioners. It helps satisfy the calls for studies of innovation implementation that focus on factors at an individual level and those asking for a better understanding of innovative behaviour. This work shows PBE practitioners how the perceptions of project-participants can have a major impact on the effectiveness of an innovation implementation. The findings provide an evidential basis that can improve implementation effectiveness, especially in PBE organisations. The knowledge built into the P-I model can also assist the planning and execution of innovation implementation strategies, aid in the assessment and redirection of those in progress, and help document lessons learned for implementations within project organisations that have been previously completed.

This research uses the P-I model to open the way for future empirical studies of innovation implementation in PBE contexts beyond construction. These would also provide data to further refine the constructs in the model.

Keywords

innovation implementation, project-based engineering, perception, influence

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Acronyms

ACL – Australian Construction Limited

CAD – Computer-Aided Design

D&C – Design and Construct

FO – Functional Organisation

PBE – Project-Based Engineering

PC – Personal Computer

P-I – Perception-Influence

PO – Project Organisation

TAM – Technology Acceptance Model

Short-hand Titles for Project Organisations Studied

TC_{PO} – Tollway Construction Project Organisation

TT_{PO} – Tunnel Tender Project Organisation

PT_{PO} – Public Transport Project Organisation

PP_{PO} – Process Plant Project Organisation

PB_{PO} – Private Building Project Organisation

CB_{PO} – Commercial Building Project Organisation

FU_{PO} – Freeway Upgrade Project Organisation

Glossary

4D CAD Modelling: Four-dimensional computer-aided design modelling – A 4D CAD model of an engineering construction incorporates a three-dimensional design model and a construction schedule by linking the two together into a spatially and temporally navigable model. It is a Virtual Construction Technology (VCT) and belongs in the domain of Virtual Design Construction (VDC).

Adoption: The process by which an individual or organisation identifies, acquires and plans to implement a new technology.

Commitment: The decision to allow the technology champions to implement an innovation.

Construction Firm: A PBE firm in the construction industry whose function is the actual delivery of the construction project (vis-à-vis a design firm that delivers the actual design).

Contributing Factor: The term used to describe an opinion or concern that contributes to the formation of a more general perception.

Diffusion: The process by which a new technology becomes accepted and used by the population of all potential users.

Dividing: The descriptor for the relationship between a theoretical construct with a broadly scoped definition and one or more other theoretical constructs with narrower scoped definitions that exist as divisions but also as examples of the parent construct.

Embodiment: The descriptor for the process of garnering empirical evidence for particular theoretical constructs.

Encompassing: The descriptor for the inclusive, multi-faceted, contribution-style relationship existing between certain secondary constructs (e.g. contributing factors) and certain primary constructs (e.g. perceptions).

Functional Organisation (FO): An organisation or firm with a continuous lifespan from year to year that has long-term objectives carried out by various departments (e.g. human resources, IT and engineering) and intra-firm interactions.

Implementation: The process of gaining targeted organisational members' appropriate and committed use of an innovation.

Implementation Strategy: The process by which technology champions pass the required operating skills and know-how on to the targeted adopters.

Innovation: A new idea that is implemented by an adopter with the intention of deriving benefits.

Major Construction Project: Large PBE tasks that include the construction of dams, tunnels, buildings, tollways, freeways and bridges etc.

Nonreactive Data Collection: A method of gathering in-context data whereby the subjects who contribute data are not affected by the process of collecting the data so that behaviours are witnessed naturally.

Paralleling: The descriptor for the relationship between two theoretical constructs of similar or synonymous definition that are labelled with different or confusing terms.

Participant-Observation: A research method whereby the researcher is participating in the context being investigated as well as observing the processes therein for the purpose of data collection. The participatory function the researcher performs helps justify their presence and can mask the fact they are observing what is happening.

Perception: An encompassing theoretical construct that is formed in an individual's mind by the combined influence of any number of relevant but more specific attitudes, opinions or concerns.

Primary Constructs: The elements of the P-I model that are proposed to directly influence the implementation outcome.

Productive Use: The key indicator of an effective innovation implementation when achieved by a project-participant.

Project-Based Activity: Describes the way projects are carried out in project-based industries, that is by the project organisations (POs).

Project-Based Engineering (PBE): Refers to those project-based industries and firms that deliver engineering projects.

Project-Based Firm: A firm whose mainstream activities are organised into projects. (NOTE: This includes both FOs and POs however FOs can participate in multiple projects at one time whereas a PO is formed solely to deliver the one project.)

Project Organisation (PO): An organisation with a finite lifespan (set by the requirements of the project for which it was formed) that has short-term objectives carried out by both intra- and inter-firm interactions.

Project-Participant: The targeted adopters at a project organisation in an initiated implementation (i.e. a commitment to an innovation implementation has been made).

Researcher Immersion: The process by which a researcher is placed in the context being studied thus creating the scenario or research setting of a situated researcher.

Secondary Construct: The terminology used to categorise those components of the P-I model that are proposed to indirectly influence the implementation outcome through an associated encompassing perception construct.

Targeted Adopters: The people associated with a potential innovation implementation as a result of being required to make decisions (i.e. management) or to actually use the innovation (usually identified by the technology champions).

Targeted Users: Those targeted adopters identified as potential users of an innovation (this may or may not include the management or decision makers).

Technology Champions: The people with the skills and know-how required to use an innovation as well as the responsibility of passing them on via implementation.

Technology Group: A group of technology champions.

Theoretical Constructs: Those specific factors and concepts from implementation research literature that have been attributed to causes of innovation implementation outcomes and user acceptances.

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1 Introduction

The development of the Boeing 787 Dreamliner, a new generation of aircraft that represents a radical deviation in the design and production of a commercial aircraft, has prompted a series of reflective speeches from the Chief Executive Officer of Boeing, Jim McNerney:

> *To innovate, in its root sense, means to renew. Innovation is critical to business success in today's world. It's about taking what's there and making it better as quickly as possible ... Innovation is a team sport, not a solo sport. It depends on a culture of technical sharing and openness to others. It takes people working together across different groups, disciplines and organizational lines to make it happen. It also takes real leadership in charting the course.* (McNerney 2007, CEO Boeing)

This insight was inspired by a large-scale and successful engineering project that had to overcome the challenge of multiple firms needing to work together to deliver the project's final product. These firms, and particularly those that carry out most or all of their activities in projects, can be referred to as project-based firms (Lindkvist 2004). The statement epitomises how important it is for project-based firms to operate innovatively. It also highlights what it takes for them to achieve this goal. Apart from the success of the Boeing 787 Dreamliner, the validity of the statement is unquestionable because it came from Jim McNerney, the former CEO of 3M, one of the most innovative and technologically diverse project-based firms globally.

1.1 Motivation

Despite the success of industry leaders such as Boeing, project-based firms are largely unsupportive of innovation (Keegan and Turner 2002). McNerney identifies organisational lines and diversity of personnel as barriers to innovation. Another likely cause is an overemphasis on planning and control systems by these firms in preference to innovation management (Grex 2004). Zabelle of Strategic Project Solutions[1] suggests six reasons for ineffective implementation of new technologies (Fischer and Zabelle 2008), and one of these for a project-based firm

[1] Strategic Project Solutions (SPS) is a global network of consultants providing products and services for effective project delivery. www.strategicprojectsolutions.com

would seem to be human factors. A significant motivation for the research presented in this dissertation is to gain an understanding of the reasons why ineffective implementations are experienced by project-based firms, in particular those involved with engineering design. Engineering design is a typical project-based task that starts with a defined problem and ends with the production of a solution (Dym and Little 2004). An example is the need for a more economical aircraft and the production of the Boeing 787 Dreamliner.

This thesis uses the term project-based engineering (PBE) in referring to industries and firms engaged in engineering projects. Some of the main PBE industries are shipbuilding, telecommunications, construction and aerospace (Hobday 2000). Interestingly, the construction industry is distinct from the other three in this group because participating firms do not organise their own work into projects, such as Boeing does — rather, the project work is dictated by others (e.g. the need for a bridge). Construction firms are some of the regular PBE offenders in failing to support innovation (Mitropoulos and Tatum 1999) and this could be a result of the ways in which they are different from other PBE firms. Regardless of the ways in which they are different however, a PBE construction firm is a typical example of a project-based firm that must characteristically contend with the tension between the long-term objectives of the parent firm and the short-term objectives of the projects when managing innovation.

One of the most common ways that PBE firms can operate innovatively is to adopt and subsequently implement new technologies on their projects. The term 'innovation' has been used thus far as the noun referring to the act or process of innovation; however it is often used as a synonym for 'new technology'. In this regard, researchers have identified a characteristically slow rate of innovation adoption in project-based industries (Taylor and Levitt 2004), and the need to improve this rate in construction firms has been documented extensively (Mitropoulos and Tatum 1999). The process of innovation implementation is an important element to this problem (Klein and Sorra 1996) and this leads to the basic motivating question:

> ***What factors influence an innovation implementation in project-based engineering?***

A significant motivation not closely related to the problem is to contribute to the growing enthusiasm for research work that involves academia and industry working together and producing comparable benefits for both (e.g. Moyes, Buur et al. 2005; Walker, Cicmil et al. 2008b).

1.2 Basic Concepts and Scope

It is important to know the definition of the key terms in this dissertation that are associated with innovation implementations by project-based firms. In conjunction with an explanation of the scope of the thesis, this section introduces some of the key terms (highlighted in *italics*) which are also defined in the glossary.

1.2.1 Innovation Implementation

Implementation is the process of achieving appropriate and committed use of an innovation by key organisational members. It is the critical gateway between the decision to adopt an innovation and its routine use (Klein and Sorra 1996). Innovation implementations need to be managed astutely and those in charge should be aware of the barriers that exist (Stewart, Mohamed et al. 2004). These people are called *technology champions* (Nam and Tatum 1995) and they are the ones who educate targeted employees and project managers who are referred to as *targeted adopters*. Technology champions must devote considerable attention, resources and conviction to ensure targeted adopters achieve productive use of the innovation or the implementation will be ineffective (Klein and Knight 2005).

The notion of *implementation effectiveness* is a key concept. It is determined by assessing the consistency and quality of the targeted adopters' use of the innovation being implemented (Klein and Sorra 1996). An effective implementation requires adopters to gain generic technical knowledge as well as local practical knowledge (Fleck 1994) in order to facilitate productive use. This should not be confused with 'innovation effectiveness', the effectiveness of the innovation itself, as this refers to benefits brought to an organisation as a result of the function that the innovation performs.

Similarly, implementation should not be confused with adoption. *Adoption* is the process by which an individual or organisation identifies and commits to the uptake of a new innovation (Rogers and Shoemaker 1971). This distinction is made clear by Rogers's (2003) widely accepted five-stage model for the diffusion of an innovation (see section 2.1). *Diffusion* is the all-encompassing process that sees a new innovation introduced and ultimately accepted (or rejected) by potential users (Mitropoulos and Tatum 2000).

1.2.2 Innovation Implementation in Construction

The construction industry presents a typical example of the complex and fragmented business relationships and processes associated with *project-based activity* (Peansupap and Walker 2005b) as well as the characteristically slow rate of innovation adoption in PBE (Mitropoulos 2001). The Australian construction industry is no exception (Manseau and Seaden 2001; ABS 2005). Accordingly, this thesis makes use of Australian construction projects as indicative examples of project-based engineering (PBE) activity. Innovation implementations in projects from a number of different construction industry sectors, including civil infrastructure and commercial building, are studied.

In the construction industry the nature of the relationship between the PBE firm and the project creates additional complexities for innovation implementation. A project is a temporary endeavour undertaken to create a unique product or service (PMI 2004) and a single PBE firm can participate in any number simultaneously depending on its size. Participating firms often combine through joint ventures, partnerships and strategic alliances to form the *project organisations* that deliver multi-billion dollar projects (Cushman and Myers 1999). In this way the relationship between the PBE firm and each project organisation where innovation implementation is concerned can be like that of an external stakeholder or consultant.

To implement an adopted innovation, a PBE firm must first gain an implementation *commitment* from one or more project organisations (Dulaimi, Ling et al. 2003). This involves technology champions from the firm marketing the innovation to raise the awareness and knowledge of its potential benefits and functionality among the targeted adopters (Goodman and Griffith 1991). If a commitment to implement the new innovation is made by project management, the implementation can proceed and the targeted adopters become *project-participants* in the ensuing implementation (Peansupap 2004). The effectiveness of this implementation process then depends on the *implementation strategy* used by the technology champions in passing the required operating skills and know-how on to the project-participants with the responsibility of being the end users. This process is central to the exploration described in this thesis for which a specific aim was to provide a tool for technology champions to employ as part of their implementation strategy.

1.3 Need for Research

The adoption of an innovation does not ensure its implementation (Klein and Sorra 1996), whether effective or not. This is of some concern because of the high cost of some innovations adopted by PBE firms and the number that experience stifled implementations or inadequate support from project management. There is a definite need to explain why innovations with obvious demonstrable benefits are rejected. Not only is the monetary cost of the implementation wasted, so too are the efforts and enthusiasm of those championing the innovation.

It is well known that change is often resisted in many areas of human endeavour, no less in innovation implementation.

> *And it ought to be remembered that there is nothing more difficult to take in hand, more perilous to conduct, or more uncertain in its success, then to take the lead in the introduction of a new order of things. Because the innovator has for enemies all those who have done well under the old conditions, and lukewarm defenders in those who may do well under the new.* (Niccolo Machiavelli, 1513, from Machiavelli 2006)

This statement clearly shows the challenge faced by technology champions involved in the transfer of new innovations to project-participants. Most people become used to performing a task the same way over and over so the ‘profit’ in maintaining the ‘old institution’ is being able to continue doing their job without having to learn anything new. The technical merits of an innovation are unrelated to this resistance as it is a result of interference with personal agendas (Hedge and Pulakos 2002). The ‘lukewarm defenders’ are those project managers interested in implementing a given innovation to obtain the project benefits yet they are aware of the challenge in having it taken up.

In broad terms, the need exists for an in-depth investigation into innovation implementation in PBE organisations. The results must be both scholarly and professionally significant in order to better understand the problems as well as provide answers to pertinent questions.

1.4 Research Design

The thesis adopted an exploratory qualitative research design. While the general or macro context of inquiry was known at the outset and some broad questions existed, a preliminary study of innovation implementation was needed to sharpen the focus of the research and find the micro context of inquiry. In this way the research leant itself to a qualitative approach (Neuman 2003).

The research design involved the immersion of a participant-observer in seven different project organisations implementing the same innovation (4D CAD modelling). The immersion occurred over a period of 3.5 years by means of the *technology group* belonging to a PBE firm in the Australian construction industry (ACL – Australian Construction Limited). As an immersed researcher I gained unfettered, daily access to the project-participants and technology champions at each project organisation where the implementations unfolded. The empirical data I collected is largely textural and was categorised into two main groups: 1) *direct observations* transcribed as field notes; and 2) *project documentation* which included reports, emails and meeting minutes. This type of research technique was chosen as it supports formulation of our understanding of natural activity (Brereton and McGarry 2000).

The data from each of the seven implementations were analysed using an iterative content analysis. This approach allowed judgments to be made on the basis of pre-determined criteria (Archer 1984). In this thesis, these criteria or propositions were identified as part of the findings from an initial empirical investigation that was informed by concepts from implementation research literature. The detailed analyses were facilitated by the content analysis software NVivo 7 (QSR International 2007).

1.5 Thesis Structure

Chapter 2 establishes the context of inquiry by reviewing relevant literature. It culminates with the research questions that capture the essence of the problem at the outset of the exploratory investigation. Chapter 3 presents the research design that delivered the investigation as well as alternatives that were considered.

Chapter 4 describes the details of an initial empirical study of practice and how it shaped the focus of the ensuing research project. This is articulated by the formation of a more specific research question regarding the perceptions of project-participants in an implementation. More literature, specifically relevant to the refined focus, is drawn in and theory is combined with analysed data to theorise an initial perception-influence (P-I) model, the P-I_1 model, for the management of an innovation implementation in project-based engineering.

Chapter 5 describes the inductive development of the P-I model theory and associated compilation technique that can be used for any given innovation implementation. The theorised refinements produce the P-I_2 and P-I_3 models, and the first illustrative examples of constructed P-I models are shown at the end of this chapter.

In contrast to chapters 4 and 5, a more-deductive analysis in chapter 6 indicates how and at which stages of an innovation implementation the model could be useful. This is done using another two illustrative examples that ultimately form a sample from which to draw quantitative as well as qualitative measures of the P-I model's power as a management tool.

The implications and potential applications of the P-I model are discussed in chapter 7. Where and how the research findings fit in and contribute to implementation theory is another feature of this chapter. Chapter 8 summarises the conclusions and recommendations resulting from the thesis.

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2 Literature Review

In my beginning is my end.

(T. S. Eliot from Raine 2006)

This chapter provides the grounding knowledge used to justify and guide the research. Reviews of innovation diffusion theory and the more specific field of implementation research are presented. This provides the background to the initial research questions and the establishment of a need for the research. The questions are relative to a macro (or broad) and micro (or focused) context of inquiry, those being innovation implementation in project-based engineering (PBE) and the individual decision-making level therein. Accordingly, this literature review also includes a background to PBE activity and presents construction as a typical example.

2.1 Innovation Diffusion Theory

Everett Rogers (2003) clearly identifies the implementation stage within the overall diffusion lifecycle (Figure 2-1). His landmark book *Diffusion of Innovations* is one of the most widely cited theories on innovation diffusion (e.g. Sherry 1997; Chan 1998; England 2004; Moseley 2004; Peansupap 2004) as it not only defines the stages of diffusion, but it also explains in detail the mechanisms at work before, after and during each stage of the lifecycle.

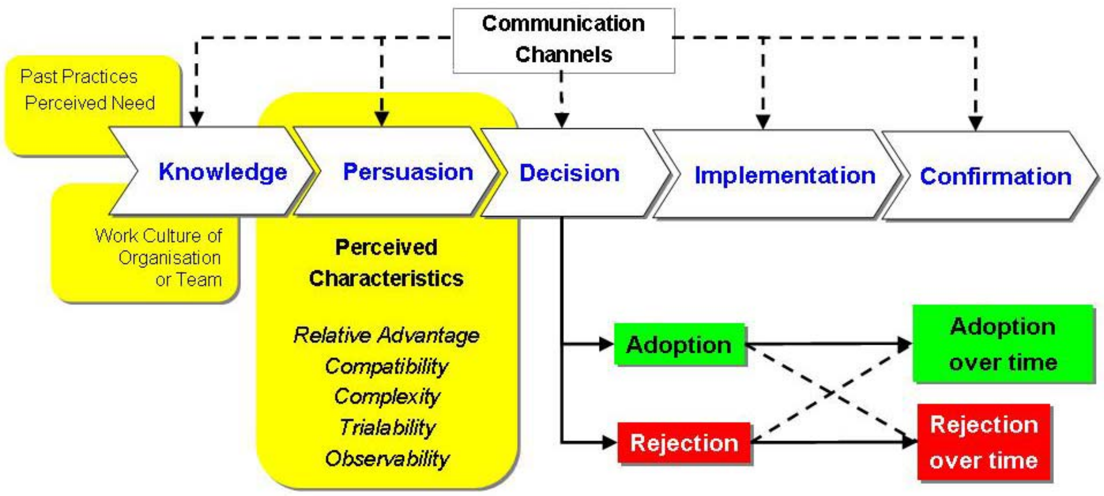

Figure 2-1: The Five Stages of Innovation Diffusion (Rogers 2003)

Although the focus of this thesis is on implementation – the fourth stage in Rogers’s (2003) model – the first three stages are also important. Innovation diffusion theory is orientated from the perspective of the adopter (Rogers 2002). Thus an individual practitioner involved in an innovation adoption must pass through the first two stages, knowledge and persuasion, before they can voice their opinions during the third stage, decision-making (or indeed, make their own decision if it is solely up to them). A practitioner can gain knowledge about a new innovation in many ways, the most common of which is the internet (Alshawi and Faraj 2002). Once basic knowledge of the innovation is gained, practitioners form opinions about using it and how this use would affect his or her normal workflows (Von Hippel 1986). This occurs at stage 2 (persuasion) in Rogers’s (2003) model, and practitioners’ opinions are represented as perceived characteristics of the innovation.

2.1.1 Innovation Characteristics – Adopter Perceptions

Moore and Benbaset (1991) focused their research efforts within Rogers’s (2003) second diffusion stage, persuasion (see Figure 2-1) and in particular on the perceived characteristics of an innovation. They developed an instrument to measure the characteristics perceived by adopters of information technology (IT) and built on the five (5) characteristics from Rogers (2003). Research efforts that seek to find different terminologies within and/or extend parts of Rogers’s (2003) innovation diffusion theory for the most part exist as subsets (Chan 1998). However, the work of Moore and Benbasat (1991) is highly regarded (Scannell 1997; Venkatesh, Morris et al. 2003) and their results proposed the following set of seven perceived characteristics to extend Rogers’s (2003) work:

1. ***Relative advantage*** – the degree to which an innovation is perceived by targeted users (potential adopters) as being better than existing systems (Ramiller 1994) if replacing them, or the extent to which it improves existing systems if used in combination with them. This characteristic depends on existing workflows (Dooley 2001).

2. ***Ease of use*** – the degree to which the adopter believes that actually using an innovation would be free from physical and/or mental effort. The negative

connotation that parallels ease of use is complexity (Davis 1989): 'the degree to which an innovation is perceived as relatively difficult to understand and use' (Rogers and Shoemaker 1971).

3. ***Image*** – the degree to which the use of an innovation is perceived to enhance the potential adopters' status or image in their social system (Moore and Benbasat 1991). This characteristic was included as part of relative advantage by Rogers (2003), however researchers have found the effect to be different enough for it to be considered a separate factor (Moore and Benbasat 1991).

4. ***Compatibility*** – 'the degree to which an innovation is perceived as being consistent with existing values, needs and past experiences of potential adopters' (Rogers 2003).

5. ***Visibility*** – 'the degree to which both potential and confirmed adopters can see others using the system in the organisation' (Moore and Benbasat 1991). Rogers's observability characteristic, 'the degree to which the results of an innovation are observable to others' (Rogers 2003), was shown to be tapping two distinctly different constructs by Moore and Benbasat (1991) in visibility and results demonstrability.

6. ***Results demonstrability*** – the tangibility of the results of using the innovation and ease with which they can be communicated (Venkatesh, Morris et al. 2003). This refers to how amenable to demonstration the innovation is and how visible its advantages are (Zaltman, Duncan et al. 1973).

7. ***Voluntariness of use*** – the degree to which adopters perceive the use of the innovation to be voluntary or of free will. It was deemed a necessary characteristic by Moore and Benbasat (1991)

2.1.2 Innovation Scope – Functional Categorisation

Innovations are commonly categorised in terms of the changes in concept or function they provide along with changes in the way they link up or interact with other systems (Slaughter 2000). Existing workflows are a major consideration when attempting to measure or predict these two levels of change and even a notional indication of them will help determine the effort required to adopt and implement the innovation in question. Figure 2-2 shows the five main categories of innovation scope or type.

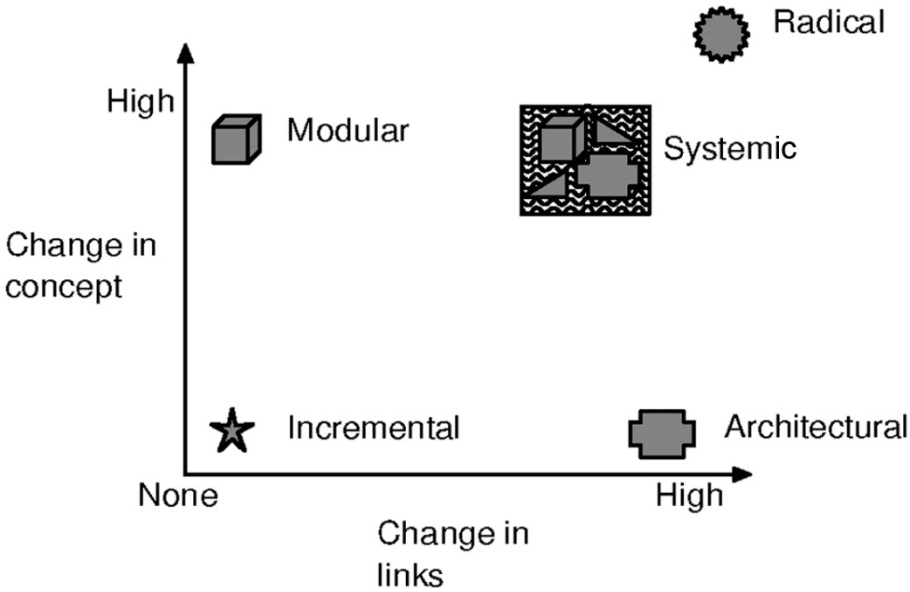

Figure 2-2: Categories of Innovation Scope (Slaughter 2000)

An *incremental innovation* represents a small improvement to current practices with minimal impacts on associated components or systems ('links' in Figure 2-2 above). An *architectural innovation* is a small advancement in a specific field or concept requiring significant change in associated components or systems. A *modular innovation* provides a significant advancement but requires little systemic change, and the *systemic innovation* describes a set of complementary innovations providing changes in concepts as well as associated systems. A *radical innovation* changes everything and often makes previous solutions obsolete (Slaughter 2000). Innovations contributing to case-based evidence in the literature concerned with adoption by project-based organisations are either incremental or systemic (Taylor and Levitt 2005a).

Some other factors can help classify an innovation's scope as incremental (simple) or systemic (complex), such as divisibility (Gopalakrishnan and Damanpour 1994) and pervasiveness (Wolfe 1994). Divisibility is the extent to which an innovation can be divided into smaller parts to help with adoption and implementation (Linton 2002). The greater the divisibility the lower the complexity (Gopalakrishnan and Damanpour 1994) therefore incremental innovations tend to have a high divisibility and systemic innovations a low divisibility. A good example of a divisible innovation in engineering is a CAD (computer-aided design) software package that has an associated free viewing program so that anyone can access models made in the parent software. Similarly, pervasiveness, which can be used to classify an innovation’s type, relates directly to compatibility (Ramiller 1994). A pervasive innovation implementation involves a large population of targeted users through which the use of the innovation must spread in order for the implementation to be effective, whereas a non-pervasive innovation implementation involves a finite and smaller number of targeted users, as little as one (Wolfe 1994). In a single organisation, systemic innovations tend to be pervasive and incremental innovations otherwise.

An innovation’s scope becomes apparent to adopters during the knowledge and persuasion phases of diffusion whereas the perceived characteristics change over time. This is an important concept for this research. Using the previous example, a CAD software package could be categorised as incremental before it is introduced due to its divisibility and the way it complements the systems that the targeted adopters use. Therefore, in order to study the perceived characteristics involved in an innovation implementation it should help to keep the scope of innovation constant. Accordingly, the empirical data contributing to this thesis comes from multiple implementations of the same innovation – an incremental, divisible and non-pervasive innovation (see section 3.2.1 for details). Another important concept or metric that is useful for distinguishing innovation scope is the rate at which the innovation diffuses.

2.1.3 Rate of Innovation Diffusion

The innovation diffusion rate is often used as a comparative metric in diffusion theory. It is the number of adopters over time and shows how an innovation was taken up by the population of potential adopters in a social system (e.g. project organisations in an industry). The most common diffusion (or adoption) curve is the S-shaped Gompertz curve (Dewick, Green et al. 2006). It represents a mathematical model of a time series where growth is slow at the beginning and end of a time period (for the case of an innovation diffusion, this is the time for the total population of adopters to begin using the innovation). Figure 2-3 shows a comparison of the adoption curves for incremental and systemic innovations. The difference between the two curves – the innovation gap – reinforces the approach of this thesis in keeping the innovation scope constant in order to focus on the perceived characteristics of an innovation.

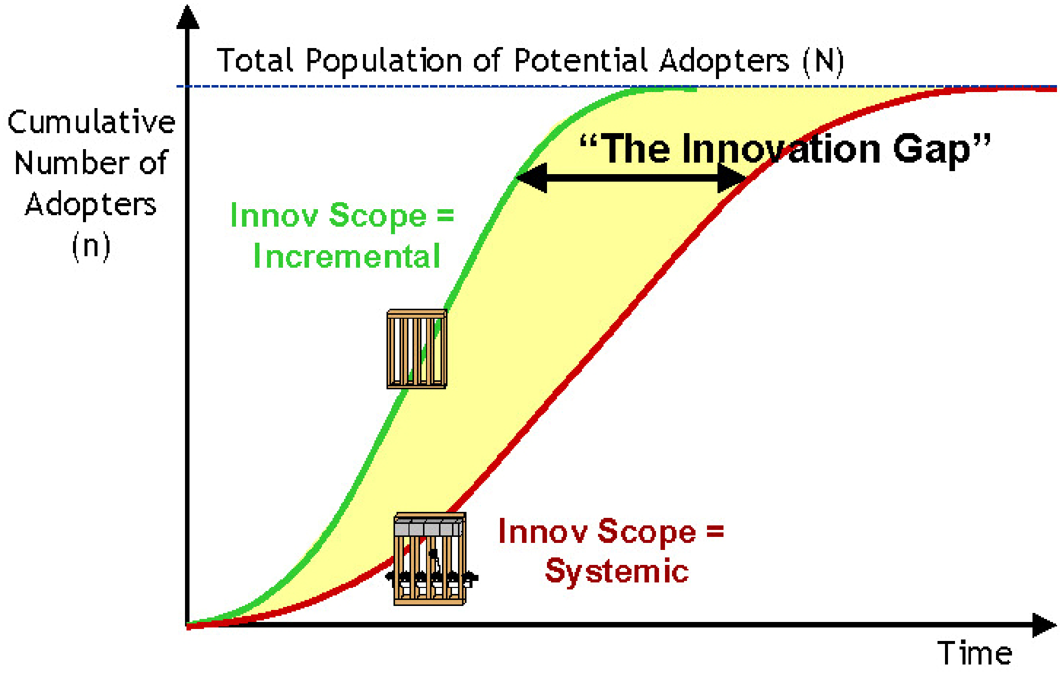

Figure 2-3: Adoption curves for incremental and systemic innovations (Taylor and Levitt 2004)

The Gompertz curve is analogous with normal distributions (Franses 1994). In statistical terms it approximates the cumulative distribution function for a normal distribution. As a result, the probability density function for a normal distribution, a bell curve, can be used to highlight some fundamental terms in innovation diffusion. This curve can be thought of in two ways: 1) as representing the rate of change in the number of potential adopters who have adopted an innovation at a point in time; and 2) the probability that a single adopter adopted the innovation at a particular point in time during the overall diffusion (e.g. early or late). The area under the curve represents the population of potential adopters, and so dividing this population, as in Figure 2-4, helps explain the various adopter categories.

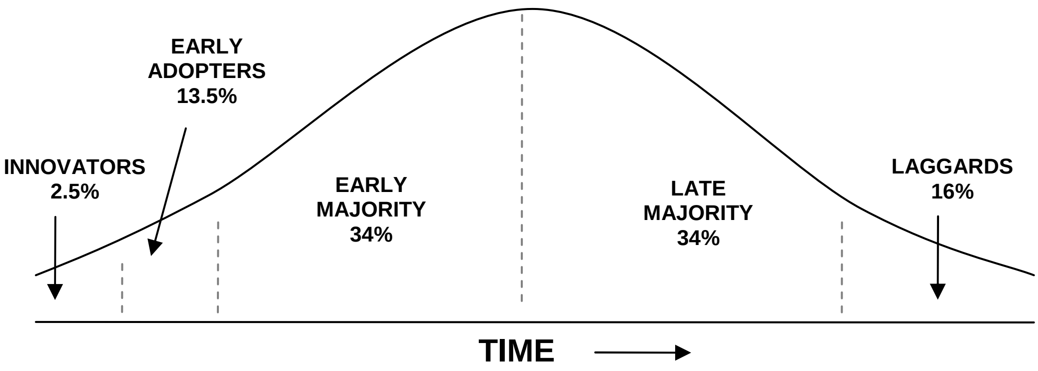

Figure 2-4: The categorisation of adopters over time (Dooley 2001)

The trends represented by the curves in Figure 2-3 and the adopter categories identified in Figure 2-4 can be illustrated by the diffusion rates of some common consumer products, as in Figure 2-5. The vertical scale is the percentage of the population in the USA who have adopted the innovation.

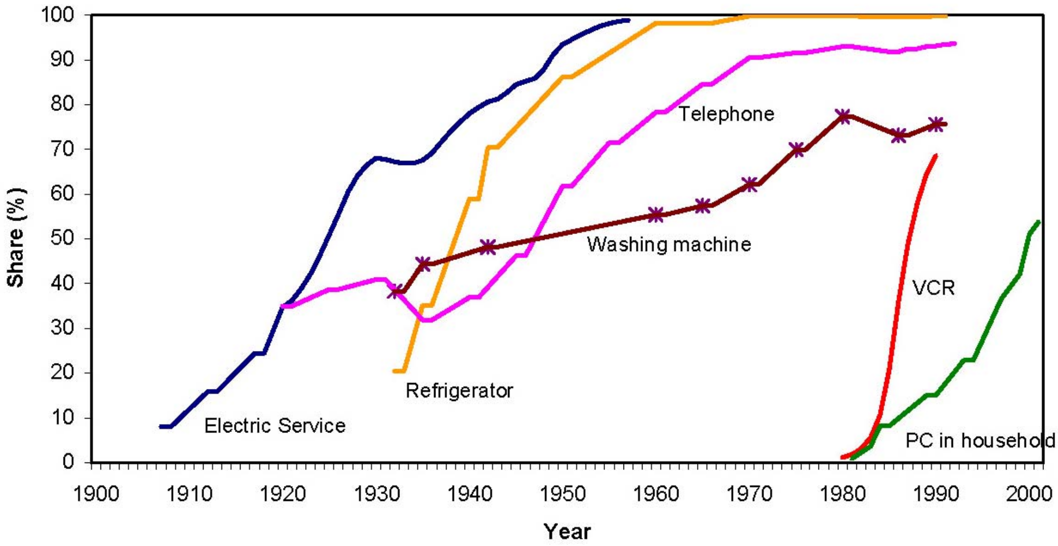

Figure 2-5: Diffusion rates in the US for selected consumer products (Hall and Khan 2003)

The curves that show the diffusion of the VCR (video cassette recorder) and PC (personal computer) exemplify some innovation diffusion principles and terminologies. The VCR was an incremental innovation as it was an add-on for the television, while the PC was a systemic innovation because it was a completely new system. Furthermore, adopters perceived the characteristics of the two innovations differently, and perhaps the most critical would have been the perception of how easy they were to use (i.e. ease of use). Interestingly, the 'innovation gap' is clearly apparent for the early and late majority of adopters along with the laggards, however there is no apparent gap for the innovators and early adopters. This could be because they did not perceive either to be more difficult to use as a result of personal motivations.

2.1.4 Terminology Confusion

There is some confusion in the literature about the terms adoption, implementation and diffusion (see 1.2.1 for definitions); and in some cases these three terms have been used interchangeably (Campbell 1996). While this can be helpful in a few instances, such as when referring to rates of diffusion and adoption, most if not all interchanges of the term implementation cloud its meaning. An example of this is a synthesis of previous research by Slaughter (2000) in which six stages for an innovation 'implementation' are proposed:

1. Identification – specification of objectives and alternatives

2. Evaluation – comparison of alternatives using benefit indicators such as design performance (project level) and competitive advantage (organisation level)

3. Commitment – allocation of resources and target users announced

4. Detailed Preparation – actually obtaining the resources and training personnel

5. Actual Use – decision makers and innovation competence sources that guide changes (i.e. technology champions) are crucial as is the necessity for on-site personnel to learn how to use the innovation

6. Post-use Evaluation – comparison of expectations with outcomes.

The stance in this thesis is that implementation is a finite period in the diffusion cycle (Rogers 2003) (see Figure 2-1) and that the stages above from Slaughter (2000) are only an altered representation of the stages for an innovation diffusion. The first three and final stages from Slaughter (2000) parallel the corresponding stages of the Rogers (2003) model (identification – knowledge; evaluation – persuasion; commitment – decision; and post-use evaluation – confirmation). Stages 4 and 5 identify two important aspects of an innovation implementation, however a much better description of this process is needed to fully understand it.

The field of implementation theory is where this knowledge is located (Linton 2002).

2.2 Implementation Theory

Both the macro and micro contexts of inquiry in this thesis lie within implementation theory (or the field of implementation research). Researchers in this field have identified decision-making levels, and works exist that categorise different implementation strategies. Implementation effectiveness has been modelled, and technology acceptance studies that consider the role of individual users have produced findings that give a number of factors affecting innovation implementation. By reviewing relevant literature, this section locates the macro and micro context of inquiry and introduces the more specific theoretical constructs that are synthesised as part of the P-I model this thesis develops.

As previously stated, implementations of the same innovation provide empirical data for analysis and it is important to note at this point that construction projects provide the data. Construction is a common example of PBE and project-based activity; this is explained as part of the chapter section that follows (2.3). Accordingly, studies in implementation research that refer directly to the construction industry are included in this section (2.2).

2.2.1 Decision-Making Levels

An extensive literature review by Stewart et al. (2004) identified three decision-making levels for the implementation of IT innovations in the Australian construction industry: 1) the industry level; 2) the organisation (or firm) level; and 3) the project level. Their findings also highlighted some barriers to innovation implementation that exist at each decision-making level, shown in Figure 2-6. With some variations in exact terminologies, these three levels have been widely used by researchers to help study innovation implementation in general, and in project-based engineering (PBE) in particular (e.g. Mitropoulos 2001; Bossink 2004; Peansupap and Walker 2005).

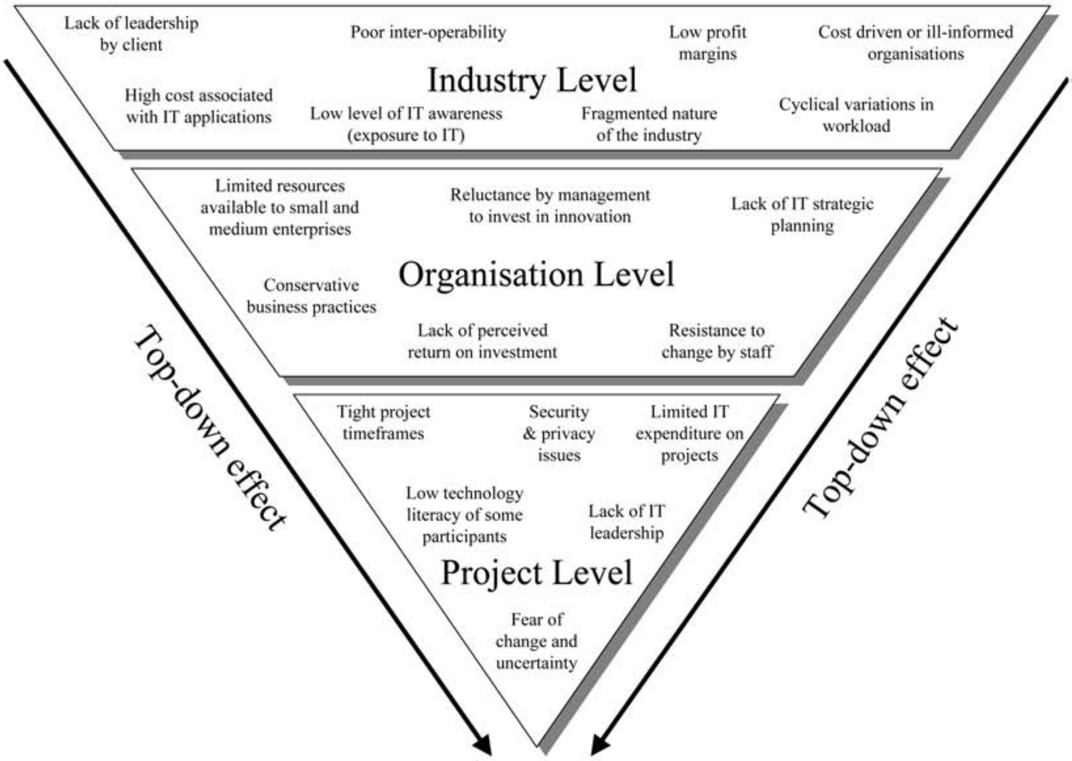

Figure 2-6: Implementation barriers at three decision-making levels (Stewart, Mohamed et al. 2004)

The top-down effect referred to by Stewart et al. (2004) is evident in how one barrier relates to the next across the three levels. For example, an industry with traditionally low profit margins will make the management of participating firms, at the organisational level, reluctant to invest in IT innovations, and in turn, the projects will limit their IT expenditure. In a similar fashion, decisions made at a higher level have the potential to avert barriers at the lower levels (Lucas 1978a). Organisational-level decisions that could avert innovation implementation barriers at a project level are of some interest to this research.

A fourth level of decision-making – the individual level – exists within project organisations (Linton 2002). It incorporates the targeted users of an innovation who are usually instructed by management to learn how to use the new innovation (Leonard-Barton and Deschamps 1988). The decision-making power of the individual targeted users can be limited when compared to managers and it is usually the ways they perceive the innovation's characteristics that affect the implementation (Jebeile and Reeve 2008). While these user perceptions, for example, satisfaction (Wixom and Todd 2005) and resistance (Beaudry and

Pinsonneault 2005), are more subtly influential than decisions made at higher levels, such as directives from project management, they are no less significant (Thompson and Higgins 1991). The individual decision-making level is pertinent to this thesis and can be explained further using the concept of the rate at which an innovation diffuses into a population of targeted adopters.

Decision levels and rates of innovation diffusion

The four decision-making levels (Linton 2002; Stewart, Mohamed et al. 2004) represent important perspectives for the rates of innovation adoption and diffusion. While these two terms are often used interchangeably, an adoption rate should refer mainly to an organisation, firm or project, and a diffusion rate to an industry or large social system. Generally speaking, the rate at which an innovation passes through Rogers's five stages of diffusion (refer Figure 2-1), when viewed from each of the four perspectives, is an order of magnitude different from each perspective. Because the construction industry is a large social system, its practices evolve slowly, thus it can take decades for an innovation to be taken up by the majority of firms. However, a single firm or organisation may take only a few years to implement the innovation as standard practice. A single project has a finite lifecycle and aims to draw benefits quickly, therefore the innovation implementation could feasibly last only a few months. From the perspective of an individual, depending on how complex the innovation is and is perceived to be, it is a matter of hours or days from the time they learn of its existence to when they can use it[2] (Yetton, Sharma et al. 1999; Gao and Fischer 2005; Taylor and Levitt 2005a). The magnitudes of the number of potential adopters also decrease in a similar fashion. This interpretation is diagrammatically shown by the four graphical scales of adoption rate in Figure 2-7.

[2] Case-based evidence in the literature includes the diffusion of a new truss system in the US building industry (Taylor and Levitt, 2005), an information system in the Australian health industry (Yetton, 1999), and 4D CAD in construction (Gao and Fischer, 2005).

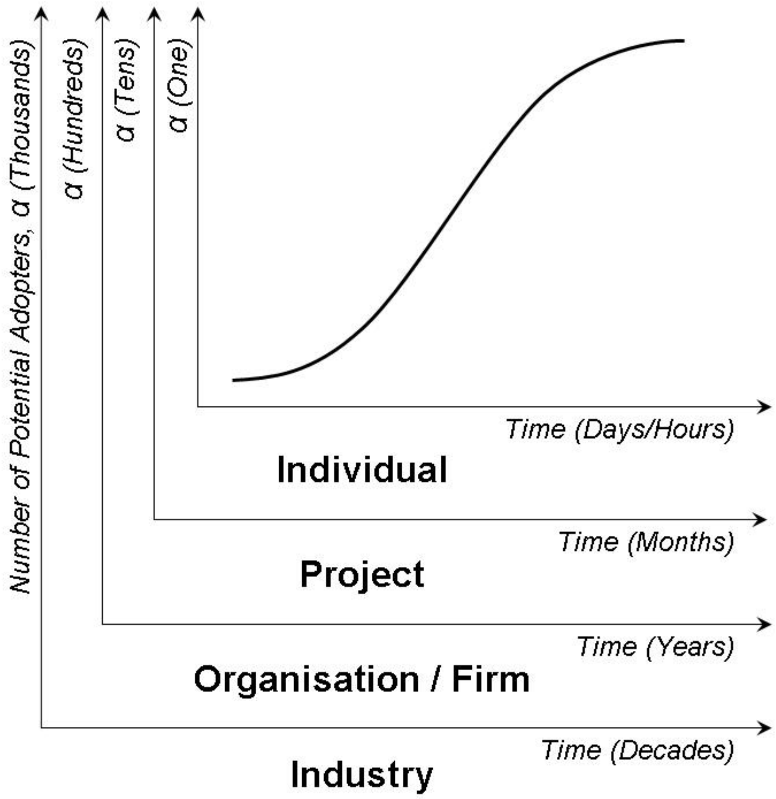

Figure 2-7: Scales of adoption rate from four perspectives

The analogy in Figure 2-7 defines the 'field of play' for research aiming to help improve innovation diffusion rates, particularly in project-based industries. Notionally, the diffusion curve for an individual represents the rate with which they pass through Rogers's five stages of diffusion while from the other perspectives it indicates the number of adopters over time. The need to improve such rates in PBE is real (Mitropoulos 2001; Taylor 2006). Because this thesis focuses on the actual implementation stage of an innovation's diffusion, it will help to know about the different approaches that firms and organisations assume in order to implement an innovation.

2.2.2 Implementation Styles

In contrast to decision-making levels, the different innovation implementation styles represent alternative perspectives. Where the implementation of an innovation that is a technology involves an actual deployment by one person or group to another person or group, three general implementation styles exist (Campbell 1996):

1) Technological Determinism;

2) Managerial Rationalism; and

3) Social Interactionism.

The rationale of technological determinism is that the advantages of a new technology will be so obvious to potential adopters they will readily embrace it. Because acquisition and utilisation are almost simultaneous, little strategic planning is required for implementation (Drury and Farhoomand 1999b).

Managerial rationalism takes a perspective that doesn’t totally ignore the human element. It assumes personal aspirations are synonymous with those of the organisation and that implementation is by a series of logical steps planned by management to achieve widespread acceptance (Campbell 1996).

Some industries reveal implementation to be a process of social interaction between the technology and a particular organisational context. From this perspective, a technology exists as, say, a piece of equipment, and its implementation is governed by the reactions of individuals with respect to understanding its role and value within the context of the organisation. In this type of circumstance, an implementation style of social interactionism is required. The social interactionist perspective arises from analyses of how organisations work in practice vis-à-vis how they ought to work. Central to this perspective is the view that innovations do not function independently of their environments, rather they gain meaning as individual users within an organisation interact with them (Campbell 1996). Table 2-1 summarises the three perspectives or implementation styles.

Table 2-1: Implementation styles or perspectives (Campbell 1996)

	Style of Implementation		
Assumption	**Technological Determinism**	**Managerial Rationalism**	**Social Interactionism**
Nature of technology	Machine and methods	Machine and methods	Machine, methods and knowledge
Nature of organisations	Machine	System	Culture
Style of implementation	Technical process	Guided by rational management strategy	Organisational process, which is problematic and uncertain
Constraints on implementation	Technical worth of the innovation	Poor management or technical worth of the innovation	Interaction between social and political processes
Likely outcome of implementation	Greater efficiency and more rational decision-making	Greater efficiency and/or more rational decision-making	Uncertain
Underlying philosophy	Instrumental rationality	Procedural rationality	Communicative rationality

A similar categorisation that helps to interpret the above implementation styles are the two different scenarios of ‘technology push’ and ‘user-pull’ (Von Hippel 1988; Drury and Farhoomand 1999b). In a user-pull scenario the main drivers of innovation implementation are the needs and desires of the users themselves (Von Hippel 1988). Technology-push implementations are centred on larger scale benefits to the project or firm therefore the drive is usually provided by management (Drury and Farhoomand 1999b). Of course, the characteristics of an innovation will play a significant role in determining which is the dominant motivation or driver, and hence the implementation style required. Table 2-1 shows some clear uncertainties for social interactionism therefore this style could conceivably be applicable in both scenarios. Managerial rationalism would seem to be most applicable to a technology-push scenario. For the case of technological determinism both the users and management would be in enthusiastic agreement as part of a user-pull scenario.

Management control is significant in a technology push where the style of social interactionism exhibits a considerably smaller amount compared with the other two styles. For managerial rationalism and technological determinism, the benefits are clearly apparent and/or management can decree that the new innovation will be used[3]. Because industries such as aerospace manufacture and product development can exercise such control, companies like Boeing and 3M have traditionally implemented innovations effectively (e.g. McNerney 2007). For reasons made apparent in section 2.3, a project-based firm has a lot less control and little choice but to approach innovation implementation from the perspective of social interactionism. If an implementation is to be successful however, one must first understand what an effective innovation implementation is.

2.2.3 Effective Innovation Implementation

A range of definitions of what an effective innovation implementation is have been identified by previous research. Perhaps the most widely cited definition of implementation effectiveness is that postulated by Klein and Sorra (1996): 'the consistency and quality of targeted organisational members' use of an innovation'. A more simplistic view of implementation effectiveness was taken by Fleck (1994): that successful implementation requires generic technology knowledge and local practical knowledge. Slaughter (2000) noted the importance of committed resources and understanding the nature of the involved activities to achieve an effective implementation of an innovation in construction, while research in manufacturing had shown technical performance to be the sine qua non of implementation effectiveness (Dean, Susman et al. 1990).

The key indicator used by this thesis to determine if an effective implementation is achieved (or not) is the existence (or otherwise) of 'productive use' of the innovation being implemented by one or more of the targeted adopters. Productive use is taken to be the actual use (Slaughter 2000) of an innovation leading to the realisation of one or more intended benefits of the innovation. This key indicator is consistent with Klein and Sorra's (1996) definition of implementation effectiveness.

[3] A good example of an innovation that was technologically deterministic is the VCR as shown by a steep 'S' curve in Figure 2-5 above.

Studies have applied both explicit and categories innovation implementation factors. These theoretical constructs have included ‘antecedents’, ‘success factors’ and ‘measures’ of innovation implementation effectiveness. Many crossovers and similarities between them exist, but the diversity also makes for some confusion (Kim and Malhotra 2005). In order to help express the existence of such intricacies in terms of the theoretical constructs found by previous implementation research, Figure 2-8 below presents an explanatory interpretation.

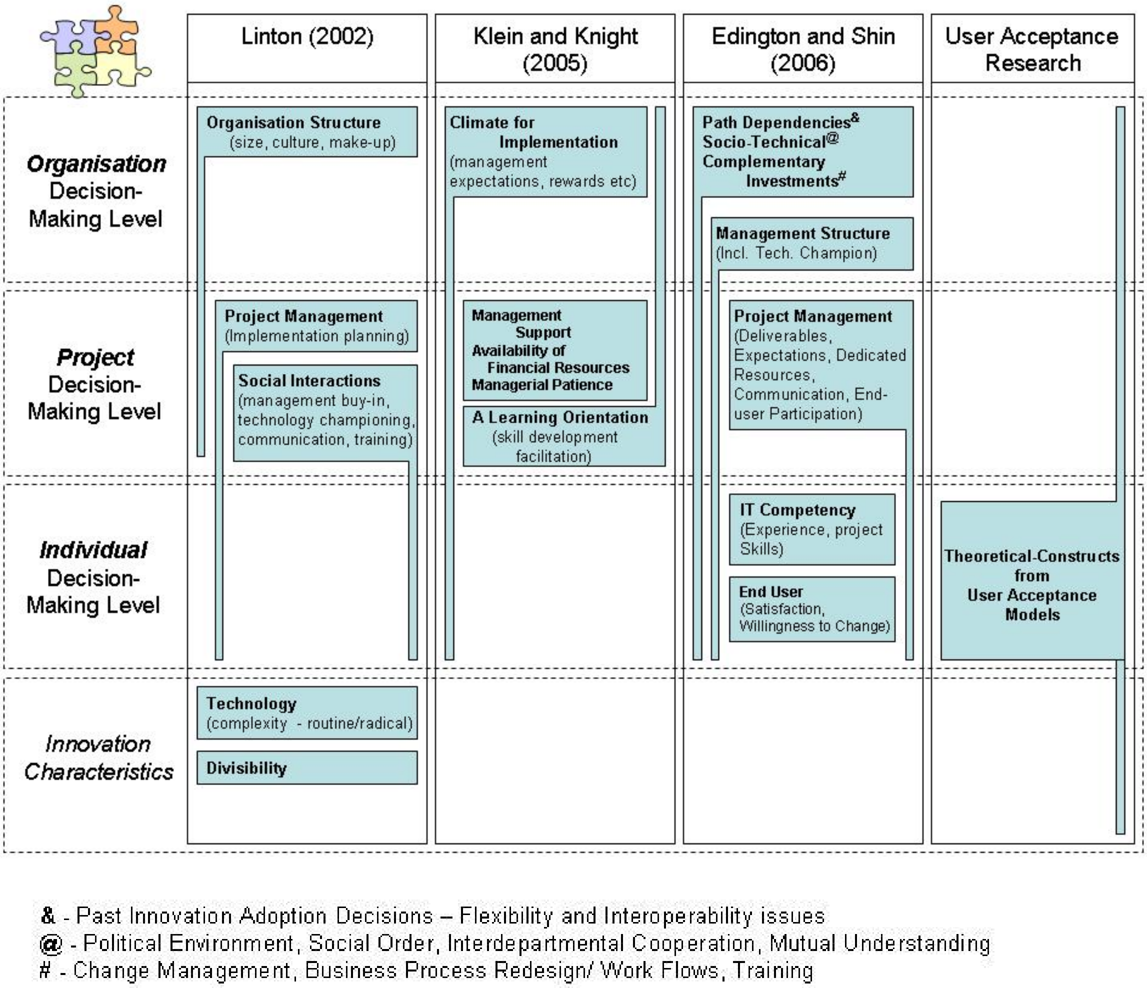

Figure 2-8: Cross-section of theoretical constructs from Innovation Implementation Research

Figure 2-8 shows a cross-section of factors associated with implementation effectiveness interpreted using the decision-making levels of relevance for each construct. The three referenced studies exemplify research efforts that have identified and applied frameworks of theoretical constructs in implementation research. Without considering the details of each particular implementation factor, the shapes representing each indicate the research perspectives assumed. That is in terms of the originating and relevant decision-making levels. It is apparent that the research perspective has most often been at levels above the individual level. When the specifics of the different constructs are considered, an imbalance is apparent between the explicit nature of those used by Linton (2002) and Klein and Knight (2005) and the more category-like constructs from Edington and Shin (2006). However the attention to the individual decision-making level in an innovation implementation by Edington and Shin (2006) and the notion they provide of its high importance is a significant statement in implementation theory. This thesis ultimately assumes a perspective that explores the factors that influence the effectiveness of an implementation at the individual level. Therefore the far right column in Figure 2-8 represents an important faction of implementation research that focuses on factors associated with implementation effectiveness originating from and existing at the individual decision-making level. Several user acceptance models have been postulated as part of this area of research, located here but presented in the following section of this chapter.

A common misconception is the confusion of innovation effectiveness and implementation effectiveness. Innovation effectiveness relates to noticeable benefits brought to an organisation as a result of using a new innovation (Klein and Sorra 1996). Klein and Knight (2005) have shown that in the absence of implementation effectiveness, the benefits of adopting the innovation in question are likely to be nil, however an effective implementation does not guarantee that the innovation will prove beneficial for the organisation (Dulaimi, Ling et al. 2003). This separation is made clear by the model of factors contributing to implementation effectiveness, postulated by Klein and Sorra (1996) and shown here by Figure 2-9.

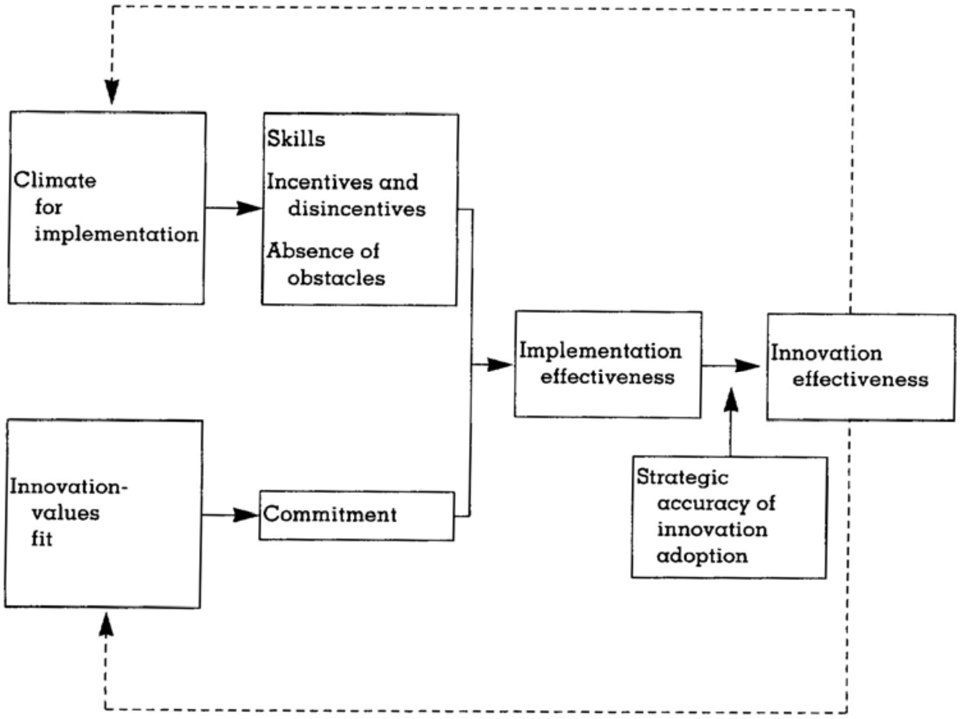

Figure 2-9: Implementation effectiveness determinants (Klein and Sorra 1996)

The model highlights two factors or theoretical constructs that influence implementation effectiveness: climate for implementation and innovation-values fit. A firm's 'climate for implementation' (Figure 2-9) refers to the extent to which targeted users are expected to use, and are rewarded or supported for the use of a new innovation. The 'innovation-values fit' (Figure 2-9) is the extent to which targeted users perceive that the use of the innovation will foster the fulfilment of their values (i.e. assist and fit with existing workflows) (Klein and Sorra 1996). These first two theoretical constructs in Klein and Sorra's model are at the macro context of this thesis. The four factors that lead into implementation effectiveness in Figure 2-9 are also good examples of the intricate factors that can influence implementation effectiveness – they are at the micro context of this thesis. By exploring this part of the implementation climate in PBE and the different concerns or perceptions project-participants have, such as innovation-values fit, this thesis seeks to further the work of Klein and Sorra (1996). The significance of this objective and the individual decision-making level as an influential aspect of innovation implementation is captured by Drury and Farhoomand (1999a):

The expected success of an innovation as perceived by the decision maker, i.e., his [or her] favourable attitude towards the outcomes of the innovation, *depends on among other things, his perceptions of the outcomes of the innovation itself.*

2.2.4 The Individual Decision-making Level

The individual decision-making level is a core element in the diffusion of an innovation (Peansupap and Walker 2005b), therefore individual-level processes are critical for implementation effectiveness (Yetton, Sharma et al. 1999; Choi 2000). The main factors affecting an innovation implementation that originate from this perspective stem from the perceptions formed by the potential adopters[4] about the innovation's characteristics (Agarwal and Prasad 1997). However, research addressing innovation implementation is reported to have largely neglected the individual level (Karahanna, Straub et al. 1999; Choi 2000). The need to further the understanding of the implementation factors therein as well as integrate previous findings has been noted (Drury and Farhoomand 1999a; Beaudry and Pinsonneault 2005).

The differences between adopters at the individual level (e.g. age, sex) are outside the scope of work in this thesis. Some studies have investigated the differences between individuals and suggested ways in which they affect innovation implementation (Agarwal and Prasad 1999; Yuandong, Zhan et al. 2005). However, these factors are most relevant to implementations of pervasive innovations where there are many target adopters in the one organisation. In these studies, data have come from user surveys en masse and have been statistically analysed which further separates them from this research (see also 3.1).

The interpretation shown by Figure 2-10 locates the individual decision-making level in terms of Rogers's innovation diffusion theory and with respect to the three other perspectives. It shows the context-timescale interpretation from Figure 2-7 for the scenario of an innovation undergoing implementation by a project-based firm that is an early adopter.

[4] For simplicity, thesis assumes users to be part of a general population of potential adopters. This is a generalisation from the view taken by Karahanna et al. (1999) as they refer to users as being separate from adopters.

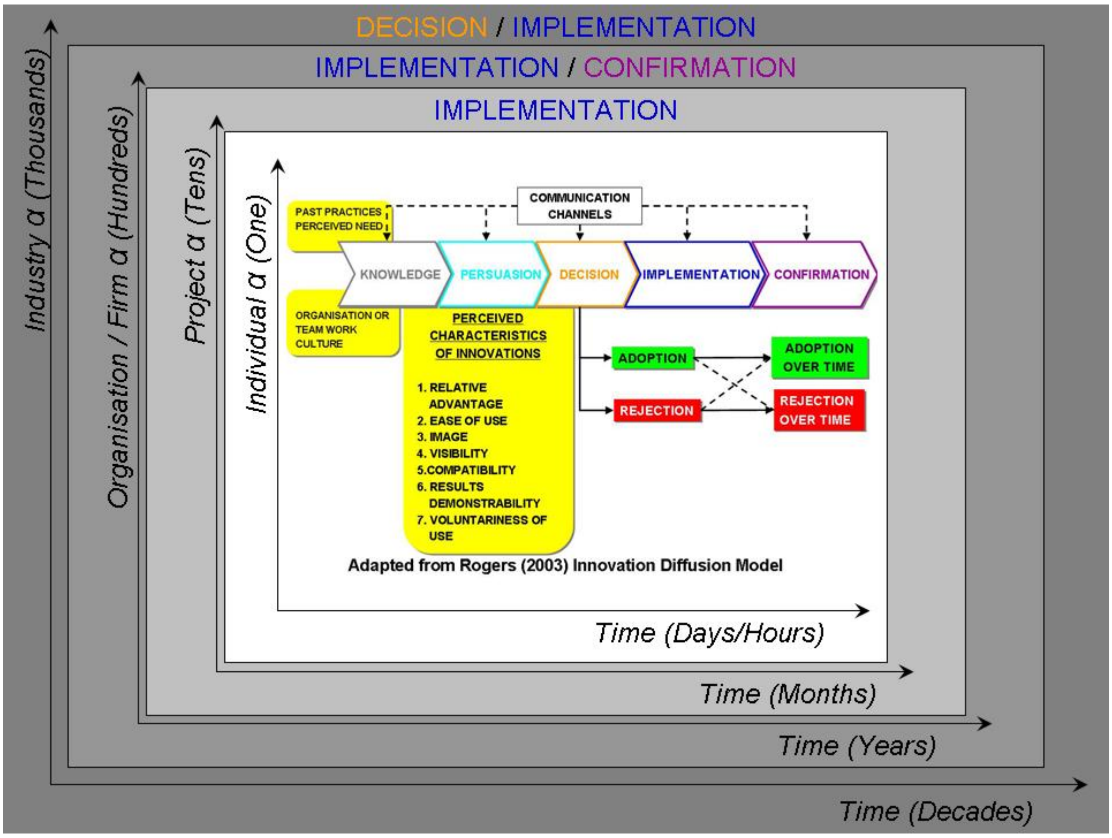

Figure 2-10: The individual decision-making level of an innovation implementation by a PBE firm

The gradual narrowing down of the focus illustrates an important objective of this research – the exploration of implementation factors at the project and individual levels in an innovation implementation. The diffusion stage from the perspective of the firm implementing the innovation is more advanced than from the project's perspective because any form of uptake at a project level constitutes an implementation. This fact alone tends to indicate the innovation will be used by the firm, even if only to a small extent. The industry perspective is lagging because the model shows the firm to be an early adopter of the innovation which means few other firms would have adopted it yet. It also shows how the perceived characteristics are important in the early stages of diffusion from the perspective of a project-participant. When the individual level has been the focus of previous studies, factors affecting innovation implementation have been grouped into user acceptance models (Venkatesh, Morris et al. 2003).

2.2.5 User Acceptance Models

User acceptance research has yielded many different models, some more prominent than others. Each model, however, has a set of acceptance determinants that are theoretical constructs with crossovers between them in terms of terminologies and rationales (Davis 1989; Agarwal and Prasad 1997; Lucas and Spitler 2000). A consistent theme aligned with the aims of this research is the objective of understanding adopter reactions, opinions, attitudes, beliefs and concerns regarding a new innovation or technology[5]. These models provide the grounding theoretical constructs for the model developed in this research. The prominent user acceptance models in the literature (Venkatesh, Morris et al. 2003) are introduced in this section so that the constructs that comprise them can be referred to in more detail by the following thesis chapters.

Theory of Reasoned Action (TRA)

The theory of reasoned action, drawn from social psychology, is regarded as one of the most fundamental and influential theories of human behaviour. It has been used in many different cases to predict a range of behaviours (Venkatesh, Morris et al. 2003). TRA has two central elements or core constructs: 1) the individual's *attitude towards behaviour* (i.e. their positive or negative feelings about performing a target behaviour); and 2) *subjective norm* which is the person's perception that most people important to them think they should or should not perform the behaviour in question (Fishbein and Ajzen 1975).

Technology Acceptance Model (TAM)

The technology acceptance model, which stems from an information systems research context, was designed to help predict on-the-job information technology acceptance. It has been widely used, and in some cases adapted, across a diverse range of both technologies and users (Venkatesh, Morris et al. 2003). *Perceived usefulness* and *perceived ease of use* were named by Davis (1989) as the two core constructs of the TAM as a result of a conceptualisation that excluded the *attitude towards behaviour* construct from TRA in order to focus more on user

[5] Is an innovation a technology? A technology is an innovation but strictly speaking an innovation can be as little as a new idea and therefore not a technology (Dooley 2001). Some research has used the term 'technological innovation' in referring to an innovation that is also a technology (e.g. Leonard-Barton 1985). This thesis uses one single technology as an example of an innovation for collecting empirical data and seeks to generalise results in implementation theory.

intention. Davis (1989) defines perceived usefulness as ‘the degree to which a person believes that using a particular system will enhance his or her job performance’, and perceived ease of use as ‘the degree to which a person believes that using a particular system will be free of effort’. The TAM was refined to produce the TAM2 by Venkatesh and Davis (2000) by the inclusion of the subjective norm construct, adapted from the TRA and theory of planned behaviour. An augmented version of the TAM was used and assessed by Taylor and Todd (1995) with the main difference the inclusion of *behavioural intention* as a parent construct but only a small variation of the *attitude towards behaviour* construct from the TRA.

Theory of Planned Behaviour (TPB)

The theory of planned behaviour is an extension of the TRA. It includes *perceived behavioural control* as a third core construct. Perceived behavioural control is the belief that a person has the ability and suitable resources or conditions to facilitate a particular behaviour (Ajzen 1991). This construct was defined in the context of information systems research by Taylor and Todd (1995) as ‘perceptions of internal and external constraints on behaviour’. In this thesis, the behaviour of upmost importance is the use of a new innovation.

Motivational Model (MM)

The motivational model, another theory used for behavioural explanation, comes from psychology research performed across a range of contexts. It has been applied to the adoption and use of new technology (Davis, Bagozzi et al. 1992) and is built on the two core constructs of *extrinsic motivation* (i.e. user perceptions of valued outcomes from an activity distinct from the activity, for example, promotion) and *intrinsic motivation* (i.e. the user will want to perform an activity simply to complete it or because it is enjoyable).

The *motivation* of individual targeted adopters for using a proposed innovation was qualitatively investigated by Griffith (1996) in more general terms and found to be an important factor with respect to implementation effectiveness.

Model of Personal Computer Utilisation (MPCU)

The model of personal computer (PC) utilisation exists as a competing perspective to that of the TRA and TPB. Largely derived from human behaviour theory, its initial function was to predict PC utilisation alone, however its core constructs make it useful across a range of information technologies for acceptance behaviour prediction (Venkatesh, Morris et al. 2003). The core constructs for MPCU and brief definitions of each are:

Job-fit – 'the extent to which an individual believes that using a technology can enhance the performance of his or her job' (Thompson and Higgins 1991)

Complexity – 'the degree to which an innovation is perceived as relatively difficult to understand and use' (Thompson and Higgins 1991)

Long-term consequences – 'outcomes that have a payoff in the future' (Thompson and Higgins 1991)

Affect [towards use] – 'feelings of joy, elation, or pleasure, or depression, disgust, displeasure or hate associated by an individual with a particular act' (Thompson and Higgins 1991)

Social factors – 'the individual's internalisation of the reference group's subjective culture and specific interpersonal agreements that the individual has made with others' (Thompson and Higgins 1991)

Facilitating conditions – 'objective factors in the environment that make an act easy to accomplish' (Thompson and Higgins 1991).

Social Cognitive Theory (SCT)

Social cognitive theory is one of the most powerful theories of human behaviour (Bandura 1986). It has been applied in the context of computer utilisation by Compeau and Higgins (1995) who produced a model with an underlying theory that enabled it to be extended to the acceptance of information technology in general. The core constructs of the model and brief definition of each are:

Performance outcome expectations – expectations about behavioural consequences relating to performance and dealing specifically with job-related outcomes

Personal outcome expectations – expectations about behavioural consequences relating to the individual's esteem and sense of accomplishment

Self-efficacy – Judgment of one's ability to use a technology to accomplish a particular job or task

Affect – an individual's liking for a particular behaviour

Anxiety – anxious or emotional reactions evoked when it comes to performing a particular behaviour.

Unified Theory of Acceptance and Use of Technology

The unified theory of acceptance and use of technology (UTAUT) is, as the name suggests, a theoretical model made up of constructs from the prominent models in user acceptance research and one that attempts to unite them (Venkatesh, Morris et al. 2003). The authors assert four constructs as the direct determinants of a user's intention to perform the behaviour of using a new technology: 1) *Performance expectancy*; 2) *Effort expectancy*; 3) *Social influence*; and 4) *Facilitating conditions*. Each is proposed to represent and combine a number of similar root constructs from the other prominent user acceptance models. Venkatesh et al. (2003) developed this model from a statistical analysis of questionnaire data that also suggests which of the constructs from the other user acceptance models are not direct determinants of intention.

Innovation Diffusion Theory (IDT)

While IDT describes the lifecycle of an innovation's diffusion into a social system (Rogers 2003), the scope of it incorporates enough detail (such as the perceived characteristics of an innovation) for it to be classed as a technology acceptance model in the literature. This research makes light of the finer principles of IDT (presented in section 2.1) as well as the broad categorisation it presents. Conversely, it is mainly the finer details of the other user acceptance models, in terms of the theoretical constructs therein, that are considered by this thesis during the exploration of innovation implementation in project-based engineering (PBE) undertaken.

2.3 Project-Based Engineering

The industry environment that project-based engineering firms must operate within is complex (Bresnen, Goussevskaia et al. 2004). Understandably, it is difficult to implement an innovation in this circumstance (Goussevskaia, Scarbrough et al. 2006). *Project-based activity* is the term given to the way participating firms and project organisations (POs) operate (Alderman 2004). The PBE industry environment and the dilemma faced by participating firms attempting to implement innovations are summed up by Youker (1975):

> *The functional, hierarchical organisation* [i.e. the project-based firm] *is organised around technical inputs, such as engineering and marketing. The project organisation is a single-purpose structure organised around project outputs, such as a new dam or a new product. Both of these are one-dimensional structures in a multidimensional world* [or industry]. *The problem in each is to get a proper balance between the long-term objective of functional departments in building technical expertise and other short-term objectives of the project* [organisation].

This problem of balance resulting from the tension between different objectives has led to a reputation for project-based activity being slow to embrace new innovations (Davis and Songer 2002). Despite this inherent resistance to innovative behaviour in project-based industries, the participating firms and project organisations must implement new technologies and innovations to be competitive (Slaughter 1998; Johnson 2001). Implementation research to date has focused on the project-based firm alone rather than on the individual POs. Where the global form of a project-based industry has been considered, the implications of the structure have rarely been explored (Taylor and Levitt 2005a).

This thesis uses the term project-based engineering (PBE) in referring to those industries and firms specialising in engineering design and construct (D&C) projects. Although little reference is made to this particular term in the literature, PBE firms and industries are those that exhibit the traits of *project-based activity* – the term commonly used to describe the way projects are carried out by the various project-based industries (Archibald 1992) in an operational sense. Therefore the construction industry is described as an illustrative example of a PBE industry in this section and those aspects relevant to innovation implementation are highlighted.

2.3.1 Project-Based Activity

A project organisation (PO) is more complex than a functional organisation (FO) as it involves extensive inter-firm interaction (Archibald 1992). The day-to-day operations of FOs are mainly concerned with intra-firm interactions which can be explained by theories on structure, motivation, communication etc (Edwards and Bowen 2005). A PO, however, involves intra- and inter-firm interactions (Edwards and Bowen 2005) which is perhaps the most prominent characteristic of project-based activity. In a project-based industry, a project is delivered by multiple firms, existing as FOs, joining to form the PO that will complete the project (Alderman 2004). For example, in construction, POs often exist as strategic alliances, consortiums and joint ventures[6] (Cushman and Myers 1999). The PO is temporary and lasts for the duration of the project only (Dulaimi, Ling et al. 2003) thus it is unique, with a defined lifecycle from a start point to an end point (Archibald 1992). On the other hand, the autonomous project-based firms (i.e. the FOs) that have combined to form the PO have long-term interests and expectations leading to the tension outlined by Youker (1975). Table 2-2 shows the fundamental differences between the project-based activity associated with POs and the functional activity associated with FOs.

[6] The main things that separate the different forms of project organisations in the construction industry are the ways in which they share risk and profits (Cushman and Myers 1999) but they have no bearing on the process of innovation implementation, thus are outside the scope of this research.

Table 2-2: Differences in project-based and functional activity (Archibald 1992)

Project Activity (in a PO)	Functional Activity (in a FO)
Specific lifecycle: conception; design; construction; test; commission	Continuous life from year to year
Definite start and completion points, with calendar dates	No specific characteristics tied to calendar dates, other than fiscal year budgets
Subject to abrupt termination if goals cannot be achieved; always terminated when project is completed	Continued existence of the function usually assured, even in major reorganisation
Often unique, not done before	Usually performing well-known function and tasks only slightly different from previous efforts
Total effort must be completed within fixed budget and schedule	Maximum work is performed within annual budget ceiling
Prediction of ultimate time and cost is difficult	Prediction of annual expenditures relatively simple
Involves many skills and disciplines located in many organisations which may change from one lifecycle phase to the next	Involves one or a few closely related skills and disciplines within one well-defined and stable organisation
Rate and type of expenditures constantly changing	Relatively constant rate and type of expenditure
Basically dynamic in nature	Basically steady-state in nature

In addition to activity-oriented differences between POs and FOs, some trends in project management principles and practices have been identified as another barrier to innovation implementation.

Project management and innovation implementation

Project management practices in POs are traditionally unsupportive of innovation implementations (Keegan and Turner 2002). A likely cause is an overemphasis on planning and control systems in preference to innovation management (Grex 2004). Both of these views are supported by a recently published and popular textbook on project management by Dobie (2007). The index to his handbook of project management has no entry for ‘innovation’ and the diagram he uses (Figure

2-11) to indicate the important efforts across a project's lifecycle refers to only two effort categories – planning and control.

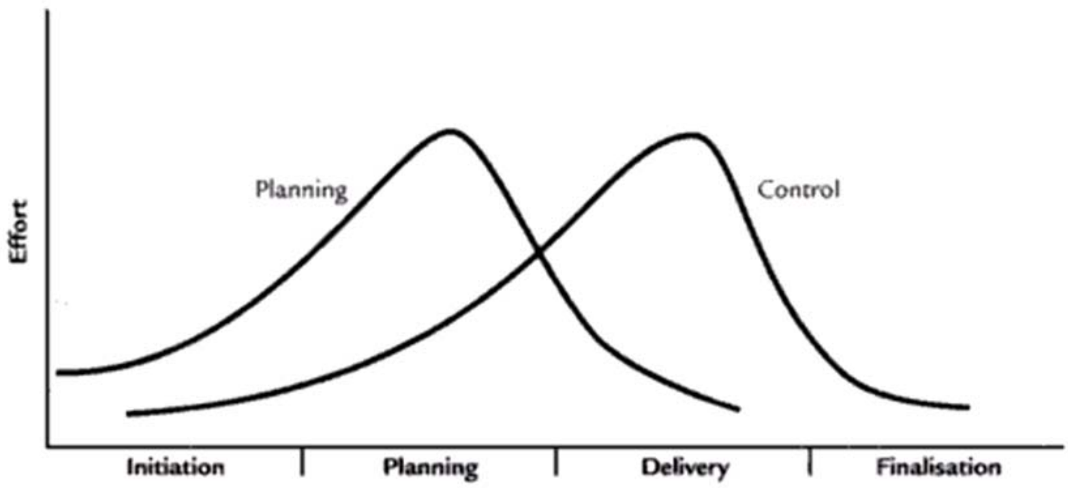

Figure 2-11: Effort elements in project management (Dobie 2007)

The diagram in Figure 2-11 shows the focus on short-term project objectives that to date has served to stifle innovation implementation in project-based industries (Keegan and Turner 2002). Projects are initiated, planned, delivered and finalised over and over by POs that prioritise efficient management as they pass through these four phases (Keegan and Turner 2002). Although the use of slack resources is a very useful catalyst for innovation implementation, project management rarely tolerate it (Linton 2002). This attitude can result in the inability of POs to sustain innovative behaviour (Grex 2004). Poor commitment to innovation implementation by project management is another reason for the existence of an innovation gap in project-based industries (Walker 2002; Dulaimi, Ling et al. 2003).

Understanding the reasons for the innovation shortfalls of PBE industries is a significant motivation for this thesis. If these reasons as well as the implementation factors can begin to be understood by the technology champions implementing new technologies, ways to help improve adoption and implementation rates may be conceived. Zabelle of Strategic Project Solutions[7] (Fischer and Zabelle 2008) suggests the following six reasons for ineffective implementation of innovations by project-based firms:

[7] Strategic Project Solutions (SPS) is a global network of consultants providing products and services for effective project delivery. www.strategicprojectsolutions.com

1. **Lack of top level support from senior management**
2. **Vague success criteria**
3. **Unrealistic expectations from management**
4. **'Forced' adoption of the new system**
5. **Overlooking cultural and human factors**
6. **Inadequate resources and training.**

Generally speaking, the uncertainties and constraints of project-based activity make innovation implementations difficult for project-based firms participating in engineering POs. The need to improve the rate of innovation adoption by these PBE firms in order to improve the diffusion rates into the associated industries has been established (e.g. Mitropoulos and Tatum 1999; Taylor 2006). A better understanding of the way innovation implementations are carried out in PBE will help to address this need.

2.3.2 Innovation Implementation in PBE

The implementation style a PBE firm must use in order to get an innovation taken up by a PO that it is part of is largely one of social interactionism (see section 2.2.2). A PBE firm that has adopted a new technology (or innovation) must first gain support for it from the management team and potential users at a PO. This involves marketing the benefits and functionality of the innovation to raise awareness and knowledge among all potential adopters (Larsen 2005). There is often little opportunity for assuming any managerial rationalism in this process (i.e. steadfast directives and logical planning) due to the fact the project-participants, usually project managers, can decide not to implement the proposed innovation (Harkola 1995). Understanding the reasons why project managers decide not to implement an innovation after having gained sufficient awareness and knowledge of it is of significant interest to this research.

If a commitment to implement a new innovation is made by the PO management, the implementing PBE firm must pass the required operating skills and know-how on to those individuals with the responsibility of being the end users (Bossink 2004). This is the functional process of innovation implementation in PBE. The people from the implementing firm are referred to as *technology champions* (Nam and Tatum 1995). They liaise throughout the implementation with the project-participants, that is, the management of the PO and those project staff who will be the end users (Harkola 1995). Liaising with potential adopters involves training them, therefore technology champions have a pivotal role in the implementation process and their performance is critical to implementation effectiveness (Maidique 1980). They must coordinate their own social interactions as well as those of the project-participants in carrying out their planned *implementation strategy*. What causes an innovation implementation by a PBE firm to fail once the management from a PO has committed to it is another exploration theme in this research. Figure 2-12 shows the relationships between the general stakeholder categories in an innovation implementation by a PBE firm.

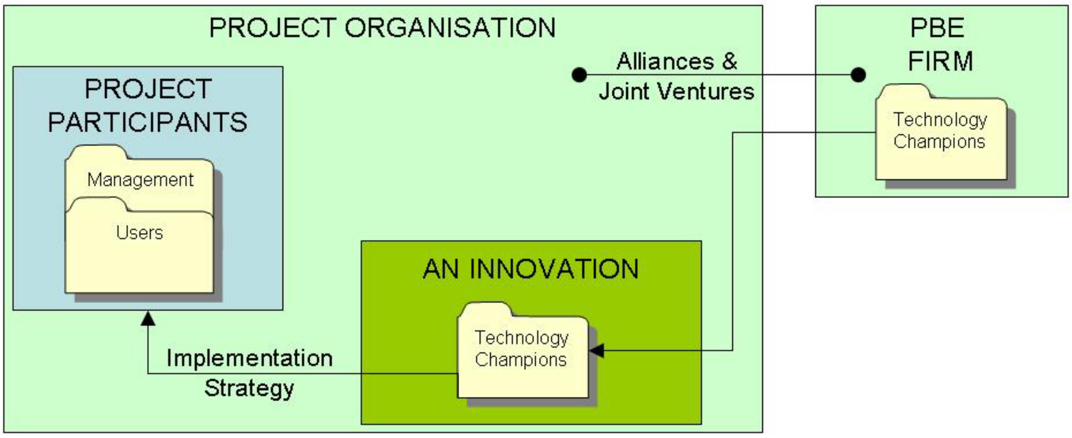

Figure 2-12: Stakeholders in an innovation implementation by a PBE firm

Figure 2-12 shows the macro context of inquiry for this thesis. This context is investigated by studying multiple instances of innovation implementation in the construction industry.

Construction – a typical PBE activity

Project organisations assembled to deliver major construction projects provide typical examples of project-based activity and the implementation environments described above (Ho and Liu 2003; Ling 2003; Miozzo and Dewick 2004; Larsen and Ballal 2005). They are comprised of individuals working for different firms brought together by the project – often for the first and last time. They are most fluid in terms of people and diversity of firms that come and go, project by project (Cornick and Mather 1999). Accordingly, the construction industry is reliant on inter-firm coordination of the various PBE firms, and innovation implementation is characteristically rendered most difficult (Dulaimi, Ling et al. 2003). Moreover, PBE firms participating in construction POs face most if not all innovation challenges described in this chapter. Therefore the construction industry provides a suitable empirical situation for investigating innovation implementation in PBE.

The delivery system that a construction PO is participating in is important and has close links with the phased construction lifecycle of the project. From the client's (or owner's) perspective there are a number of different delivery systems that can be employed. Each of these are categorised by the different phases they are comprised of and by the contracts the client or owner enters into with the construction PO and any other organisations that are involved, for example, separate design firms or an independent construction manager (Bennett 2003). From the construction PO perspective however, there are only two types of delivery system: 1) Design-Tender-Build, and 2) Design-Build (or Design and Construct, D&C) (Kymmell 2008). Figure 2-13 shows a phased-timeline comparison of these two delivery systems.

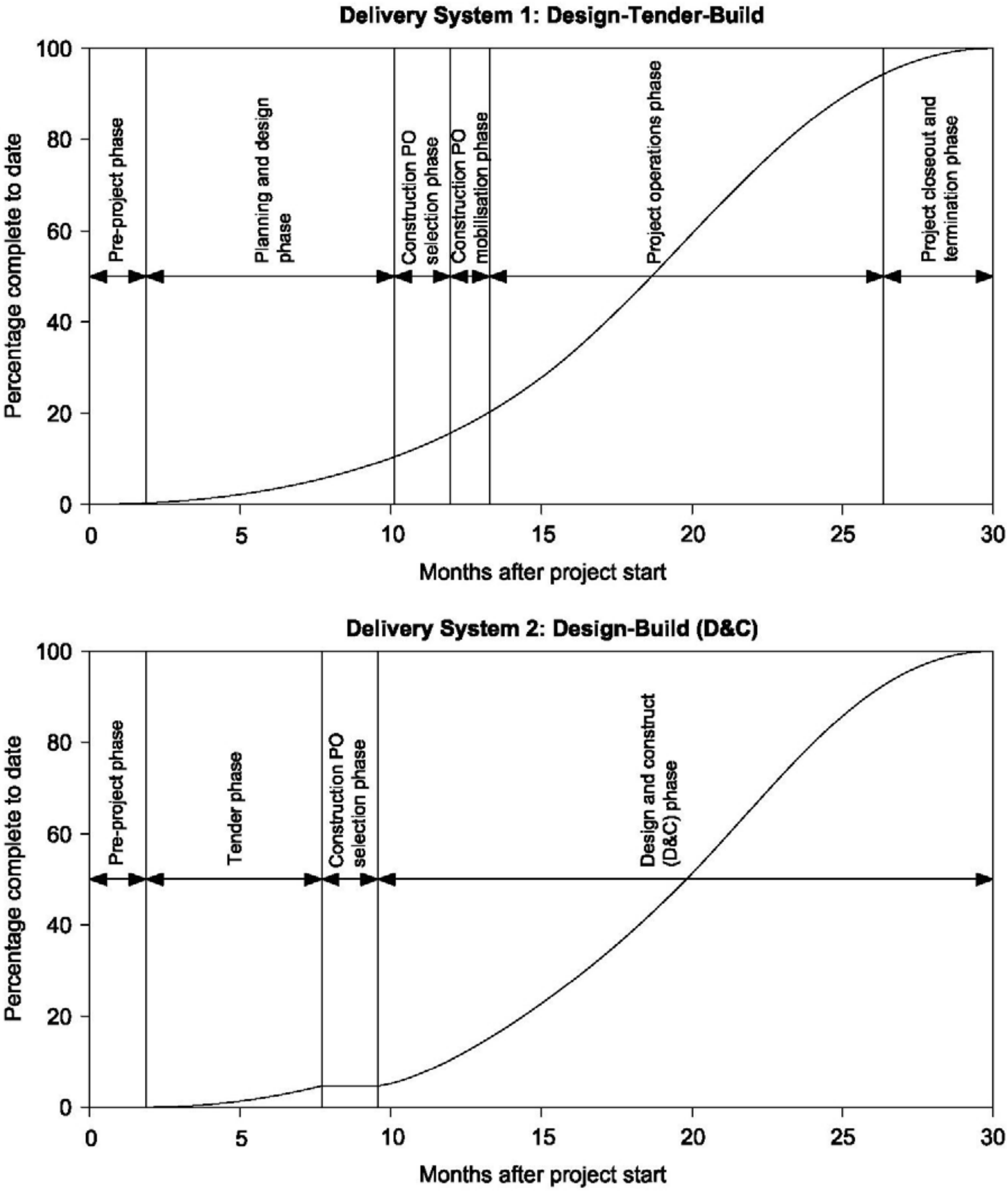

Figure 2-13: Design-Tender-Build and Design-Build (D&C) delivery systems (adapted from Bennett 2003)

The main difference between delivery systems 1 and 2 for the construction PO is their liability for the design of the project. For the more traditional delivery system of Design-Tender-Build, the construction PO tenders to construct a design that is set (Fewings 2005). In a D&C delivery system, the construction PO is liable for the design of the project as well as the construction of it (Bennett 2003). Delivery system 1 in Figure 2-13 is most common in European construction industries whereas major infrastructure projects in the Australian construction industry (such as those contributing data to this thesis) are delivered using delivery system 2 (ABS 2005).

Procurement Systems

The organisational structure a PO uses to deliver a project to a client is called the building procurement system (Masterman 1992). In the Australian construction industry the two most common types of procurement system are an Alliance and a Joint Venture (JV) (Walker and Rowlinson 2008). There are differences between the two relating to the way the project risk is shared and the way in which the participating firms are remunerated (Masterman 1992), however this scope of this thesis requires only the relational differences to be noted. In an Alliance-type PO, exchanges between participating firms are more collaborative that in a JV PO. Put another way – in a JV type PO, exchanges between participating firms are more transactional than in an Alliance type PO. Nevertheless, both types of PO experience similar innovation challenges (Walker, Hampson et al. 2002) therefore in the context of this thesis the type of procurement system is used only to help classify each of the seven different PO's contributing data[8].

The data analysed in this research was collected by a researcher who was immersed in several Australian construction industry POs, each implementing the same innovation. These organisations were formed to deliver major construction projects (see section 3.2 for project specific details). The broad significance of this is the fact that the data provide multiple examples of the same process, innovation implementation in PBE, and they are explored by an analysis that addresses some of the needs and knowledge gaps in implementation theory.

2.4 The Knowledge Gaps

Implementation research has been criticised as having significant difficulties in its execution (Linton 2002) and failing to produce generalisable theory (Wolfe 1994;

[8] A continuing Alliance (i.e. one that delivers more than one project) can foster improved innovation implementation (Walker and Rowlinson 2008) however no two of the seven PO's contributing data to this thesis are the same and the focus is on the individual level decisions as they happen during an innovation implementation.

Klein and Sorra 1996). In Linton's review 'Implementation research: state of the art and future directions' (2002), it is claimed that researchers typically review the difficulties prior to discussing the factors that past studies have suggested and before modelling the relationships between previous findings. This outlines some significant areas where knowledge gaps exist and suggests an approach that has seldom been tried, that is, bypassing the review of known difficulties and getting straight onto filling the gaps. This thesis aims to address these knowledge gaps and particularly those that exist at and stem from the individual decision-making level (micro context of inquiry). This context and the background to the knowledge gaps have been outlined in the preceding chapter sections. This section articulates the gaps by highlighting specific calls for research in the literature and forming a set of motivating research questions.

2.4.1 Calls for Research

There are several clear calls in the literature for the reasons why innovation implementations fail to be exposed. They also identify the importance of gaining a better understanding of the individual decision-making level and the influences on the implementation process that can come from this context:

> *Our understanding of innovative behaviour in organizations remains relatively undeveloped as the results of organizational innovation research have been inconclusive, inconsistent, and characterized by low levels of explanation.* (Wolfe 1994)

> *We must go beyond the meanings posed by the traditional definitions of innovation characteristics and develop richer conceptualizations that reflect the embedding of the innovation in contexts of implementation and use.* (Ramiller 1994)

> *Whereas both innovation diffusion research and technology acceptance models include a hypothesised relationship between user perceptions and adoption outcomes, the relevance of different characteristics for the two outcomes is moot. There are also conflicting empirical results regarding the saliency of the various perceptions.* (Agarwal and Prasad 1997)

> *In changing work environments, innovation is imperative. Yet, many teams and organizations fail to realise the expected benefits of innovations that they adopt. A key reason is not innovation failure but implementation failure—the*

> *failure to gain targeted employees' skilled, consistent, and committed use of the innovation in question.* (Klein and Knight 2005)

> *The growing innovation-implementation literature draws needed attention to the challenge and the importance of effective innovation implementation. In the absence of effective implementation, the benefits of innovation adoption are likely to be nil. After all, how physically fit can you get if you buy a top-of-the-line exercise bike or treadmill but never use it?* (Klein and Knight 2005)

> *A business environment is a microcosm of social networks where many of these factors are interacting in dynamic relationships. A better understanding of the factors associated with IT implementation is valuable to organizations since it will help identify the environmental context needed to improve the chances of successful IT implementation.* (Edington and Shin 2006)

2.4.2 Initial Research Questions

An empirically supported synthesis of the vast number of theoretical constructs relating to the individual decision-making level for innovation implementation in PBE is needed. Some studies in implementation research have sought to combine theories in order to reach a unified view, for example, Legris and colleagues (2003) in user acceptance research. The findings have echoed the significant impacts on the outcome of an implementation that can come from the individual level (e.g. Yuandong, Zhan et al. 2005). A consistent theme is the influence that targeted adopter perceptions have on an implementation (e.g. Drury and Farhoomand 1999a). However, the resulting models and theoretical constructs are largely competitive with ambiguities in terminologies resulting in some confusion (Kim and Malhotra 2005).

A simplified view presented by Venkatesh and colleagues (2003) provides a clear message and helps state three concise research questions (see below). It shows the basic concept underlying user acceptance models (Figure 2-14). The simple diagram is similar in structure to that of Klein and Sorra's model of implementation effectiveness (Figure 2-9) in that it uses an iterative and cyclic flow for the thoughts of new users and managers involved in a technology implementation. It clearly shows that the actual use of an innovation is a telling outcome and point of feedback throughout an implementation for the evolving perceptions, attitudes, beliefs and concerns of users and managers.

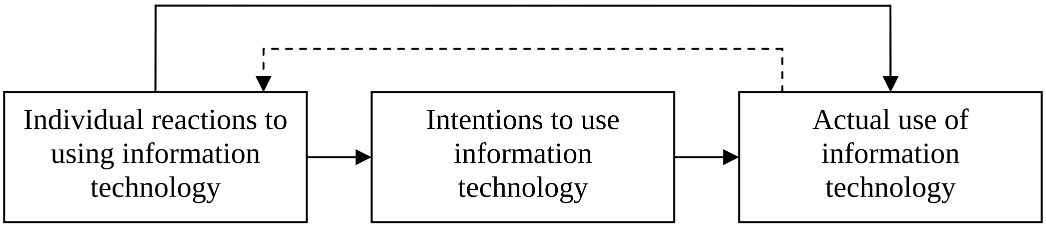

Figure 2-14: Basic concept underlying user acceptance models (Venkatesh, Morris et al. 2003)

In the context of innovation implementations in PBE, consideration of this concept leads to the initial research questions. The concept shows the typical flow of targeted adopter attitudes at the project organisation and typifies the associated social interactions. Reactions become intentions which in turn initiate (or otherwise) the behaviour of actually using the innovation. Project management will form an attitude that causes them to decide if they should or should not commit to implementing the innovation that the firm's technology champions have proposed (Pennings 1987). The perceptions of a user may affect the implementation commitment decision by management (Leonard-Barton 1985) but once it has been made, user perceptions will definitely affect the ongoing implementation (Drury and Farhoomand 1999a; Green, Hevner et al. 2005; Lippert and Forman 2005). There is a need for a better understanding of this part of the implementation process and one that provides a synthesis of theoretical constructs in implementation research. Concordantly, three concise research questions were phrased from the above literature review as motivation for the ensuing exploration:

1. ***For an innovation with justifiable benefits to a project, what causes project managers to decide not to implement it?***

2. ***Why do innovation implementations fail after project management decides they are a good investment?***

3. ***At the individual decision-making level within a project organisation, what implementation factors significantly influence the process of innovation implementation?***

3 Research Design

> *Researchers need to be alive, not only to the constraints and challenges of research settings and research aims, but to the nature of their data. They must also be alert to the temporal aspects or phasing of their researches, the open-ended character of the 'best research' in any discipline, the immense significance of their own experiences as researchers and the local contexts in which the researches are conducted.* (Strauss 1987)

This research employed a qualitative exploratory research design. The approach was to immerse a participant-observer in seven different project organisations from the Australian construction industry. All were implementing the same innovation, 4D CAD modelling. The researcher was immersed in each project organisation for the duration of their 4D CAD implementation by way of the technology group from a parent construction firm of the project organisations. Each 4D CAD implementation enabled the collection of descriptive data from the individual decision-making level of an innovation implementation. This data is viewed from the perspective of a social interactionist (see 2.2.2) and the epistemological stance is one of constructivism[9] vis-à-vis objectivism[10] (Denzin and Lincoln 2003; Neuman 2003). Using this research design, the thesis explores the context and finds a synthesis between the empirical data and existing theory.

The methodology was iterative on two levels; the research investigates innovation implementation across three different research phases, each of which revisits the data iteratively using content analysis. Although there were three discrete phases, at times they occurred in parallel. The *initial phase* identified the micro context of inquiry within the established macro context of inquiry, and the result was the conception of the initial perception-influence (P-I) model. The ensuing more formal content analysis of the *middle phase* developed the P-I model in the software NVivo7 (QSR International 2007). The middle phase was largely inductive in order to establish and help explain the empirical-theoretical synthesis that the P-I model provides. The *final phase* of analysis was also carried out using NVivo7 but with

[9] Constructivism maintains that knowledge is constructed by scientists and not discovered from the world by strict scientific methodologies. It assumes that peoples' interactions and beliefs create reality.

[10] Objectivism is the view that reality exists entirely independent of the human mind. It assumes things are the way they are by nature.

the intent to deductively test and validate the P-I model. This phase helps explain the possible applications for the P-I model and some quantitative measures from the qualitative analyses are achieved. The methods applied during each of the three phases are explained in section 3.3 in this chapter.

This chapter explains in detail the research design in terms of approach and methodology. An immersed participant-observer methodology in combination with a qualitative approach is shown to be the most appropriate for carrying out this type of exploratory study. This is largely done by considering the research aims with respect to the characteristics of qualitative research. The important physical elements to the research design are the seven project organisations and the innovation being implemented by each of them, 4D CAD modelling. This innovation is shown to be an example of one that can bring widespread benefits in project-based engineering (PBE) by referencing an established and growing body of research focused on 4D CAD functionality and merit. The main advantages and disadvantages of the chosen methodology are also explained with reference to the literature and so the possible alternatives to the chosen research methods that were considered are presented.

3.1 Qualitative Research Methods

There was no predetermined approach established at the outset of the research, rather just a context for inquiry and a basic motivating question about innovation implementation. This created three facets or requirements of this research that aligned with three characteristics of qualitative research (Gibbs 2002):

1. Flexibility in research structure and design **–** Qualitative methods allow for a relatively open research strategy that permits research questions to be developed and become more focused (Neuman 2003)

2. Exploration of the process of innovation implementation **–** Qualitative methods are used to focus on interconnections, change and the processes that produce them (Gibbs 2002)

3. A focus on the project and individual decision-making levels of innovation implementation as it occurs in project organisations **–** In qualitative research a particular setting (i.e. context) of occurrence is often used to interpret phenomena and their implications for larger social systems as well as the participants therein (Bryman 1988).

While qualitative methods have not been widely used in engineering they are gaining in both popularity and recognition (e.g. Munoz 1997; Seaman 1999; Love, Holt et al. 2002; Leydens, Moskal et al. 2004). They have been used recently to investigate social aspects in software engineering (Green, Hevner et al. 2005), interorganisational innovation in engineering (Taylor 2006), technical managerial transitions in engineering (Munoz 1997) and IT diffusion in construction (Peansupap and Walker 2005a). A study by Tantoush and colleagues (2001) explains how organisational processes contribute or otherwise to the adoption of computer-aided design (CAD) in manufacturing. They also used a conceptual model during the data analysis. These studies leant support and direction to the qualitative methods applied in this study. The main advantage of qualitative research is expressed by Seaman (1999):

> *The principal advantage of using qualitative methods is that they force the researcher to delve into the complexity of the problem rather than abstract it away. Thus, the results are richer and more informative.*

The rich and informative results from qualitative methods are complemented by conducting them in a nonreactive manner (Webb 1981).

3.1.1 Nonreactive Data Collection

The use of nonreactive data collection techniques in preference to traditional surveys and questionnaires is an important aspect of this research. Nonreactive methods of collecting data are unobtrusive (Neuman 2003) which means that the act of collecting the data does not interfere or affect in any way the data that is collected (Webb 1981). This research explores the process of innovation implementation at the project and individual decision-making levels so it is crucial that any evidence obtained represents the process as it usually occurs. Obtrusive data, such as that created by surveys and questionaries, typically results from the researcher asking direct questions of individuals and respondents answering them as an extra task on top of their normal activities. Unobtrusive data is created as part of normal workflows, ergo many forms of it are artefacts and can be literally collected (James, Milenkiewicz et al. 2008). Observations of phenomena can also be recorded unobtrusively by the researcher but it should not be openly pronounced to participants that their behaviours are being recorded (Berg 2004). In this way, there is no disturbance at all to what is being studied (Seaman 1999), therefore unobtrusive data provides unbiased evidence. Put simply, the main advantage of collecting data in this way is that participants do not react to the data collection process (Abler and Sedlacek 1986) but leave evidence of their actions and behaviour 'naturally' (Neuman 2003). It is important to note that in the nonreactive data collection contributing to this thesis the project participants being observed were well aware that there was an ongoing research effort being conducted.

3.1.2 A Multi-Faceted Evolving Approach

This thesis is based on a qualitative methodology that has ethnographical, reflective, grounded theory and hermeneutic characteristics (Harvey and Myers 1995; Neuman 2003; Soliman and Kan 2004; Winter, Smith et al. 2006; Jensen 2007). An understanding of these research traditions along with the particular aspects from each that were being applied as part of a multi-faceted research approach evolved purposefully. As a result and also because this thesis aims to portray this progression, these methodologies are mentioned only briefly here in this chapter. Ethnography is the study of meaning within a particular social context (Harvey and Myers 1995). Hermeneutics is the theory of understanding (Jensen 2007) and is discussed further in section 5.4.1 of this thesis. Reflective thinking is also established as an important aspect of this research and this can be seen in the work of others (e.g. Winter, Smith et al. 2006). A typical characteristic of grounded theory is a single story line that offers a core concept and an attendant theory as a way of making sense of the data (Morse and Richards 2002). The qualitative methods described in this chapter are more procedural in comparison to these four higher level categorisations. The ways in which they form part of the multi-faceted approach is established throughout this thesis and discussed in chapter 7. This thesis and investigation was facilitated by an immersed participant-observation technique.

3.2 Immersed Participant-Observation

In conducting this study, I was immersed as a participant-observer in seven different construction project organisations. This immersion was over a period of 3.5 years and by means of the *technology group* belonging to one of the largest PBE firms in the Australian construction industry (Dale 2005), referred to in this thesis by the pseudonym Australian Construction Limited (ACL). ACL operates as the primary construction contractor for the bulk of the project organisations it participates in, a role that provides a high level of control and enables opportunities to implement new innovations and technologies (Manley and CRCCI 2006). The technology group is based in ACL's head office and is responsible for identifying the prospective new technologies before working with construction project organisations to implement them. The group is comprised of technology champions (see 2.3.2) dedicated to adopting and implementing the innovations that add value to the delivery of major projects. All seven project organisations used the technology group as their support network in implementing the same innovation – 4D CAD modelling. Flyvbjerg (2006) highlights the advantage provided by researcher immersion:

> *… the most advanced form of understanding is achieved when researchers place themselves within the context being studied. Only in this way can researchers understand the viewpoints and the behaviour which characterizes social actors*.

The seven different placements in this research were helped significantly by the fact that the researcher would participate in each 4D CAD modelling implementation. By working with the technology champions developing the models, I gained access to each implementation with a purpose in addition to but other than for research. This also led to further participatory roles on-site as part of the technology champions' implementation strategies such as assisting with user training. In this way, I was afforded unfettered access to the project-participants (both management and users) as they responded to the implementation of 4D CAD modelling on a daily basis.

3.2.1 The Innovation: 4D CAD Modelling

4D CAD modelling is an example of a beneficial innovation being implemented in project-based engineering. A dedicated focus on one technology in PBE keeps some of the variables in an implementation constant (e.g. innovation scope) so that other factors and perhaps some not previously considered in implementation research can be studied. It was important that the chosen innovation be justified as being beneficial to PBE in order to address the specific research questions that emerged from the literature review. To this end, this thesis section provides evidence to support and justify 4D CAD modelling as a beneficial innovation for PBE.

4D CAD modelling functionality

In PBE a 4D CAD model allows all project stakeholders to see how a project or a part thereof will be built (Collier and Fischer 1995). It inextricably links the activities in a construction schedule with the three-dimensional CAD design to give a temporal and spatial model of a planned construction (Fischer and Aalami 1996). The adoption of 4D CAD modelling has been extensively fostered since the early 1990s by the work of Martin Fischer and other researchers at the Centre for Integrated Facility Engineering (CIFE) at Stanford University (e.g. Fischer 2006). The technology was conceived by research associated with expectations and concepts of time-space graphics in the early 1980s (e.g. Stradal and Cacha 1982) that developed into proposed solutions involving visualisations in the early 1990s (Connor 1993) until actual software tools began to be produced in the mid to late 1990s (e.g. Collier and Fischer 1995). Today 4D CAD modelling is an ‘off the shelf’ and relatively automated innovation (Heesom and Mahdjoubi 2004) that can bring widespread benefits to a construction project throughout the entire project lifecycle (Gao and Fischer 2005). Figure 3-1 shows the basic inputs and general functionality of a 4D CAD model.

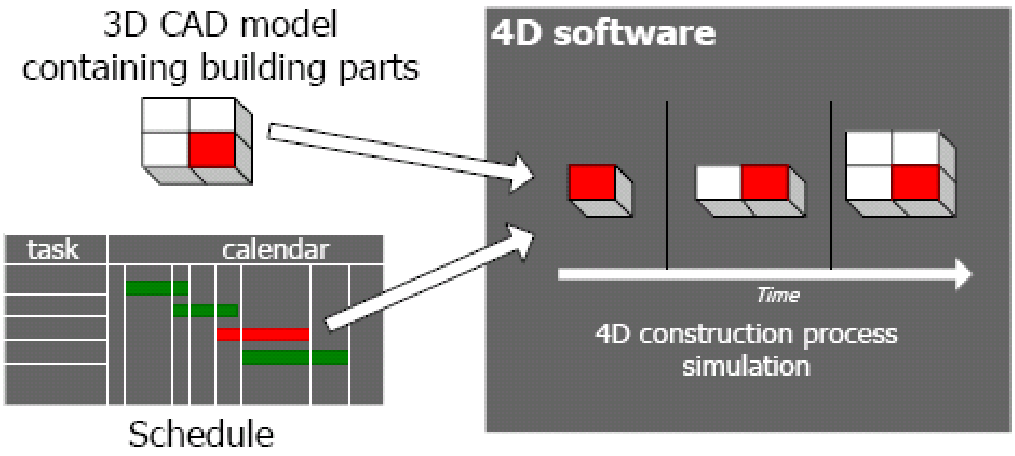

Figure 3-1: 4D CAD model functionality (De Vries and Broekmaat 2003)

This workflow requires inputs from stakeholders within the project organisation. As a result, there are potential benefits for internal and external stakeholders to the project organisation (Cory 2001; Kanagasabapathi and Ananthanarayanan 2004; Dawood and Sikka 2007; Khatib, Chileshe et al. 2007).

Stakeholder benefits of 4D CAD models

> *The advantage of using 4D CAD for all individuals involved with the construction process is fundamentally the same: these models enable people to quickly perceive and understand complex information about physical geometry.* (Collier and Fischer 1995)

Perhaps the most important input to a 4D construction model not at a functional level is for all stakeholders to agree on the purpose of the model (Koo and Fischer 2002). The purpose of a 4D model is closely aligned with the benefits that are intended to be brought to the project by its use (Gao and Fischer 2005). By locking down discrete intended benefits for a proposed 4D CAD model, the scope is set and all associated workflows can be better planned. A simple example of a purpose for a 4D construction model is the representation of durations for the construction of each separate module within a design in order to identify scheduling clashes between them (Khatib, Chileshe et al. 2007). The most significant benefits a 4D model can provide each of the possible stakeholder groups in construction are shown in Table 3-1 (Collier and Fischer 1995).

Table 3-1: Benefits of 4D CAD modelling for construction stakeholder groups

Stakeholder Group	Significant Benefits
Clients and Owners	Clear presentation of how the construction will take place Negates the need for schedule and drawing printouts in client-contractor meetings Increases their involvement Consideration of scheduling options
Planners	More trialling of alternative schedules Greater awareness of spatial requirements to be factored into the schedule Increased communication with all other stakeholders
Designers	Increased efficiency of the final design by the early integration of construction sequencing constraints
Subcontractors and Trades People	Identification of specific tasks Graphical representation of the interfaces between trades and other subcontractors Increased awareness of how their work fits into the larger picture
Suppliers	Increased awareness of construction schedule – both planned and actual dates Better judgment of most critical deadlines
Government Approval Authorities and Community Groups	Enhanced understanding in impact studies Better and more rapid understanding of the construction during post-construction litigation

For these benefits to be realised by stakeholders, a 4D CAD model should be used in collaborative communications (Chau, Anson et al. 2005). Meetings or workshops held by the stakeholders within the project organisation are the most common form of such communications. Collaborative exchanges in the form of presentations are often the means by which these internal stakeholders engage external stakeholders in a 4D CAD Model (Gao and Fischer 2005). Figure 3-2 shows the involvement of each possible stakeholder in a 4D CAD model that is implemented by a project organisation and highlights the inherent flow of inputs and benefits. It is important to note that each internal stakeholder category may have management or decision makers as well as users.

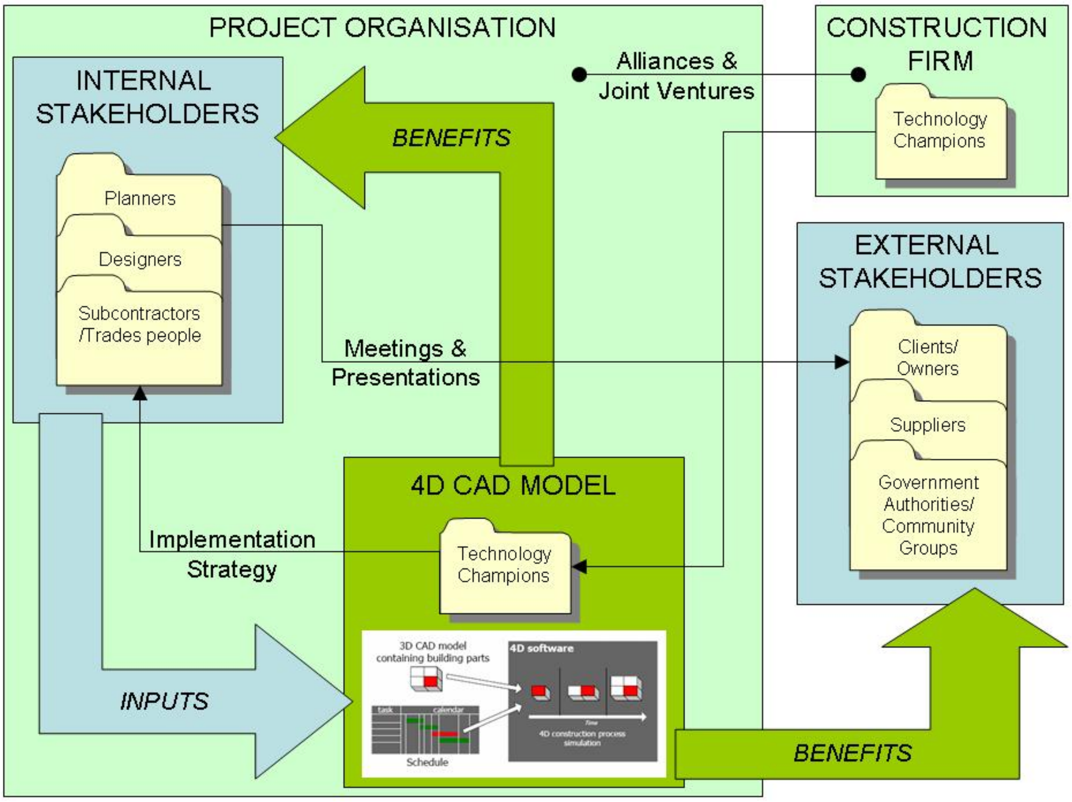

Figure 3-2: Stakeholder involvements in 4D CAD modelling

Figure 3-2 presents the process of a 4D CAD modelling implementation by a PBE organisation. It illustrates the innovation implementation challenge faced by any PBE firm that adopts 4D CAD modelling and highlights this challenge in terms of social interactionism (see 2.2.2). As an addition to the way Figure 2-12 captures the macro context of inquiry, Figure 3-2 expands the understanding for the case of 4D CAD modelling as the innovation being implemented. The number of possible stakeholders along with the communications and flow of data required by the implementation of a 4D CAD model are extensive. This echoes the importance of the statement by Koo and Fischer (2000) that the purpose or intended benefits of a 4D CAD model must be agreed to by all stakeholders. If this is done at a planning stage prior to the actual implementation, it may in fact limit the number of stakeholders involved and simplify the modelling effort (Koo and Fischer 2002). Irrespective of the number of stakeholders and agreed purpose of the 4D modelling, the critical role of the technology champions in carrying out the implementation strategy is clarified by Figure 3-2. An important part of any implementation strategy is training relevant project-participants (the targeted users) in the skills required to interrogate a 4D CAD model.

4D model interrogation

Central to the communications that facilitate the benefits of a 4D CAD model is the repeated interrogation of it (Robinson 2007). Interrogating a 4D model involves playing or stepping through time in the model so that each construction activity or task linked to a piece of CAD is animated. It may also involve moving around inside the spatial 3D environment of the model to examine all objects thoroughly (Kamat and Martinez 2003). Construction tasks are usually represented by the relevant piece of CAD changing to a particular colour for the duration of the task and perhaps in combination with its appearance or disappearance[11] (De Vries and Broekmaat 2003). The ability to interrogate a model should be relatively easy for any computer-literate stakeholder to obtain through basic training (Heesom and Mahdjoubi 2004).

The fact that model interrogation is the means by which stakeholders derive their benefits from the model is also important. There is no requirement for them to gain the skills required to create and/or update the model – this remains the responsibility of the technology champions. This shows 4D CAD modelling to be divisible and is the main reason it is classed as an incremental innovation for the project organisation[12] (see Figure 2-2). It also highlights again the importance of the implementation strategy as well as the methods used by the technology champions in carrying it out. Technology champions include model interrogation training of some kind in their implementation strategy to help relevant stakeholders derive the intended benefits. This is one of general similarities the implementation of 4D modelling has with the vast majority of innovations that are implemented in PBE. Therefore analysing seven separate instances of its implementation provides a significant and diverse exploration.

[11] One of the most common examples is a general 'build' or 'construct' activity for a concrete structure. Here the 3D CAD pieces that are the structure in the model appear at the task's start date but coloured green before changing to concrete grey and remaining visible at the completion date. In this way, the planned period of construction for the structure is clearly shown and the implications of this activity can be assessed for other modelled tasks or activities.

[12] For the construction firm implementing 4D CAD modelling on a project, it may not be classed as an incremental innovation depending on the systems that were in place at the time of adoption. However, this is outside the scope of this thesis because the research seeks to study innovation implementations in project organisations with a view to helping the technology champions from the construction firm.

3.2.2 The Seven Construction Project Organisations Studied

The project organisations formed to deliver the seven construction projects that contribute data to this thesis implemented 4D CAD modelling at some level. The projects were spread across three industry sectors: 1) *building* – commercial high-rises and private complexes; 2) *civil infrastructure* – roads, bridges and tunnels; and 3) *process engineering* – oil refining, gas reticulation and coal washing. Each was a major project of the order of hundreds of millions of dollars in value. The ACL technology group members facilitated the 4D CAD implementations. Table 3-2 identifies each project organisation as it is referred to by this thesis along with the associated scope of the 4D CAD modelling and the research phase in which the data from each project was analysed.

Table 3-2: The seven project organisations, their 4D CAD scope and research phase

Project Organisation	Scope of 4D CAD modelling	Research Phase
Tollway Construction Project Organisation (TC_{PO})	The construction of a large tollway interchange[13]	Initial Phase
Public Transport Project Organisation (PT_{PO})	The construction of a large bus station on a busway[14]	Middle Phase
Process Plant Project Organisation (PP_{PO})	The construction of a coal-washing plant	Middle Phase
Tunnel Tender Project Organisation (TT_{PO})	Presentation of the planned construction of one tunnel portal during tender	Middle Phase
Private Building Project Organisation (PB_{PO})	The construction of an equestrian centre	Final Phase
Freeway Upgrade Project Organisation (FU_{PO})	The construction of an upgrade[15] to an existing freeway	Final Phase
Commercial Building Project Organisation (CB_{PO})	The construction of a high-rise building	Final Phase

The data collected at each project organisation came from individuals who fit into three different categories: 1) staff within the project organisation involved in the

[13] An interchange in a tollway construction project is the built structures at the place where the tollway meets other roads or freeways that allow motorists to drive on and off the tollway.
[14] A busway is a road built for use by public bus services only.
[15] Upgrade refers to the addition of new structures and road surfaces to existing structures and road surfaces.

implementation of 4D CAD modelling, i.e. the project-participants; 2) staff from the ACL technology group that was implementing the innovation, i.e. the technology champions; and 3) the researcher physically experiencing the implementation process, i.e. the participant-observer.

3.2.3 The Data

The empirical data, mostly text and a few photos, belong in one of two categories: 1) direct observations (from conversations, meetings, phone calls etc.) transcribed as field notes; and 2) project documentation (i.e. reports, emails, meeting minutes and presentations). Communications between the technology champions, project-participants and any external stakeholders associated with the innovation implementations provided the bulk of the data. The data were collected with very little or no interruption to the normal workflows of the project-participants and technology champions. This, along with the fact that I, as the immersed researcher, did not knowingly attempt to influence the perceptions of the project-participants being studied, created unobtrusive data sets and helped remove researcher bias. The breakdown of each project's data set is presented in chapters 4, 5 and 6 as they sharpen the focus of the research and explore the perceptions of 4D CAD implementation participants. These chapters each document one of the three research phases and the data analyses therein.

3.3 Research Phasing and Methods of Analysis

Each of the three phases in this research applied qualitative methods and principles but in differing ways. Qualitative methods can be separated into two categories that characterise their intent or strategy: *theory-generation* and *theory-confirmation* (Seaman 1999). These two categories and the methods used to apply them are explained in terms of where and how they were used during the three research phases.

3.3.1 Initial Research Phase

Theory-generation methods were used to analyse the qualitative data during the initial phase of the study. Theory-generation is a collective term for the qualitative methods used to extract statements and propositions from sets of data (Seaman 1999). The methods used can also be grouped as *content analysis* techniques, and content analysis is considered a theory-generation method itself (Neuman 2003). The iterative way in which content analyses and qualitative research is carried out is highlighted by Richards (2005):

> *The goal [of content analysis] is to learn from the data, to keep revisiting it until you understand the patterns and explanations.*

The *content* refers to the meanings embedded in passages of textural data such as themes, ideas, messages and opinions. The text is anything written that exists as a medium of communication including books, emails, documents, and visually or aurally stimulated field observations (Neuman 2003). Content analysis is often used to make inferences about the attitudes held by the senders of particular communications and can help predict the implications for the associated social systems (Archer 1984).

The two content analysis techniques used in the initial phase were *constant comparison* and *pattern matching*. They were applied in a broad sense and by a manual process. Constant comparison involves coding (or labelling) passages of textural data that represent and are relevant to particular themes or ideas of interest in the study (Miles and Huberman 1994). In a similar way, pattern matching compares patterns of circumstances, informed by relevant predictions from previous knowledge, in the collected data (Gibbs 2002). Accordingly, this content analysis was done in parallel with the review and ongoing cognition of previously identified theoretical constructs in the literature. This produced the initial P-I model, the P-I_1 model, which was a summary of the propositions taken forward into the middle research phase. The conception of this model refined the research focus, thus highlighting the micro context of inquiry, and it established the initial coding structure for the ensuing, more formal analysis. The conception of the P-I_1 model and details of the analysis carried out in the initial research phase are presented in chapter 4.

3.3.2 Middle Research Phase

During the middle phase of the research, theory-generating content analysis methods were again used to inductively develop the P-I model. This analysis was formally carried out using the software package NVivo7 (QSR International 2007).

NVivo7 provides a functional platform for the execution of content analyses (Richards 2005). In addition to pattern matching and constant comparison, two more methods were introduced and performed in NVivo7 during the middle research phase: *triangulation* and *crosscase analysis.* Triangulation is the process of using measures or accounts of the same phenomenon from different sources (Love, Holt et al. 2002; Yin 2003) and is similar to crosscase analysis, comparing data across partitions established by virtue of where or what the data came from (Eisenhardt 1989). With a more established coding structure being applied to the data through the functional software platform of NVivo7, the content analysis in the middle research phase was more extensive.

In content analysis, the data are partitioned and interrogated by the way it is coded, the coding structure. The coding structure was based on the P-I_1 model constructs as well as descriptive attributes, such as data source. Four main types of coding (Morse and Richards 2002) were used:

- *Descriptive coding* of implementation attributes such as project type and construction stage (i.e. pre-tender, tender, or design and construct [D&C] – both 'early' and 'late') as well as data source (i.e. observations and project documentation)

- *Topic coding* in combination with *open coding* so that new P-I model constructs could emerge from the data. Topic coding is category creation followed by consideration of the categories' in-context location in terms of how it fits with other data. Open coding is also used to identify concepts that seem to fit the data.

- *Axial coding* to expand the understanding of identified constructs. Axial coding is focusing on a concept.

- *Analytic coding* of participant perceptions and the factors that contribute to their formation. Analytic coding is pursuing category comparisons in order to develop new categories theoretically and illustrate existing concepts.

The coding structure and hence the P-I_1 model were developed with each iteration of the content analysis during the middle research phase. This made for an evolving coding structure. The initial $P\text{-}I_1$ model-based coding structure was developed through two revisions, the $P\text{-}I_2$ and $P\text{-}I_3$ models. This is a characteristic function of content analysis and one often used for exploring specific research contexts (Gibbs 2002). The finer details of this process, including the specific functions that NVivo7 performs to carry out content analyses, are explained in chapter 5.

3.3.3 Final Research Phase

The final phase of the research was largely deductive and used methods associated with theory-confirmation. The aim of theory-confirmation or theory-strengthening analysis is to build the weight of evidence behind what the research is proposing (Seaman 1999) – the P-I model-based synthesis for the case of this thesis. The methods employed in the content analysis of the final phase were much the same as those in the middle phase, however the coding structure had evolved considerably and was far more set (i.e. from the $P\text{-}I_3$ model constructs). As a result the data collected in the later stages of the research were more focused than before and could be processed more efficiently. Some theory-generation occurred in terms of enhancements to the established method for compiling a P-I model. The theory-strengthening analysis in the final research phase serves mainly as fuel for the discussion about the actual implications of the P-I model. The details of this analysis are presented in chapter 6. Figure 3-3 shows a summary of the research methods and phasing by illustrating the evolution of the P-I model through which this thesis establishes meaning.

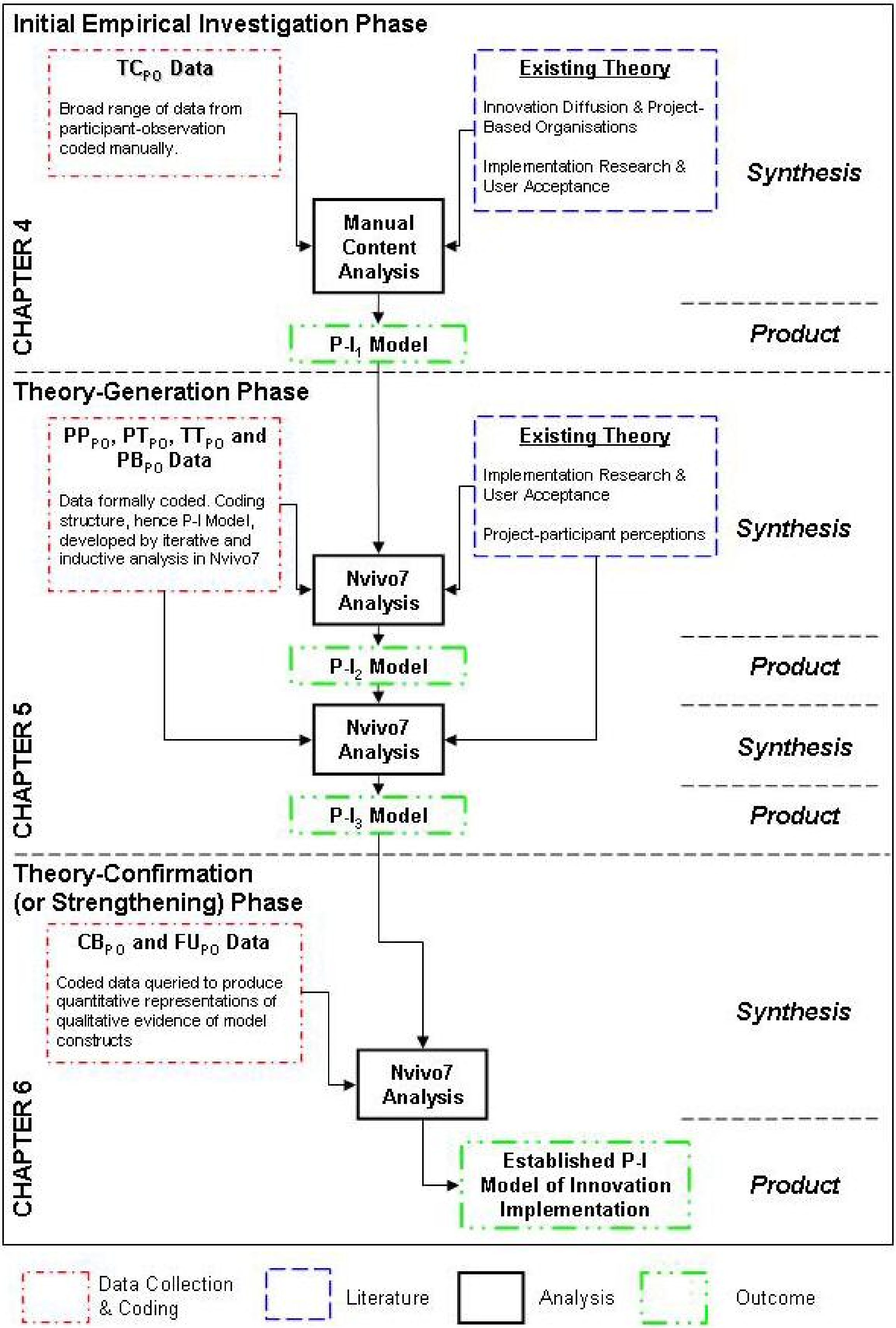

Figure 3-3: Research design and P-I model evolution

Figure 3-3 summarises the research design. It was able to be established in part by the consideration of other methods. By documenting these other options, the fitness for purpose of those methods selected can be justified.

3.4 Fitness for Purpose

There is support for the use of qualitative methods in innovation implementation research that specifically considers the individual-level and user acceptance models. Based on their study of innovation implementation, Lucas and Spitler (2000) concluded that combining user acceptance models like TAM (see 2.2.5) with qualitative research methods 'offers the best opportunity for understanding the implementation of modern information technology.' They went on to say:

> *These two approaches to research complement each other and their combination will provide the most insights possible into the complexities of implementation in an environment of workstations, LANs, intranets and the Internet*. (Lucas and Spitler 2000)

The main alternatives to qualitative methods are quantitative methods. The nature of the research questions and the particular situational opportunity available for a given research project can determine if a qualitative or quantitative method or a mixture of both (e.g. Seaman 1999) should be chosen (Eisenhardt 1989). Qualitative methods use soft or descriptive data in the form of words, photos or symbols while quantitative methods use hard data in the form of numbers. These numbers often represent frequencies of occurrence of particular events or tallies of responses to survey questions. Quantitative data analyses are more often associated with explanatory research, and qualitative analyses with exploratory research (Neuman 2003). Table 3-3 shows the main differences between quantitative and qualitative methods (Neuman 2003).

Table 3-3: Differences between quantitative and qualitative research methods

Quantitative	Qualitative
Measures objective facts	Constructs social reality, cultural meaning
Focuses on variables	Focuses on interactive processes, events
Reliability is key	Authenticity is key
Independent of context	Situationally constrained
Many cases, subjects	Few cases, subjects
Statistical analysis	Thematic analysis
Researcher is detached	Researcher is involved

By considering these differences in conjunction with the aims and macro context of inquiry of this thesis (see Figures 2-12 and 3-2 above), qualitative methods were an appropriate choice for this research. The research aims to explore the individual decision-making level as it exists in the process of innovation implementation by using seven examples of this process from the construction industry. It also seeks to include the intricacies of the project-based engineering context. In light of these aims and the characteristics of qualitative research (Table 3-3), a qualitative methodology was chosen and subsequently relevant methods of analysis were then examined.

Analysis method alternatives

Many alternatives to the data analysis methods used by this research exist within the domain of qualitative research methodologies. Researchers have identified numerous interconnected categories for these methods (Gibbs 2002). Morse and Richards (2002) claim there are three ‘methods’ while Creswell (1998) defines a set of five ‘traditions’ in qualitative research. Harre (1997) assumes a significantly different perspective and labels seven different ‘analyses’ while Tesch (1990) reviews the huge number of approaches that have been used in qualitative research and reduces them to four ‘categories’. In assessing alternatives, this thesis pertains to the apparent continuity in the work of Gibbs (2002), Denzin and

Lincoln (2003) and Neuman (2003) as they all refer to the different ‘strategies’ of qualitative research. Neuman (2003) lists seven strategies for qualitative data analysis (Table 3-4).

Table 3-4: Summaries of seven strategies for qualitative data analysis

Strategy	Description
1. The narrative	Tells a detailed story about a particular slice of social life
2. Ideal types	Compares qualitative data with a pure model of social life
3. Success approximation	[Iteratively, inductively and] Repeatedly moves back and forth between data and theory, until the gap between them shrinks or disappears *(As in Theory-generation – section 3.3)*
4. The illustrative method	[Deductively] Fills the ‘empty’ boxes of theory with the qualitative data *(As in Theory-confirmation – section 3.3)*
5. Path dependency and contingency	Begins with an outcome and traces a sequence of events back to its origin to see a path that constrained the set of events
6. Domain analysis	Locates the included terms within cover terms that make up the cultural domain
7. Analytic comparison	Identifies many characteristics and key outcomes, then checks agreement and difference among the characteristics to learn which ones are associated with the outcome

It is evident from Table 3-4 that the research design used for this thesis applies both research strategies 3 and 4 in preference to the others. The terminologies for these strategies from Neuman (2003) are not used however because the theory-generation (inductive) and theory-confirmation (deductive) phasing explains more clearly what was done (Seaman 1999). Nevertheless the principles from Neuman’s (2003) strategies still hold. In any investigative activity that formulates a theory of some sort, common sense suggests a testing phase can only complement the theory-generation phase. Therefore a combination of strategies 3 and 4 from Table 3-4 appears as a logical approach for this study that seeks to find a better understanding of the individual level in an innovation implementation in PBE that incorporates a synthesis of previous research. The analysis technique central to the research design chosen to deliver the exploratory-inductive-deductive strategy was content analysis.

Because content analysis is a commonly used method for delivering the full range of qualitative strategies (Neuman 2003), there were few if any alternatives to consider. All content analyses involve a coding procedure, even if only very simple, and it's the way in which the coding procedure is carried out that defines the research strategy. This can be seen in the descriptions of each strategy in Table 3-4. Most common types of coding were used to conceive, develop and strengthen the theory of the P-I model that is presented by this thesis (see 3.3.2 above).

Alternative data gathering techniques

Methods of data gathering were considered in terms of reactive and nonreactive methods to evaluate two options. Nonreactive data gathering is limited in the sense that it often conflicts with ethical issues associated with the privacy of the subjects as they are not aware they are being studied[16] (Abler and Sedlacek 1986). Another disadvantage is that large amounts of data often need to be collected in order to be sufficiently representative of theoretical constructs (Abler and Sedlacek 1986). Reactive methods such as interviews, surveys and questionnaires have the advantage of asking specific questions, however the integrity of peoples' responses as being truly representative of their opinions or behaviours has been extensively questioned and stated by many as decidedly unreliable (Neuman 2003). In light of these main advantages and disadvantages of reactive and nonreactive data collection, a nonreactive or unobtrusive method was chosen. This method, as part of a phased inductive/deductive strategy, made the most of the immersed opportunity that I was presented with.

[16] This was mitigated by my participation in the innovation implementations. There was justification for my handling the data for reasons other than to collect it as a result of the tasks and permissions given to me by the ACL technology group manager. These permissions show that the subjects at the organisation or firm level (see 2.2.1) were aware of the data being collected, however at the project and individual levels (the micro context of inquiry), it was not obvious. This scenario (or in fact, opportunity) helped enable one of the advantages of unobtrusive data collection in providing naturally occurring evidence for exploratory investigation.

Alternative innovations

There were a number of possible alternatives in making the choice to use 4D CAD modelling as the exemplar innovation. The ACL technology group had adopted and implemented a diverse range of innovations in the last five years, including laser scanning[17], virtual traffic modelling[18], geographic information systems (GIS) and 3D printing. Any of these innovations could have been used to collect data but none would have provided more discrete implementations than 4D CAD modelling. This is due to the fact it was one of the more established innovations and suited to a wide range of industry sectors. In a functional sense, it was also the best fit for the research as it was most suited to my undergraduate and early career experience in mechanical engineering and 3D CAD modelling. Assessing other options for analysis methods and techniques, as above, increases validity.

Validity

This thesis intends to establish validity in implementation research in a number of ways. Validity in field research is defined by Neuman (2003) as: *the confidence placed in a researcher's analysis and data as accurately representing the social world in the field.* The confidence in the findings of this thesis stem from the establishment of their plausibility and authenticity. That is, the findings are presented as unexclusive but representing the genuine experiences of the researcher with the empirical data (Neuman 2003). The validity and transferability of the findings is further enhanced by the fact that the observed theoretical constructs are evident across different data sources. Furthermore, the research is longitudinal, in terms of the contrast in the objectives of the three phases and the number of autonomous implementations contributing to the data, which also increases validity. These are integral aspects of the research design, the first phase of which involved the initial empirical investigation of a 4D CAD modelling implementation at the main office of a A$2.5 billion tollway construction project organisation (TC_{PO}).

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[17] Laser Scanning is survey acquisition of built and natural environments as a 3D cloud of points.
[18] Virtual Traffic Modelling combines traffic flow requirements (e.g. number of lanes, signalised intersections), traffic management plans and site environment (i.e. survey and built) to produce realistic models of planned traffic flows at each stage of a construction project that is modelled.

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4 A Preliminary Study of Innovation Implementation

It is important to gain a better insight by developing distinct models that identify the determinants of the adoption choice and chronology. In developing substantive theories, it is necessary to borrow and extend germane theories ... In this endeavour, the complexity of the diffusion/implementation interface will have both a foundation in theory and practical impact identifying conditions favourable to increasing the speed and spread of innovation adoptions. (Drury and Farhoomand 1999a)

This chapter presents the initial research phase. The findings from an exploratory investigation at the first project organisation (PO) studied help identify the focused or micro context of inquiry for the thesis: *the perceptions of project-participants in an implementation and the influence they have on the outcome*. Further reference is made to relevant literature and some of the concepts explained in chapter 2 are expanded. The initial P-I model is proposed as a synthesis of the theoretical constructs in implementation research and those that are observable in the empirical data. Figure 4-1 below presents an overview of this phase of the research design.

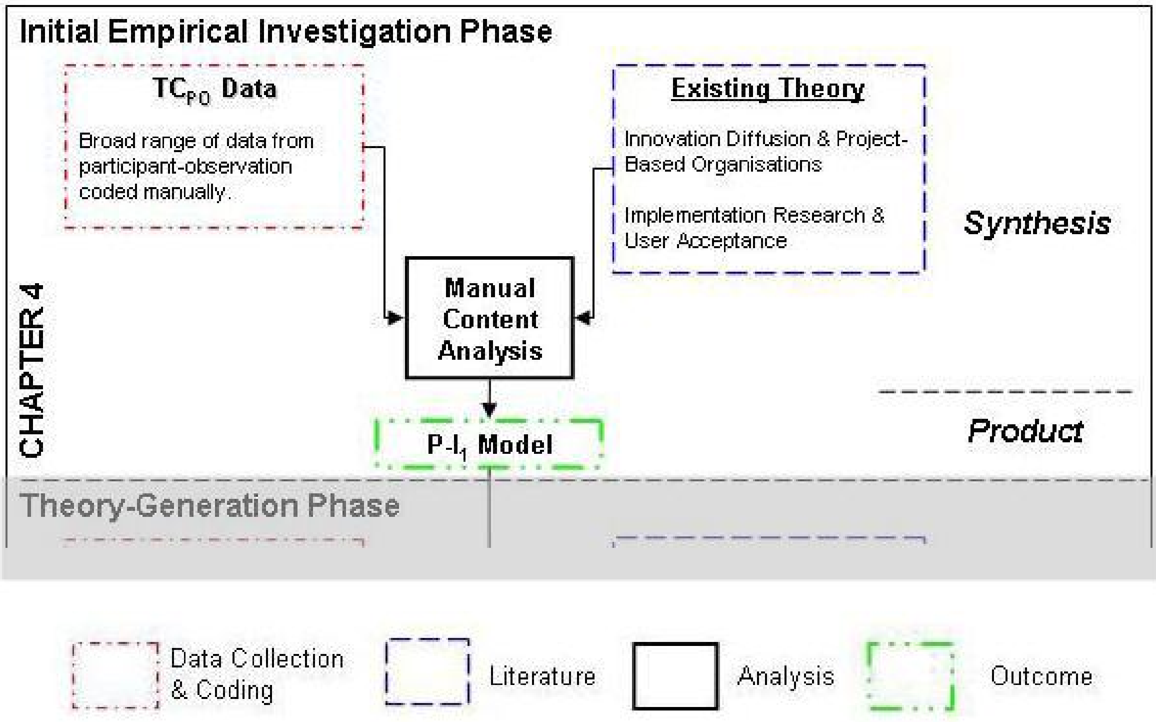

Figure 4-1: Research design – Initial research phase

4.1 Empirical Study of Innovation Implementation in Practice

The data for this preliminary study came from within a PO delivering a A$2.5 billion tollway design and construct (D&C) contract. The 4D CAD implementation was carried out by the Australian Construction Limited (ACL) technology group at the main office of the tollway construction PO (TC_{PO}) over a period of three months. The TC_{PO} was formed with the sole purpose of constructing the 45km tollway which included 17 interchanges[19], 89 bridges and a 1.6km twin three-lane tunnel as well as extensive urban design and landscaping works. With more than 2000 employees, the project was the largest civil infrastructure project undertaken in Australia's history when it commenced. ACL's participation in the TC_{PO} was as one of two primary contractors. An innovation budget was included in the tender that allowed for the implementation of 4D CAD modelling. This section (4.1) presents the analysis of the data collected at the TC_{PO}. The findings propose some conditions that should be satisfied by an implementation in order for it to be effective (Miller, Radcliffe et al. 2006).

4.1.1 The Data

Data were collected from a variety of sources. Researcher observations were recorded by witnessing most aspects of the 4D CAD implementation and TC_{POs} workflows in addition to the collection of project documentation. It was important to collect as diverse a range of data as possible during this initial research phase so that a rich description of the macro context of inquiry could be achieved by the analysis. This maximised the number of intricacies exposed within the macro context and aided the function of the initial research phase in refining the focus of the thesis to identify the micro context of inquiry. A summary of the largely textural data sets that were gathered and created by observation (see 3.2.3) is shown by Table 4-1.

[19] An interchange in a tollway construction project is the built structures at the place where the tollway meets other roads or freeways that allow motorists to drive on and off the tollway.

Table 4-1: Data gathered from the TC_{PO}

Data Sets	Item/Source
Project Documentation[20]	Newspaper articles ACL intranet[21] fact sheets and web pages Emails regarding the 4D CAD implementation: - Tech. Champ. – Tech. Champ. - Tech. Champ. – Project management - Tech. Champ. – Targeted user Meetings minutes referring to 4D CAD Training outline CAD design and construction schedule data
Observations	Participant field notes from the 4D CAD implementation, from: - Meetings - Conversations (both on the phone and in person on-site) - Training sessions - Email exchanges

Each source contributed data that provided an introduction and grounding to the TC_{POs} 4D CAD implementation as well as the macro context of inquiry. There are both general data (e.g. intranet fact sheets or broad observations) and specific data (e.g. training outline or detailed observations), however the more purposeful categorisation of this cumulative and descriptive data is by the two ‘data sets’ shown in Table 4-1. The collection that formed these two sets occurred over a period of three months which corresponded to the duration of the 4D CAD modelling implementation and researcher immersion at the TC_{PO} (See Appendix A for a cross-section of data collected at the TC_{PO}). Once collected, the data were analysed by a manual content analysis.

[20] A web-based data and communication management system was in place at the TC_{PO} that facilitated transfer, tracking and archiving of all formal interpersonal communication and project data exchanges. The immersed researcher had access to this system in collecting the research data.

[21] An intranet is a company-wide or firm-wide web, vis-à-vis a world-wide web. Company intranets are updated daily with recent company news as well as housing long-term informative databases with details about the firm’s operations.

4.1.2 Data Coding and Analysis

The data analysis explored the implementation of 4D CAD modelling at the TC_{PO} using theory-generation methods (see 3.3.1). These methods were carried out by a manual technique that involved inspecting and comprehending the data before applying a simple coding structure to each passage of textural evidence. This was done repeatedly and across the two main data sets so that the data were constantly revisited in search of details and descriptive evidence of the following three themes from the literature:

- ***The implementation strategy***
- ***The existence of any barriers to innovation implementation***
- ***The outcome of the implementation.***

These themes provided three foci for the data analysis. They were broad enough to allow exploration of the implementation with some freedom but were also limiting so there was clarity in the direction that the investigation was heading. By performing the analysis, an understanding of the three themes was built using direct evidence of what had transpired during the 4D CAD implementation. The data were iteratively processed by labelling relevant textural passages with the coding structure shown in Figure 4-2. This helped organise the data and find patterns within them.

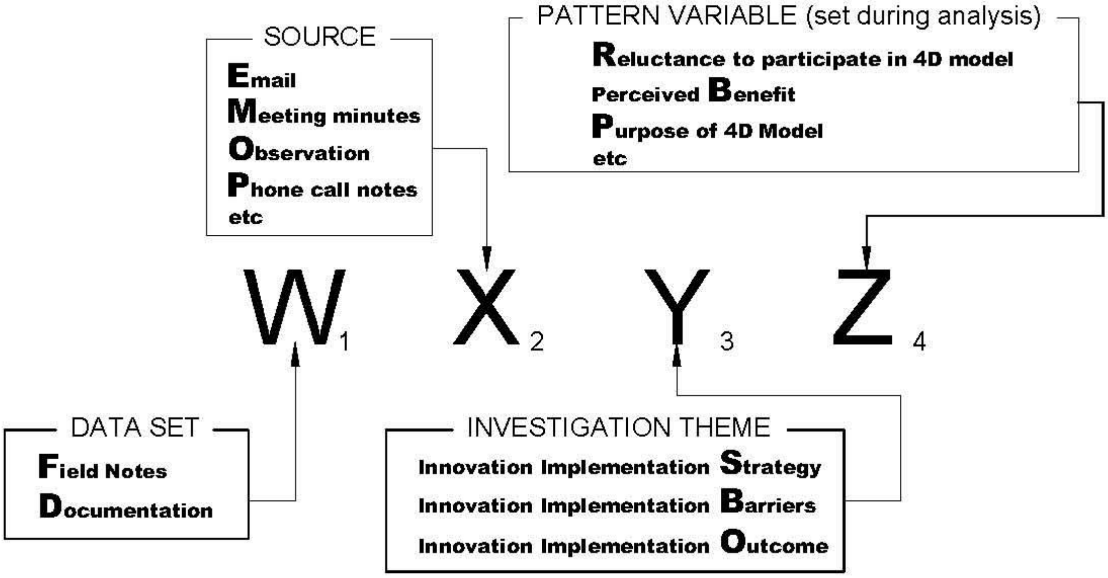

Figure 4-2: Initial research phase coding structure

The coding structure in Figure 4-2 enabled the evidence to be grouped and facilitated the methods of constant comparison and pattern matching. This is because it was manually applied[22] to the relevant passages of textural data to isolate the details of the innovation implementation strategy and outcome as well as the innovation barriers that existed. The evidence detailing the three different facets of the implementation was coded using the third digit in the coding structure (Y_3). The different descriptions in the data were constantly compared between the two main data sets using the first digit in the coding structure (W_1). The second digit in the coding structure (X_2) was used in a similar way to compare evidence between different sources within the same data set. The coding process also helped highlight interesting aspects within each theme via a pattern matching technique. Contrary to the grouping mechanisms of the first three digits in the coding structure, the values for the final digit (Z_4) were set to fit particular aspects of interest (or patterns) within each theme as they arose. It was predominantly used for identifying different implementation barriers as well as different themes to the implementation strategy[23]. The findings from this analysis provide a descriptive exploration of a real-world innovation implementation.

[22] Manual application means using pen or highlighter on printed copies of the data as opposed to being applied digitally.
[23] In some cases this digit was not used and was entered with a place-keeping 'X'.

4.2 Findings

The findings are detailed accounts of the three focal themes for the exploratory investigation of innovation implementation. These descriptions are based on the data itself as well as the results from the textural analysis. Accordingly, what transpired over the lifecycle of the 4D CAD implementation is presented in terms of: 1) the strategy applied by the technology champions; 2) barriers to innovation implementation that were encountered; and 3) the implementation outcome. In addition to these findings, this preliminary study suggests three conditions that, if met, increase the chance of an effective innovation implementation.

4.2.1 The 4D CAD Modelling Implementation Strategy

The data show that a commitment by project management to implement 4D CAD modelling was agreed to before the project organisation submitted their tender. This was largely a result of the awareness of the benefits of 4D CAD modelling that the ACL technology group had established among project management. By gaining this agreement at an early stage in the tollway project, the 4D modelling implementation was budgeted for in the tender submission. When the project organisation was awarded the construction project, the existence of this budget removed most, if not all, cost-associated barriers that have historically prevented similar proposals for 4D modelling implementations (e.g. Collier and Fischer 1995).

Soon after the awarding of the contract, at the time when refinement of the construction schedule was commencing, 4D CAD modelling was applied to the largest and most complex interchange in the project. The rationale was that the 4D model would benefit the project as a schedule development tool for the planners by facilitating visualisation of the construction programme for the major interchange. The primary purpose of the 4D model was to aid in the resolution of spatial-temporal issues[24] in the construction programme, and a minor function was as an accessible, realistic 3D model of the interchange design for all interested stakeholders. An email from the Start-Up Planning Manager in Figure 4-3 (below)

[24] An example of a spatial-temporal issue is the need to correctly time the construction of a new bridge if it is required for use in a temporary or interim traffic phase.

captures the actual commitment to the 4D CAD modelling implementation by the TC_{PO} management (for further data see also Appendix A.1 *Participant notes made at start-up of TC_{PO} 4D modelling*).

From: [redacted]
Sent: Monday, 23 May 2005 3:55 PM
To: [redacted]; [redacted]; [redacted]; [redacted]; [redacted]
Subject: 4D Planning - [redacted] Cut
When: Thursday, 9 June 2005 1:00 PM-2:00 PM [redacted].
Where: Teleconference - [redacted]'s Office

[redacted]/[redacted]/[redacted],

We are going to do our first 4D planning exercise on the [redacted] cut. To ensure we can get this going as soon as the 4D hardware is available (approx 2 weeks time), I would like to set up a teleconference with the 4D modeller ([redacted]), [redacted], [redacted], myself and the relevant lead designer from [redacted]. The purpose is to establish what 3D design information will be available and if it is sufficient to allow [redacted] to undertake the 4D modelling. We can then agree actions to ensure the required 3D data is made available in the next two weeks to allow the 4D planning to commence on June 6.

[redacted], can you please advise who from [redacted] should attend.

Note that I will be in [redacted] with [redacted].

Regards,

[redacted]
Start-Up Planning Manager
[redacted]

Figure 4-3: Email from TC_{PO} Start-Up Planning Manager

The initial 4D model of the interchange construction was modelled off-site[25] by the technology champions. This model was based on the latest revisions[26] of 3D CAD design and construction schedule data supplied by the on-site project team. The technology champions believed it would be advantageous to have the initial modelling effort removed from the day-to-day workflows in order to present 4D modelling as an additional and complementary project delivery process with respect to the normal workflows. This meant the 4D CAD model was implemented with resources that were flexible and additional, which emphasised it as an incremental innovation for the project organisation and targeted adopters. As a result, start-up concerns commonly seen in project-participants were largely appeased.

[25] The term ‘on-site’ refers to work carried out at the main office of the project organisation. Thus ‘off-site’ work is that which occurs elsewhere, usually the normal office for the technology group at the head office of the implementing firm.
[26] Each design version is called a revision, for example, revision A, B, or C etc.

When the initial 4D model was introduced, it was installed in the planning section of the project's main office on a new computer (PC) dedicated solely to the model interrogation. This helped the ACL technology champions to establish an ongoing presence which helped foster support for the model (i.e. both the physical presence of the technology champions and the PC dedicated for its interrogation). The technology champions held one-on-one model interrogation training sessions for 30 minutes with five key personnel: four planners and one planning manager. The intention was for at least two of these project-participants (or targeted adopters) to become proficient at interrogating the 4D model (see Appendix A.2 *On-Site ACL Technology Team member Email Reporting on* TC_{PO} *Implementation Status*).

The technology champions had full control of the development and implementation of the 4D model except for one thing – any work associated with the 4D model had to be approved by the planning manager. This constraint was the only obvious implementation barrier that the technology champions had to negotiate. It was not significant however, and the technology champions worked both on- and off-site keeping the 4D model up to date and conducting on-the-spot training sessions with the planners with little impediment from this constraint. The less obvious barriers to implementation that were evident in the data were far more significant.

4.2.2 Barriers to Innovation Implementation

Staff turnover was found to be a significant innovation implementation barrier. Two of the four planners who underwent model interrogation training were transferred to other projects within a month of the initial model set up which excluded them as targeted adopters. Similar staff reallocations also added to the initial modelling effort in two other circumstances whereby key decision makers who were already familiar with the 4D model were transferred and their replacements had to be introduced to the technology.

Planning personnel weren't working with 4D model development in mind either. The collected emails show slow response times to requests from the technology champions as well as a constant concern that 4D modelling would take away valuable time from normal responsibilities (see the three emails in Appendix A.3 for a key example of this type of discontinuity). Furthermore, the field notes from informal communication networks show that the concerns of most project-participants about the model realising its intended benefits were more significant than their concerns about the cost of the 4D modelling work. This was also confirmed in the minutes of model review meetings and the notes from formal discussions between the technology team and planning management.

Generally, individual project-participants showed a low level of interest in the innovation. Field notes from key phone conversations provided evidence of this barrier as did the collected emails. This interest level appeared as insufficient because project-participants did not warrant the use of their spare time for the 4D modelling effort – the only time spent on it was that approved by planning management. The 4D model was generally seen as an extracurricular activity; it was more important for project-participants to get on with their usual work than to spend a lot of time becoming familiar with the 4D model or the technology itself. This barrier is clearly evident in the field notes in Figure 4-4 (below) that were taken from a key phone call conversation.

TCPO Transcribed Field Notes

060205 TCPO Transcribed Field Notes .doc

Date/s notes taken: 22.11.05 – 5 Months into Implementation

Event description: Phone call with TP

Project Participants Involved: [redacted] TCPO PLANNER (TP)
[redacted] ACL TECHNOLOGY CHAMPION (AC)

Field notes	Post-event notes	Code
Call purpose was to obtain the latest version of the construction schedule to update into the model but a conversation about the perceived merits of the 4D model ensued.		
TP: "While it's interesting to look at it we haven't used it that much at all and the vibe is that it's not worth it"	This sounds like general feedback about what the other planners are thinking too.	FPOX, FPBR, FPBB
AC: "I realise that the model doesn't include the earthworks but it shows the temporary traffic plans and construction of the structures, isn't easy access to that information useful?"		FPSX
TP: "Yeah that's good but I just never seem to have the time or a need to go to the machine and use it."	Need or inclination? These TCPO planners are very set in their ways.	FPBR, FPBB
AC: "Fair enough. If you do find yourself or any of the other guys using it we'll still be here to support any user interface issues or whatever"		FPSX

Figure 4-4: Transcribed field notes from a key TC_{PO} phone conversation[27]

A more functional barrier experienced by this implementation of 4D modelling is also evident in Figure 4-4. There was a misalignment between the levels of detail in design and construction schedule data. This meant that the 4D model experienced periods of stifled development while the technology champions were waiting for updated information. The evidence of this came by using the CAD and schedule (or programme) data to create research data. In some cases, field notes were made about particular pieces of CAD and schedule data thus combining the two forms of data. This evidence showed that although bridge construction and temporary traffic management activities in the schedule were detailed, those for

[27] The coding on the right in this figure corresponds to the structure shown in Figure 4-2.

the earthworks and road construction were lacking in detail and referred to sparse areas of land at the interchange. This created an imbalance in the 4D model that was spoken about during the phone call captured by the field notes in Figure 4-4 (refer to Appendix A.4 for the exploratory notes made just after this key TC_{PO} phone call).

Of the barriers to the implementation of 4D modelling that were evident at the TC_{PO}, the three most prominent were concisely stated as:

1. ***The reluctance of project-participants to engage in 4D modelling activity***
2. ***Misalignments in the level of detail for different parts of the construction program***
3. ***Insufficiently perceived benefits by project-participants.***

These three barriers are discernable in the context of the TC_{PO} 4D modelling implementation by considering their basic nature. Barrier 1 was apparent on a daily basis by the ways in which project-participants reacted to the 4D model with respect to its use and ongoing update. Barrier 2 is a functional issue that eventuated as a result of uncontrollable reasons more than human factors and was observable over weekly or monthly increments. Similarly, barrier 3 could only be identified from longitudinal data because the formulation of a project-participant's perception of benefit is something that requires the establishment of awareness, knowledge and a comprehension of the innovation's characteristics (Slaughter 2000; Rogers 2003). Each of the three main barriers had a significant negative impact on the outcome of the implementation.

4.2.3 The Implementation Outcome

According to the definition of an effective implementation used in this research (see 2.2.3), the 4D CAD modelling implementation at the TC_{PO} was ineffective. The implementation strategy employed by the technology group failed to achieve productive use by the adopters it targeted. This meant the opportunities for realising the intended benefits of the 4D model were few. This was noticeable in most of the data as there is very little evidence of any project-participants actually using or interrogating the 4D model, whether by themselves or by requesting the help of the technology champions.

A useful way to explain the implementation outcome is in terms of how the barriers prevented the productive use of the 4D CAD model. This is because the coded data that shows the implementation to be ineffective are closely aligned with that representing the implementation barriers encountered. Barrier 1, identified as 'the reluctance of project-participants to engage in 4D modelling activity', increased the time spent gathering design and construction schedule information. This problem was exacerbated by the number of locations from which the data inputs for the 4D model had to come despite the excellent standard of communication that existed[28]. In addition to this problem was the issue that once the information was gathered, there was a significant mismatch in the level of detail in the design and schedule data (barrier 2). This resulted in the 4D model accurately presenting the construction of the bridge structures and temporary traffic phasing but lacking clarity with respect to the staged earthworks and road surface constructions it presented. Regardless of the 4D model's adequacies however, it was seldom used productively, if at all.

Barriers 1 and 2 in some ways led to barrier 3 which also hindered the productive use of the 4D model. A day-to-day reluctance of project-participants (barrier 1) combined with the functional issue of barrier 2 made for large amounts of time spent gathering CAD and schedule information. During these periods the development of the 4D model was constrained and this had a knock-on adverse effect for the productive use of the model. Barrier 1 also had a direct contribution to the lack of attention to the use of the model. With most project-participants assuming observer rather than active roles in the 4D modelling effort, a quick and easy conclusion from their perspective could be made – 'the model is not

[28] This high standard was largely due to the web-based data and communication management system. The nature of the tollway project, that is a major PBE D&C project, and 4D modelling (presented by 3.2.1) accounts for the existence of so many stakeholders (see Figure 3-2) which could also have helped cause the reluctance of potential adopters to engage in 4D model activity.

complete therefore it is of no benefit'. This perception naturally had a negative effect on any intention the project-participants had to try and use the innovation.

Hypothetically, removing the barriers shows how a different outcome was possible. If the adopters had been keen to be involved in the 4D modelling effort, a better understanding of the technology may have been spawned. Without such reluctance, the benefits of the innovation may have been sufficiently perceived thus enabling project workflows to be oriented towards creating a more complete 4D model. If one of the trained project-participants had assumed the role of on-site champion by occasionally interrogating the model or exhibiting any personal interest, perhaps a significant in-house drive for model completion would have occurred. In this scenario, project-participants would be working with the 4D modelling effort in mind and the misalignment between the two major inputs to the 4D model (the 3D design and construction schedule) could have been addressed. In this circumstance, the project-participants would most likely have perceived the benefits far more positively because the interrogation of a detailed and more complete 4D model should have helped develop the construction schedule. Had this occurred, an effective implementation of 4D CAD modelling may have been realised.

4.2.4 Three Conditions of an Effective PBE Innovation Implementation

The three implementation barriers identified by the data analysis can be restated in positive terms as conditions that need to be met for an effective implementation to be realised (Miller, Radcliffe et al. 2006):

> *The data analysis suggests that even though the project organisation committed to the innovation implementation, an effective implementation cannot be realised unless the following conditions exist:*
>
> *• Sufficient perceived benefit exists in project-participants*
>
> *• A proficient user of the innovation is emergent on-site*
>
> *• The nature of the technology is recognised and realised.*

These three conditions, along with the hypothetical scenario described above, show how important mitigating implementation barriers are to achieving implementation effectiveness. These things also help identify which commonly experienced barriers were not witnessed by the TC_{POs} 4D CAD implementation as well as help explain the findings in terms of the theoretical constructs that exist in the literature.

4.2.5 Comparisons with Known Theoretical Constructs

Many of the common barriers to technology implementation were not witnessed at all by the TC_{PO} 4D CAD implementation. Two such examples were high costs and limited expenditure (Stewart, Mohamed et al. 2004). This was most likely due to the fact 4D modelling was established as a useful tool in the ACL technology group and its use on the project had been approved in the tender budget. The technology champions along with the 4D model itself had a purpose that was additional to the normal workflows of the project-participants. This fact and the complementary intentions of the implementation helped mitigate some of the more common barriers and made for smooth running during the early stages of the implementation.

Most of the barriers that were encountered after the initial implementation also fit with the literature. The reluctance of personnel to engage in 4D model activity (barrier 1) demonstrates aspects of three factors in the Stewart et al. (2004) model (Figure 2-6): 1) tight timeframes; 2) security and privacy concerns; and 3) the ever-present fear of change. An interesting variation to one of the factors in this model was the lack of perceived return on investment, or perceived benefit (barrier 3) being witnessed at the project and individual levels in key participants, rather than at the organisation level. The investment here however was one measured in terms of time used as opposed to money spent. This is also because the work was budgeted for and cost was not a major concern. Nevertheless, barriers 1 and 3 are perhaps best explained by theoretical constructs from implementation and user acceptance research. A number of these constructs were outlined in chapter 2 and by reflecting on them, a list of factors that plausibly could have contributed to the creation of barriers 1 and 3 was created, Table 4-2. These constructs were not found during the content analysis. Rather, it was in hindsight that they were identified as helping to explain why the barriers existed.

Table 4-2: Theoretical constructs possibly contributing to formation of implementation barriers

Implementation Barrier	Possible Theoretical Constructs
Barrier 1 – The reluctance of project-participants to engage in 4D modelling activity	Thompson and Higgins (1991): - Job-fit[29] - Affect[30] Rogers (2003): - Ease of use Compeau and Higgins (1995): - Self-efficacy[31] - Anxiety[32] Griffith (1996): - Motivation
Barrier 3 – Insufficient perceived benefit by project-participants	Rogers (2003): - Relative advantage - Image Klein and Knight (2005): - Managerial patience Venkatesh and Davis (2000): - Subjective norm[33]

The proposed theoretical constructs behind barriers 1 and 3 shown in Table 4-2 are all perception-based factors (Ramiller 1994). This is because the two barriers are a direct result of the way the project-participants perceived 4D CAD modelling and the particular aspects of the implementation. Finding the connection between these constructs with the formation of project-participant perceptions was a significant discovery for this research. This realisation is also consistent with the vast number of theories in implementation research (e.g. Stewart, Mohamed et al. 2004; Peansupap and Walker 2005a) as well as results from research into 4D CAD modelling (e.g. Khatib, Chileshe et al. 2007; Gao and Fischer 2008). This

[29] *Job-fit* is the extent to which a project-participant believes that using an innovation can enhance the performance of his or her job.
[30] *Affect* is an individual's liking for a particular behaviour.
[31] *Self-efficacy* is the judgment of one's ability to use an innovation to accomplish a particular job or task.
[32] *Anxiety* is anxious or emotional reactions evoked when performing a particular behaviour.
[33] *Subjective norm* is a project-participant's perception that most people important to them think they should or should not perform the behaviour in question.

finding helped shape the focus of the larger research project in the following section of this chapter.

Barrier 2, the availability of a detailed construction program, was unexpected and couldn't be readily explained by the literature. It could be viewed as having links with the reluctance of the project-participants to engage in the 4D modelling effort (barrier 1) although it was more likely that situational factors caused it to happen. The extensive earthworks that made up a large portion of the construction work on the interchange itself were not programmed in sufficient enough detail to allow the model to present the complete construction. Because this barrier did not align with any theoretical constructs and there is a possibility that it was an unfortunate anomaly, it does not exist as a significant finding in shaping the ongoing research project.

4.3 Refining the Focus of the Research

In this section the findings from the preliminary investigation are combined with the literature to better focus the research. The rationale is to document the critical and reflective thinking that occurred at the conclusion of the initial research phase in the context of the wider thesis. This is done by developing a series of propositions into a model regarding project-participant perceptions; a theme or implementation factor evident as influential in both the preliminary study and the literature. During this important narrowing of the scope, the motivating research questions are revised into a two-part question that summarises the refined focus and direction of the thesis. The proposal of the initial perception-influence model (the $P\text{-}I_1$ model) for further investigation culminates.

4.3.1 The Perceptions in an Innovation Implementation in PBE

To bring some clarity to the research at the time when the preliminary investigation findings were known, a set of three influential project-participant perceptions was proposed. The findings show a distinct connection between practice and theory[34]. However, they also allude to some of the ambiguities identified in chapter 2. With

[34] This connection is also indicative of the real-time links to the literature that were inherent to the research design through the analysis methodology. Appendix A.5 shows an example of researcher notes that emphasise this connection.

a view to resolving such ambiguities and helping to better understand innovation implementation in PBE, the set of three perceptions shown in Figure 4-5 were posited. This was the first step to developing a synthesis.

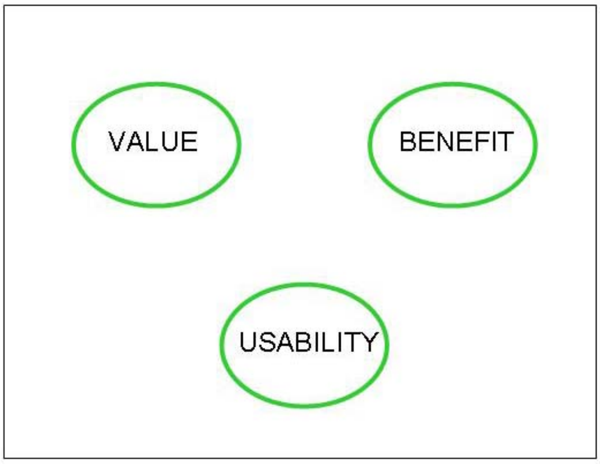

Figure 4-5: Initially proposed set of influential project-participant perceptions

Each of the three project-participant perceptions has embedded meaning associated with the fundamental principles of innovation diffusion and implementation research. In Figure 4-5, the terms for each perception and the way they are arranged (in a left-to-right and top-to-bottom sense) allude to when each perception is formed and/or when it becomes important throughout the progression of an innovation implementation. This is in keeping with the pre- and post-implementation categories for the attitudes and beliefs of potential adopters (Drury and Farhoomand 1999a) as well as the five diffusion stages from Rogers (2003). The 'value' perception is proposed to be the main pre-implementation perception that leads to a commitment to the proposed innovation (or otherwise). The 'benefit' and 'usability' perceptions may begin to form in the minds of project-participants before an implementation has been committed to but they develop and are more important as the implementation proceeds. An important question associated with each perception is given by Table 4-3 in order to explain the essence of each proposed perception construct.

Table 4-3: A pertinent question for each initially proposed perception.

Perception	Pertinent Question
VALUE	Is it worth committing the required investment and resources to the innovation implementation?
BENEFIT	Will this innovation bring sufficient benefits to existing and/or required workflows?
USABILITY	Is this innovation easy to use?

These simple questions helped identify the need to have separately labelled perceptions for the two different types of project-participants – project management and individual users. Financial concerns are mostly associated with the perception of ‘value’ in project management, while most beliefs and concerns about the ‘usability’ of the proposed innovation will come from the individuals at the project who are responsible for actually using the innovation. These two associations are logical, however the perception of ‘benefit’ has an association with both decision-making levels therefore it needs to be divided. Two perceptions of ‘project benefit’ and ‘personal benefit’ emphasise the separation, thus expanding the set of three perceptions to a set of four. Project management are concerned about the benefits an innovation brings to the project in a global sense whereas an individual will be more concerned about how the innovation benefits his or her own workflows. In a further development of the emerging theory, a bank of encompassed contributing factors was proposed for each of the four perceptions – Table 4-4. The term ‘encompassed’ is a commonly used term in this sense (e.g. Jamieson 2007; Walker, Bourne et al. 2008a) and the four perceptions are referred to as ‘encompassing perceptions’ hence forth. In taking this stance, a proposition was tacitly made.

Table 4-4: Contributing factors to project-participant perceptions – initial phase

	Perception	Contributing Factors
Project Management	VALUE	**Transaction costs** (Williamson 1975) **Results demonstrability** (Rogers 2003) **Management support** (Klein and Knight 2005)
	PROJECT BENEFIT	**Job-fit** (Thompson and Higgins 1991) **Relative advantage, Image** (Rogers 2003) **Managerial patience** (Klein and Knight 2005) **Motivation** (Griffith 1996)
Individual User	PERSONAL BENEFIT	**Job-fit, Affect** (Thompson and Higgins 1991) **Relative advantage, Image** (Rogers 2003) **Subjective norm** (Venkatesh and Davis 2000) **Motivation** (Griffith 1996)
	USABILITY	**Compatibility** (Ramiller 1994; Rogers 2003) **Ease of use, Voluntariness of use** (Rogers 2003) **Self-efficacy, Anxiety** (Compeau and Higgins 1995)

Table 4-4 lists and references the theoretical constructs that could be plausibly linked as being encompassed by each of the four perceptions. They were proposed by comprehending the findings from the TC_{PO} data analysis in combination with the implementation theory literature. They are the initially proposed factors that can contribute, depending on the circumstances of a given innovation implementation, to the formation of each of the four proposed project-participant perceptions. These factors have been described in the literature using a number of terms, the most prominent of which have been *reactions, opinions, attitudes, beliefs* and *concerns,* therefore, the most appropriate for this thesis needed to be selected. The terms *attitude* and *belief* have mainly been used in studies that analyse data collected by survey and/or questionnaire, whereas this research proposes a model theorised from empirical data collected via nonreactive techniques (e.g. emails and field observations). With this in mind, it makes sense to refer to the contributing factors using terms that immediately suggest they are observable implementation factors. To this end, the terms *opinions* and *concerns* were chosen.

Opinions and concerns as contributing factors to perceptions

The theoretical constructs that make up user acceptance models in implementation theory can be thought of as opinions (Fishbein and Ajzen 1975), or concerns about anything associated with the innovation being implemented (e.g. Malone 1984). By considering these parts of implementation theory in this way, their similarities and applicability to the collective formation of the same perception (e.g. reluctance) becomes apparent. A study by Holahan and colleagues (2004) investigated the notion of collective human perceptions in the implementation of a new innovation and concluded that they are influential. This thesis follows the recommendations of the study by Holahan and colleagues (2004) in three ways: 1) in searching for an understanding of the antecedents of implementation effectiveness; 2) by studying longitudinal examples of implementations; and 3) by developing a synthesis of adopter opinions and concerns.

Adopter opinions and concerns associated with an innovation implementation, such as those listed in Table 4-4 above, can be separated into two categories: those that are formed before the implementation and those formed during it (Drury and Farhoomand 1999a). Those formed during an implementation are largely associated with the characteristics of the innovation such as with *ease of use* and *job-fit* (see sections 2.1.1 and 2.2.5 respectively). Those formed before an innovation implementation, often in the persuasion stage of its diffusion (Rogers 2003), are associated with beliefs about how effective the innovation will be and how well the targeted adopters might use it. They are often used in determining whether a project organisation should commit or otherwise to an innovation implementation (Walker 2002). An example of this type of theoretical construct is the cost of the innovation. Theories about actual *transaction costs* can be found in economic literature (e.g. Williamson 1975) however the construct in this thesis refers to a project-participant's opinion or concern about the *transaction costs* as an aspect of an innovation implementation. In a similar way, opinions or concerns about the *results demonstrability* of an innovation (Rogers 2003) and about the availability or likelihood of *management support* (Klein and Knight 2005) exist as important theoretical constructs in an innovation implementation.

Like a lot of theoretical constructs, most of those used in this thesis have been studied under different pretences and with other interpretations by authors. A good example can be seen in a study carried out by Davis (1989) that investigates the perceptions of *usefulness* and *ease of use* with the aim of developing an improved measure of each. There are two terminology differences here: 1) the definition of *usefulness*[35] used by Davis (1989) is synonymous with that of the *job-fit* construct (see Table 4-2); and 2) the term 'perception' is used in a different sense to that applied in this thesis. With the existence of this type of ambiguity it is vital that any proposed synthesis should identify them and include a solution. To this end, where competing terminologies such as *job-fit* and *usefulness* exist, one term was chosen and the other posited as a 'paralleling construct'. In this case, the term *job-fit* seems more explanatory, therefore it is used hence forth as the label for a secondary construct that is paralleled by *usefulness*. In taking this stance the proposition of a parallel relationship between certain theoretical constructs in implementation theory was made.

During the thought process described in this section (4.3.1), the basic motivating question stated in chapter 1[36] and the research questions that emerged from chapter 2[37] were combined and revised to summarise the new focus and direct the ongoing research project.

4.3.2 The Focused Research Question

The succinct statement of a two-part research question, at a time when the findings from the initial research phase had been discovered, captured the micro context of inquiry for the thesis:

[35] Usefulness is the extent to which an innovation contributes to the enhancement of the user's performance (Davis 1989).

[36] What factors influence an innovation implementation in project-based engineering?

[37] 1) For an innovation with justifiable benefits to a project, what causes project managers to decide not to implement it?

2) Why do innovation implementations fail after project management decides they are a good investment?

3) At the individual decision-making level within a project organisation, what implementation factors significantly influence the process of innovation implementation?

> ***"What influences do the perceptions of project-participants have on the outcome of an innovation implementation and how is the perception-influence relationship played out across the implementation lifecycle?"***

This refinement to the focus and direction of the thesis immediately inspired the collation of all propositions and critical thoughts about the factors involved in innovation implementation into a model.

4.3.3 The Initial Perception-Influence Model: P-I_1 Model

The P-I_1 model (Figure 4-6) is the original sketch that pictorially assembled the work to date at this early stage of the research into a format that could be developed. In other words, the inputs to the P-I_1 model were: 1) what had become known from the review of literature; 2) the TC_{PO} analysis findings; and 3) the reflective thought processes that made use of both 1) and 2).

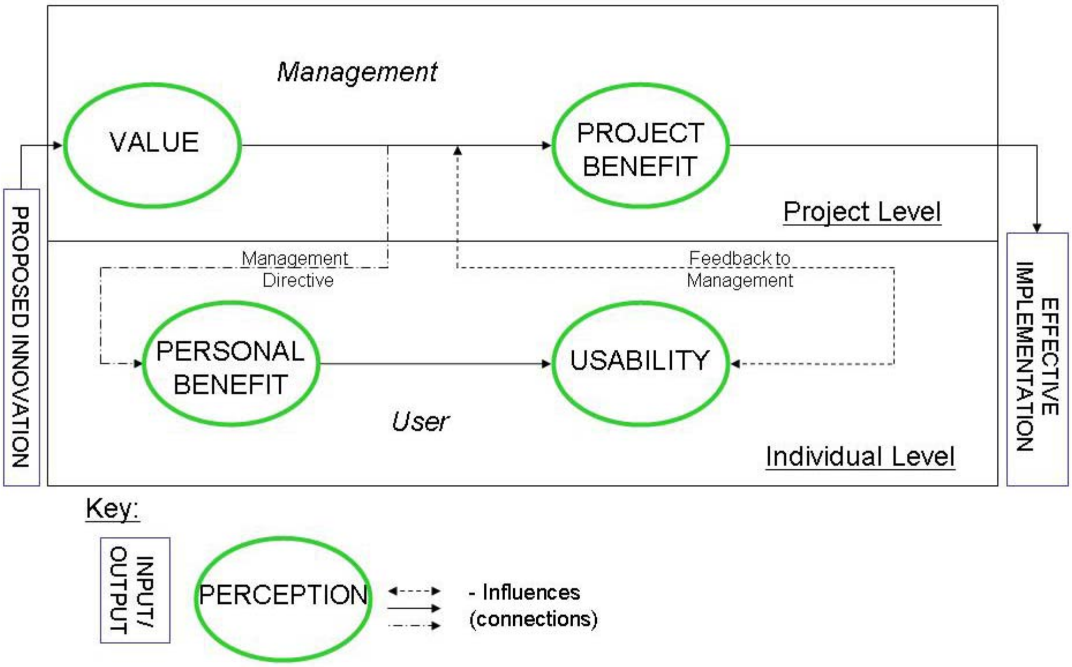

Figure 4-6: Initial perception-influence model, P-I_1 model

The P-I_1 model presents a possible map of an implementation lifecycle that uses four participant-perceptions as primary constructs and the influences they provide as the connecting secondary or transmittal constructs. The perceptions of value and project benefit are at the management or project level while personal benefit and usability perceptions are at the individual or user level. Each perception is formed by a number of contributing factors (theoretical constructs from implementation research literature) that exist as individual opinions or concerns about the different aspects of an innovation and its implementation. In the context of the model they are secondary constructs. The opinions or concerns a project-participant holds will be positive, negative or indifferent and they contribute accordingly to the formulation of the relevant perception. In turn, each perception has an influence on the ongoing implementation and may also influence the formulation of other perceptions in the model. This possibility is allowed for by the inclusion of the connections which represent the communications that occur between the project-participants in real life.

The conception of the P-I_1 model is the first step towards gaining a better understanding of the micro context of inquiry taken in this thesis. It is a notional synthesis in the field of implementation research in which the most prominent propositions are the two types of relationships between the theoretical constructs in the implementation literature:

1. ***Encompassing*** – With regards to perception-based constructs in implementation research, a theoretical construct encompasses another in a primary–secondary or parent–child like relationship if the encompassed construct is a contributor to the formulation of the encompassing construct.

2. ***Paralleling*** – With regards to perception-based constructs in implementation research, a theoretical construct is paralleled by another if it has a significantly similar or synonymous definition but is labelled using a different term or terminology.

While these present as plausible propositions, further investigation of each as well as the integrity of the P-I_1 model is required. There may also be other types of ambiguities that can be identified, proposed and perhaps resolved as part of the suggested and evolving synthesis. Furthermore, in order to adhere to qualitative research traditions, the initial theory of the P-I model requires extensive subsequent development and evaluation. To this end, the P-I_1 model is developed through two revisions by the middle research phase.

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5 The Development of the P-I Model

Implementing an innovation… is a process of internal diffusion, involving numerous individual 'secondary' adoption decisions by target users even after successive layers of management have passed along the 'authority decision'. (Leonard-Barton and Deschamps 1988)

This chapter presents the theory-generation (middle) phase of the research in which the P-I model was developed. The research data for this phase came from four separate instances of innovation implementation, each a different construction project organisation implementing an innovation – 4D CAD modelling. The researcher immersions and data collection at each were carried out in much the same way as those in the preliminary investigation with the exception that the data gathering was more focused. The data analysis was facilitated by NVivo7 and involved iterative interpretation of the data, therefore in explaining this analysis it is divided into 'early' and 'later' iterations to help explain the outcomes. The main outcomes from the early analysis iterations were the embodiment[38] of the $P\text{-}I_1$ model constructs with empirical data and a developed coding structure which translates to an extended bank of secondary P-I model constructs. In this chapter a comparison of these findings with the literature leads to the proposition of another type of primary construct and it, along with the new secondary constructs, was included in 'the developed P-I model': the $P\text{-}I_2$ model. The outcomes from the later analysis iterations are the embodiment of the new constructs in the $P\text{-}I_2$ model, the proposition of some small changes in 'the final P-I model revision', the $P\text{-}I_3$ model, and a suggested method for compiling a P-I model. Figure 5-1 below presents an overview of this inductive phase of the research design.

[38] Embodiment is the descriptor for the process of garnering empirical evidence for particular theoretical constructs.

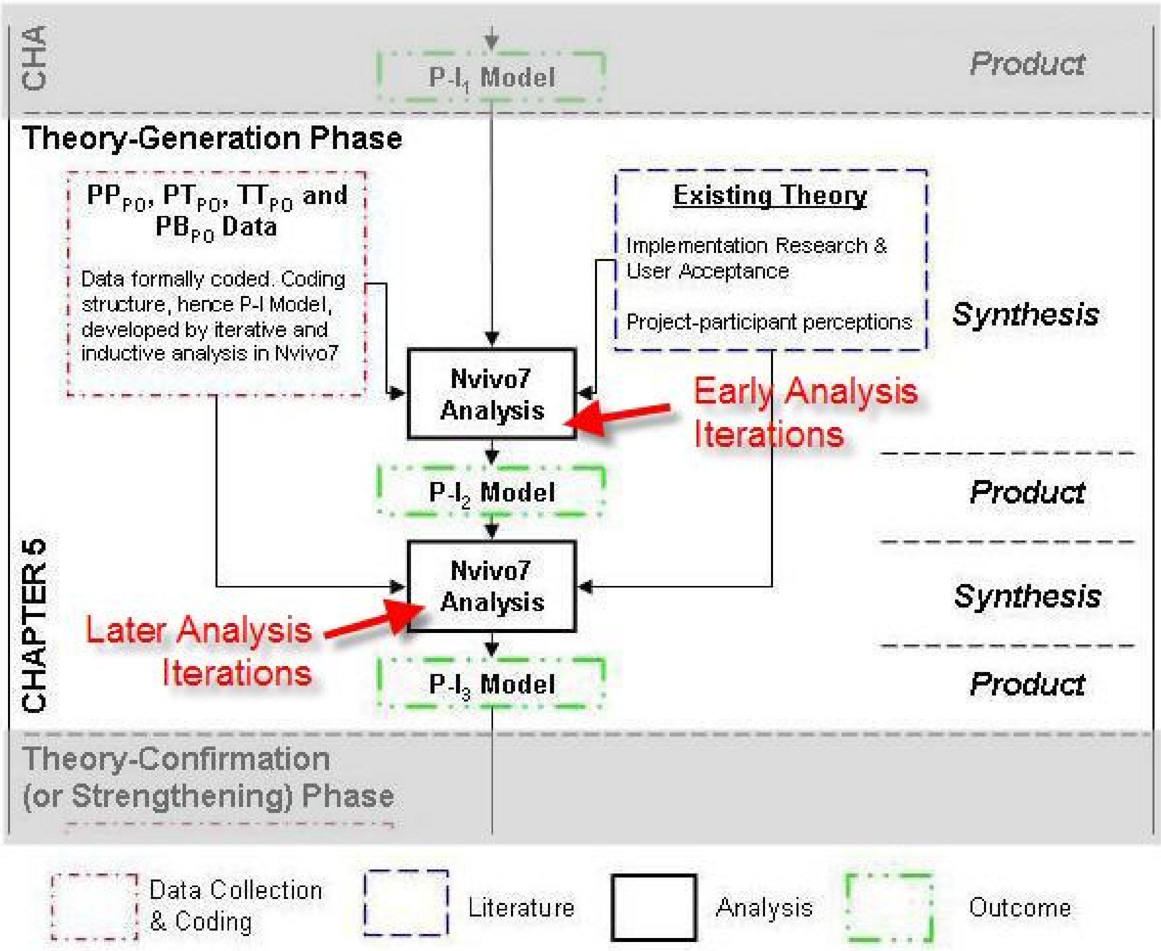

Figure 5-1: Research design – Middle research phase

Figure 5-1 presents the concepts and terms that are important for explaining the structure and delivery of the middle research phase. Constant inputs from and reference to the literature is an ever-present part of the analysis. Relevant studies are called on to explain the operational aspects of NVivo7 used to perform the qualitative data analysis and also to extend the understanding of the primary constructs in the P-I_1 model, the four perceptions.

Regarding the flow of the chapter, the NVivo7 operations are explained as a lead-in to how they were used in the analysis. Then, the findings from the early analysis iterations are documented. After this, the extension of the theoretical background for the construct of a perception is presented because this was the chronological stage in the development of the P-I model at which it was attained. This reflective period is emphasised by the separation of the early and late analysis iterations and it leads to the inclusion of 'actions' as new primary constructs in the P-I_2

model. The outcomes from the later analysis iterations are then documented and a summary section is included to finalise the chapter.

5.1 Four Innovation Implementations Studied

The definition of a micro context of inquiry in the initial research phase provided direction to the theory generation phase. In moving forward, that process also provided me with a valuable grounding in the technique of participant-observation. Having been an immersed participant-observer once, I was able to refine the protocol during this subsequent research phase. Being able to look specifically for evidence of theoretical constructs from the P-I_1 model as well as associated data that could contribute to its development had a significant impact in creating more-focused data sets. This was because I could be selective with the documentation collected and there was more guidance for recording observations. The savings in time and effort that resulted during the data collection allowed the middle research phase to include data from a total of four 4D CAD modelling implementations by major construction project organisations.

5.1.1 Project Organisation Descriptions

The innovation implementations studied during this phase of the research involved project organisations (POs) from the civil infrastructure, coal processing and private building construction industry sectors. The backgrounds of the four POs and the projects they were contracted to deliver as well as the scope and outcome of the 4D modelling performed at each project is summarised in this section. A short-hand notation is used to refer to each project. The first two letters of the full title identify it and the subscript ‘PO’ is used to indicate it is a project organisation, the exemplar entity implementing an innovation.

Process Plant Project Organisation (PP_{PO})

The PP_{PO} was delivering the design and construction (D&C) of an upgrade to an existing coal-processing plant[39]. The upgrade was to increase the processing

[39] A coal-processing plant accepts raw coal from a mine (in this case, by overland conveyor) and separates the waste from the coal then washes and loads it onto transport (in this case, railway).

capacity of the plant by about 70% at a cost of approximately A$300 million. When the D&C contract was awarded to the PP_{PO}, it was the largest of its kind in the Australian coal industry. In the alliance-type PO, ACL was one of the primary construction contractors and the technology group was employed by the PP_{PO} to create, implement on-site and maintain a 4D CAD model of the design and planned construction. The rationale of the 4D CAD model was to improve the planning and coordination of the steel structure construction with plant machinery installations, both spatially and temporally. The model succeeded in this endeavour and the implementation was effective (Appendix B has key excerpts from the data collected at the PP_{PO}).

Public Transport Project Organisation (PT_{PO})

The PT_{PO} was delivering the D&C of a new section of a busway. At a cost of about A$200 million, the section of busway to be constructed was 1.5km long and included two bus stations and a short tunnel. The PT_{PO} was an alliance between a government transport authority and ACL as the primary construction contractor. The technology group was employed by the PT_{PO} to create, implement on-site and maintain a 4D CAD model for the part of the job that included the larger bus station. The objective of the 4D CAD model was to help present the construction plans to external stakeholders. The outcome was an ineffective implementation and this is confirmed by the PT_{PO} data (see Appendix D for PT_{PO} data excerpts).

Tunnel Tender Project Organisation (TT_{PO})

The TT_{PO} was tendering for the construction of a A$3 billion traffic tunnel project. The scope of works that included an approximate tunnel length of 5km was required to have four different tunnel portals[40]. ACL was one of the primary construction contractors in the alliance and the technology group was employed by the TT_{PO} to create, implement on-site and maintain a 4D CAD model of the 3D design and planned construction for one of the tunnel portals. The primary intended benefit of the 4D CAD model was to improve the presentation and communication of the scheduled construction works as well as interim traffic

[40] A tunnel portal is a surface entry for primary access. In this case, the portals were for traffic (i.e. cars and trucks).

management plans. These communications were between the TT_{PO} management and the stakeholders responsible for assessing the tender submissions and awarding the contract. The objectives of the 4D model and the implementation thereof were achieved (see Appendix C for TT_{PO} data excerpts).

Private Building Project Organisation (PB_{PO})

The PB_{PO} was delivering the construction of a A$400–500 million sporting facility. The technology group was requested by project management to propose an implementation of a 4D CAD model showing the planned construction. The main benefit of the 4D model was to help planners and construction management develop the construction schedule. The PB_{PO} project management ultimately decided not to implement 4D CAD modelling but for simplicity it is referred to as an implementation example. In this way it provides a good example of a negative perception of 'project value'. The reason it was not implemented is evident in the data that were gathered (see Appendix E for excerpts) and described in some sections of this chapter.

5.1.2 Data Gathered

The emphasis of the collection processes was on data that embodied any of the contributing factors in the $P\text{-}I_1$ model. Regarding the project documentation collected, the data sets eventually analysed were actually a small selection from many more available documents. I looked for detailed data related to how project-participants experienced innovation implementation day to day. Therefore of upmost importance was data that provided evidence of any project-participant perceptions, opinions or concerns about the 4D CAD implementations. Data that had lesser, descriptive association with the micro context was also collected but often these textural passages were either not included in the analysis or were transcribed to very brief summaries (i.e. for the case of field observations). The intent of this on-the-run filtering of the data were a logical approach to precluding data that would have no contribution to the focused investigation. This made for a significantly different data collection to that in the initial phase even though the same participant-observation and nonreactive[41] methods were being used. Table 5-1 summarises the data that was collected and analysed during the middle research phase.

Table 5-1: Data gathered from the PP_{PO}, PT_{PO}, TT_{PO} and PB_{PO}

Project Org.	Data Sets	Item/Source
Process Plant Project Organisation (PP_{PO})	Project Documentation	Emails regarding the 4D CAD implementation (33 emails) Other documents (6 pages)
	Observations	Researcher field notes from the 4D CAD implementation (12 pages – 6 pages when transcribed)
Public Transport Project Organisation (PT_{PO})	Project Documentation	Emails regarding the 4D CAD implementation (57 emails) Other documents (3 pages)
	Observations	Researcher field notes from the 4D CAD implementation (21 pages – 9 pages when transcribed)
Tunnel Tender Project Organisation (TT_{PO})	Project Documentation	Emails regarding the 4D CAD implementation (71 emails) Other documents (6 pages)
	Observations	Researcher field notes from the 4D CAD implementation (27 pages – 10 pages when transcribed)
Private Building Project Organisation (PB_{PO})	Project Documentation	Emails regarding the 4D CAD implementation (7 emails)
	Observations	Researcher field notes from the 4D CAD implementation (7 pages – 3 pages when transcribed)

The emails exchanged about the 4D CAD implementations provide authentic evidence of the theoretical constructs that the $P\text{-}I_1$ theory proposes. They are the immediate thoughts, expressions and reactions to the 4D CAD implementation of the project-participants. Similarly, there is an inherent but perhaps less obvious authenticity in the other documents that were collected (e.g. meeting minutes, reports and training documents). Together they contribute as part of the project documentation data sets from each project organisation. This data source was

[41] Methods of gathering data whereby the subjects contributing data are not affected by the process of collecting it so that events are witnessed naturally.

favoured as the first choice to lead the empirically driven exploratory analysis due to its natural authenticity.

The data obtained directly from the words and work products of the project-participants were complemented by the observations or field notes. The authenticity of the transcribed field notes in the observations data set was due in part to the fact they were recorded unobtrusively (or via nonreactive methods) but also because they existed as an actual account of the micro context of inquiry. These observations were transcribed from their handwritten form into electronic text which enabled compression[42] thereof and import to NVivo7 (QSR International 2007).

5.2 NVivo7 Data Analysis

Just as the data collection was more streamlined and detailed in the middle research phase, so too was the data analysis. This was largely because a software application was used to collate and analyse the collected data. NVivo7 is a qualitative data analysis software application that provides a suite of tools for handling large data sets so that the content of the data can be easily and systematically explored (Richards 1999). The tool helps the researcher to record and link specific ideas as part of the analysis process which allows patterns within the data to emerge and the divisions between the data and its interpretation to be removed (Richards 1999).

This section (5.2) explains the NVivo7 operations that were used to perform the data analysis in both the middle and final phases of the research. It begins with a general explanation of the specific NVivo7 operations that were used to perform the analyses (5.2.1) which is useful for those readers who have a limited or no understanding of NVivo7. The section (5.2.2) that follows expands this basic understanding in an explanation of how the propositions from the initial research phase (i.e. the P-I_1 model) were built into and used in the NVivo7 data analysis.

[42] The field notes were condensed during the transcription process by filtering out the main details from the handwritten text and reconstructing the descriptions in a shorter, more concise hand. Many were event focused and categorised into real-time and post-event field notes as in Figure 4-4.

5.2.1 Qualitative Methods by NVivo7 Operations

In simple terms, NVivo7 allows the researcher to sort the data and make the important parts readily accessible. The specific analytic functions for which it was used were: 1) sorting and coding each piece of data by source; 2) establishing the coding structure elements in an NVivo7 analysis file; 3) coding the data; and 4) searching within the coded data. This section presents a general explanation of how these basic qualitative methods are performed in NVivo7. It introduces the Graphical User Interface (GUI) and associated terminologies shown in Figure 5-2 that come from the NVivo7 User Guide (QSR International 2006). Furthermore, the four methods are shown in this section to be delivered by the researcher processing the data in the *Navigation View, Detail View* and *List View* parts of the NVivo7 GUI.

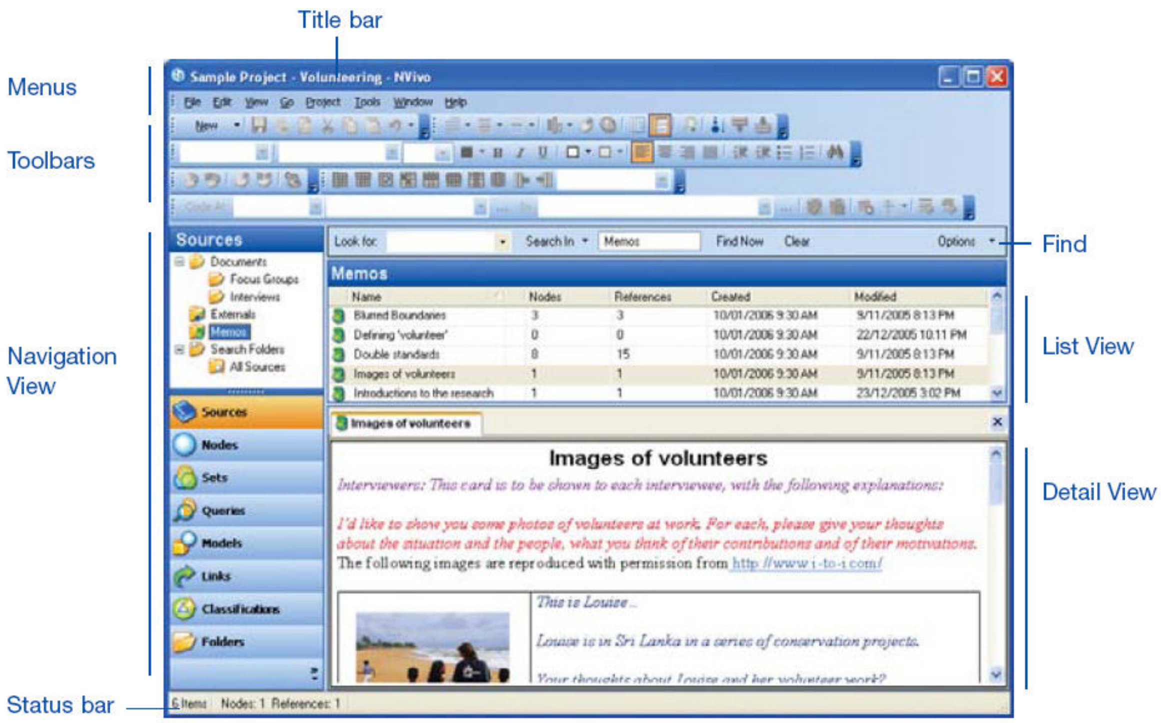

Figure 5-2: The NVivo7 Graphical User Interface, GUI

Figure 5-2 is a screenshot from a typical NVivo7 analysis that shows the names of the different GUI windows (or views). In order to understand how the qualitative methods were delivered by the data analysis the basic NVivo7 operations need to be comprehended; hence the inclusion of this explanatory section (5.2.1). Furthermore the associated terminologies and nomenclature, most of which are contextually unique to NVivo7, are defined as part of the important explanation.

Sorting and coding each piece of data by source

Figure 5-3: NVivo7 Sources navigation view

The lower left-hand corner of the NVivo7 GUI has the main controls used to access the different organisational and analytic functions in NVivo7. It is known as the *Navigation View*. This control panel is shown by Figure 5-3 with the *Sources Navigation View* activated to present how NVivo7 locates any imported documents in source folders. Any text file in a common format can be imported to folders created by the researcher under either the *Documents* or *Externals* folders. The intention is that textural data be imported and organised in the documents folder, and attached external data (such as audio, video and images) be organised in the externals folder (QSR International 2006). The *Search Folders* function is available with the *Sources Navigation View* active and this also occurs when the *Nodes* view is active (see Figure 5-5 below). It allows the researcher to quickly see the exact computer directory where the data is located.

Notes made in the process of setting up, coding and searching in an NVivo7 analysis file are entered into an NVivo7 analysis file as *Memos* or *Annotations*. Memos are linked to the data source or particular parts of the coding structure that they are relevant to (i.e. NVivo7 nodes). They can be sorted into different folders and coded in the same way as the imported documents and externals. Annotations can be inserted and linked to particular passages of data but not coded as actual research data. They are useful in making exploratory notes however, and can be accessed via the source or node they are linked to.

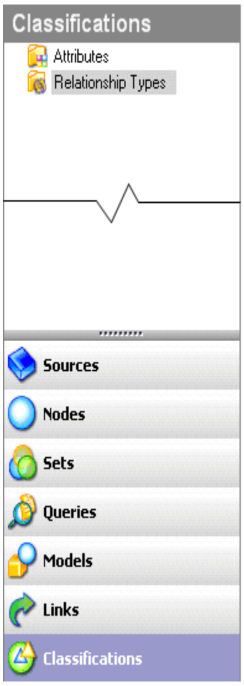

Figure 5-4: NVivo7 Classifications navigation view

A researcher can also formally code the origins of a document in NVivo7 by creating source attributes in the *Classifications Navigation View* (Figure 5-4). If an *Attribute* is created for each relevant origin for a piece of text in a project, it is simply applied by right-clicking on the appropriate imported documents and ticking a check box for that source *Attribute*. Attributes can be set to any distinguishing feature or characteristic of a data source so that the data from that source can be retrieved or searched through at a later date based on the set criteria. This is an aspect of NVivo7 that gives significant freedom to the researcher in tailoring the coding structure to the specific research aims.

The *Relationship Types* tab in Figure 5-4 works in much the same way. In this tab the different aspects of each relationship element in the coding structure can be set. The most common use for relationship types is to provide directional properties to each relationship in the coding structure. For example, communication between a boss and employee is evidence of one relationship but it could be upstream or downstream in type. The relationships and other main elements of a coding structure are built into an NVivo7 analysis via the *Nodes Navigation View*.

Establishing the coding structure elements in an NVivo7 analysis file

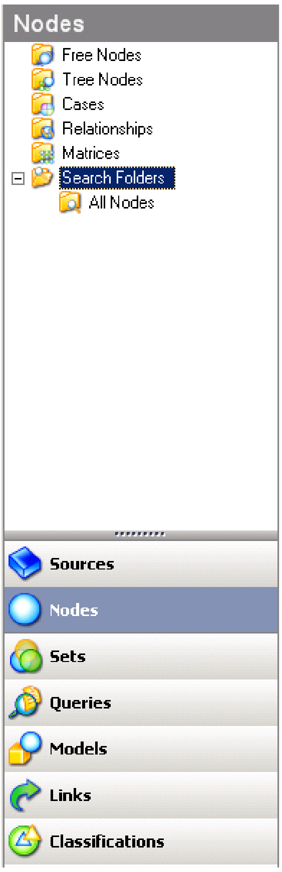

Figure 5-5: NVivo7 Nodes navigation view

The coding structure in qualitative analyses performed using NVivo7 needs to be built into an NVivo7 analysis file. This is done via the *Nodes Navigation View* (Figure 5-5). There are four main ways in which the various types of theoretical constructs and aspects of interest in the data can be differentiated by a researcher who is building a coding structure into NVivo7. *Free Nodes* tend to be used for explicit constructs whereas *Tree Nodes* allow for subcategories within the one coding structure element. This is achieved by creating a *Parent Tree Node* element with associated *Child Tree Node* elements. Similarly to these two nodal types of coding structure elements, *Cases* and *Relationships* can also be created and used at the researcher's discretion to represent aspects of the data that are or could be valuable to code.

The *Matrices* tab is not an option for the coding of data, rather a folder where the results of searches within the coded data can be stored. It is unused by this research because search results are stored in the *Results* tab within the *Queries Navigation View* (see Figure 5-7 below). Before searches can be run however, the researcher has to code the data.

Coding the data

When the *Nodes* and *Classification*s that make up the coding structure have been built into NVivo7, the data is coded by using all three views in the GUI (see Figure 5-2 and 5-5). Each document or attached external is retrieved by navigating to it through the *Sources Navigation View.* The *List View* shows each data item that has been imported from a particular source and allows the researcher to open them by double-clicking. Each opened data item appears on a tab in the *Detail View.* From this view, the text in each data item can be coded by highlighting and right-clicking on the mouse to bring up the nodes, cases and relationships in the coding structure. A screen print from one of the NVivo7 analysis files is shown in Figure 5-6 to clarify this procedure.

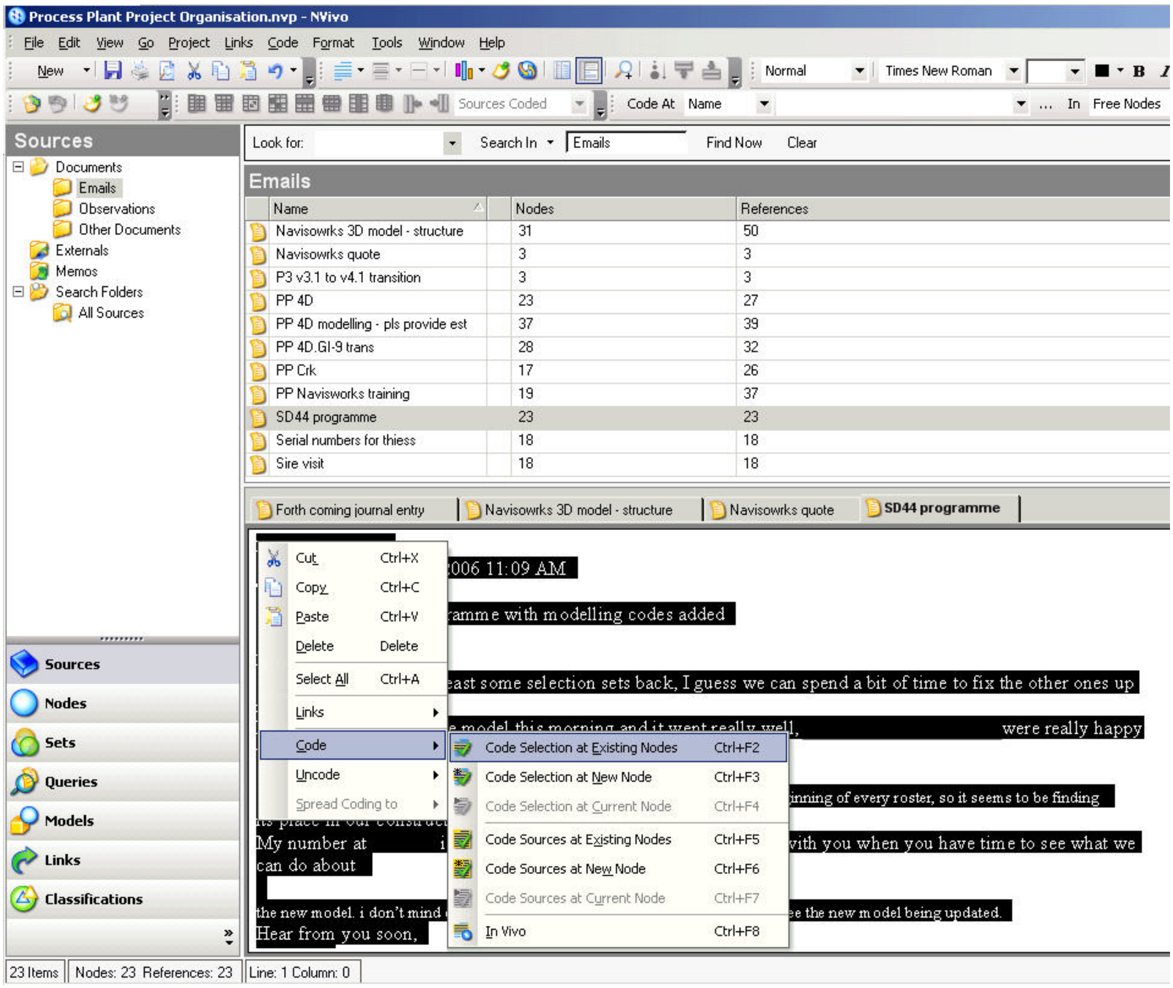

Figure 5-6: Coding data in NVivo7

This screen print also shows some of the more basic functions NVivo7 provides. The *List View* tracks and presents statistics about each data item such as how many times that document has been coded (in the *References* column) and how many different nodes in the coding structure the different passages of text within it have been coded to (in the *Nodes* column). Figure 5-6 also shows how text can be uncoded if an error has been made and how the coding structure can be added to during the coding procedure (i.e. via the *Uncode* and *Code Selection at New Node* options, respectively). Even though these are basic functions, it is important in exploratory research to have mechanisms that allow for error correction and for new coding structure elements to emerge from the data. Perhaps the most common way of finding new coding structure elements and hence theoretical constructs in qualitative analysis is searching within coded data sets.

Searching within the coded data

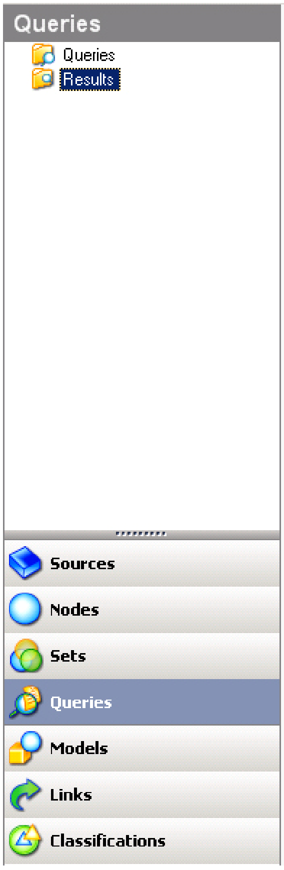

Figure 5-7: NVivo7 Queries navigation view

Searches within coded data in NVivo7 are established and run as *Queries*. The NVivo7 Getting Started Guide summarises their purpose and how they operate (QSR International 2006):

> *Queries enable you to question your data, find patterns and pursue ideas. You can save queries, re-run them through new data and track the evolution of results.*

Queries can be as simple as a word search or as complex as a compound coding inquiry involving logic functions of any elements within the coding structure. The *Results* tab saves the outcomes of every query that is run along with the details of when it was run and how many sources and references were identified.

The two remaining navigation views are for *Sets* and *Models*. Although the *Sets Navigation View* (not shown) provides a number of ways for data to be grouped together, sets were not used by the analysis in this research. The *Models Navigation View* (see Figure 5-9 in 5.2.2, below) allows the researcher to set up schematic diagrams for accessing the coded data. Elements within the coding structure (i.e. nodes, cases or relationships) can be linked to model components. By double-clicking on a particular component, the researcher can access the data coded to the linked element. This function provided a useful, visual parallel between the P-I_1 model and the NVivo7 analysis in establishing and applying the initial coding structure.

5.2.2 The P-I_1 Model Coding Structure and Procedure

The P-I_1 model from Figure 4-6 (section 4.3.3) and the theory behind it provided the initial coding structure that was built into the NVivo7 data analysis. A logical approach was to add the primary constructs, or four project-participant perceptions, from the P-I_1 model (see Figure 4-6) as *Tree Nodes* in the NVivo7 coding structure. This enabled the secondary constructs, or contributing factors (see Table 4-4), to exist in a 'child–parent like' position with respect to the primary constructs. Figure 5-8 shows how each of the perceptions in the P-I_1 model were added as parent tree nodes in NVivo7 and how the contributing factors (or opinions and concerns) were included as child nodes.

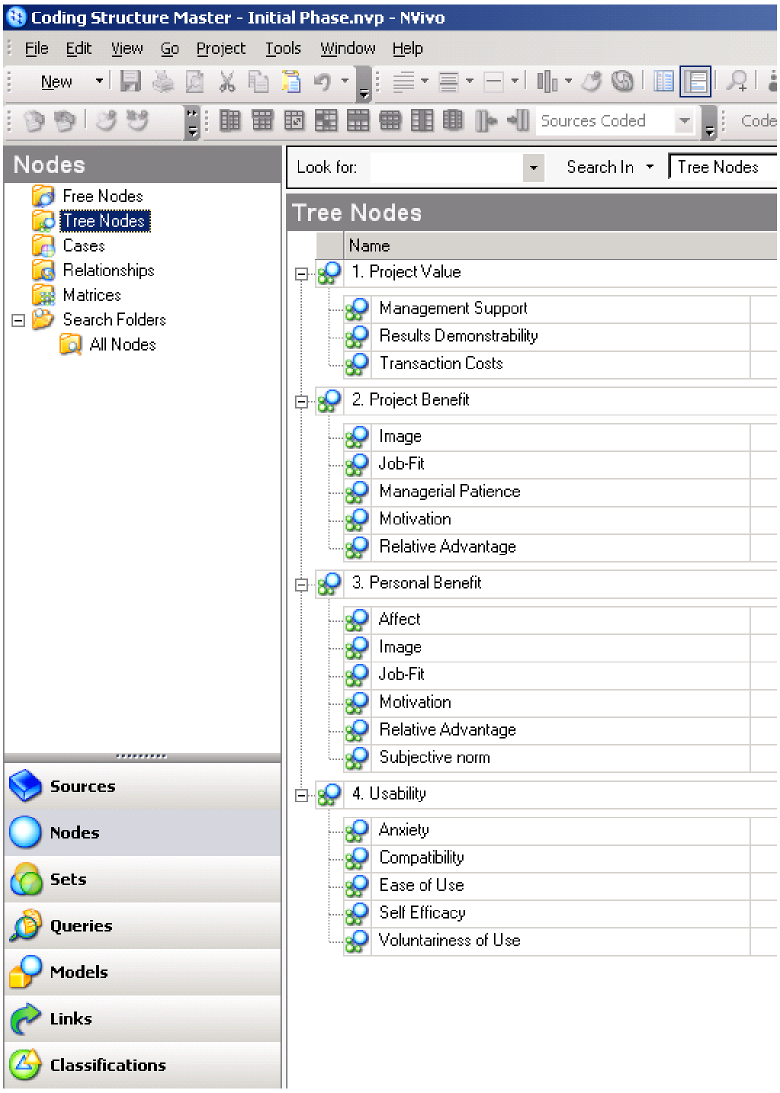

Figure 5-8: Initial coding structure elements

In addition to creating these tree nodes, *Relationships* in NVivo7 were created as the coding structure elements for each of the connecting influences in the P-I$_1$ model. The benefit of using multiple relationships to represent the different influences was the fact that each could be set as having directional properties by allocating different *Relationship Types*. In this way, the notional flow of the P-I$_1$ model was included. This is made clear by Figure 5-9 (below) as it shows the P-I$_1$ model reconstructed in the *Models Navigation View* of NVivo7. The 'directive' influence between the perception of 'project value' in management and 'personal benefit' in the user is set with a unidirectional *Relationship Type* whereas the other three 'feedback' influences are bidirectional. Similar to the directional flow of the influences, the elliptical shapes of the perceptions are consistent with the P-I$_1$ model (see Figure 4-6 in 4.3.3).

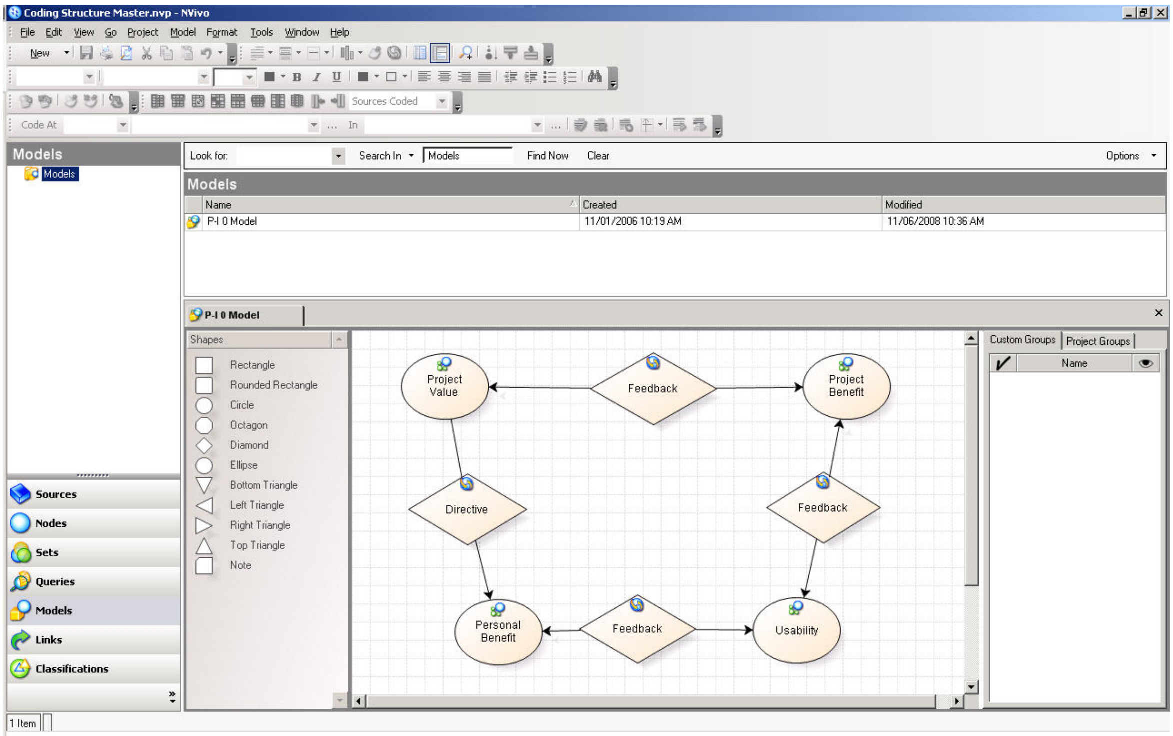

Figure 5-9: NVivo7 Models Navigation View – P-I$_1$ model structure

The final elements built into the initial coding structure were three *Free Nodes.* They were created to represent *Positive, Negative* and *Indifferent* contributions so that the nature of each passage of text, in terms of how that piece of evidence was contributing to the formulation of the construct, could be coded. Once the initial coding structure was established in NVivo7, the documents and observations from all four project organisations could be imported.

Importing the textural data into NVivo7

The data from the four project organisations (Table 5-1) were imported into four separate NVivo7 analysis files, one for each. This was done via the right mouse click options in the *List View* while the *Sources Navigation View* was activated (Figure 5-10).

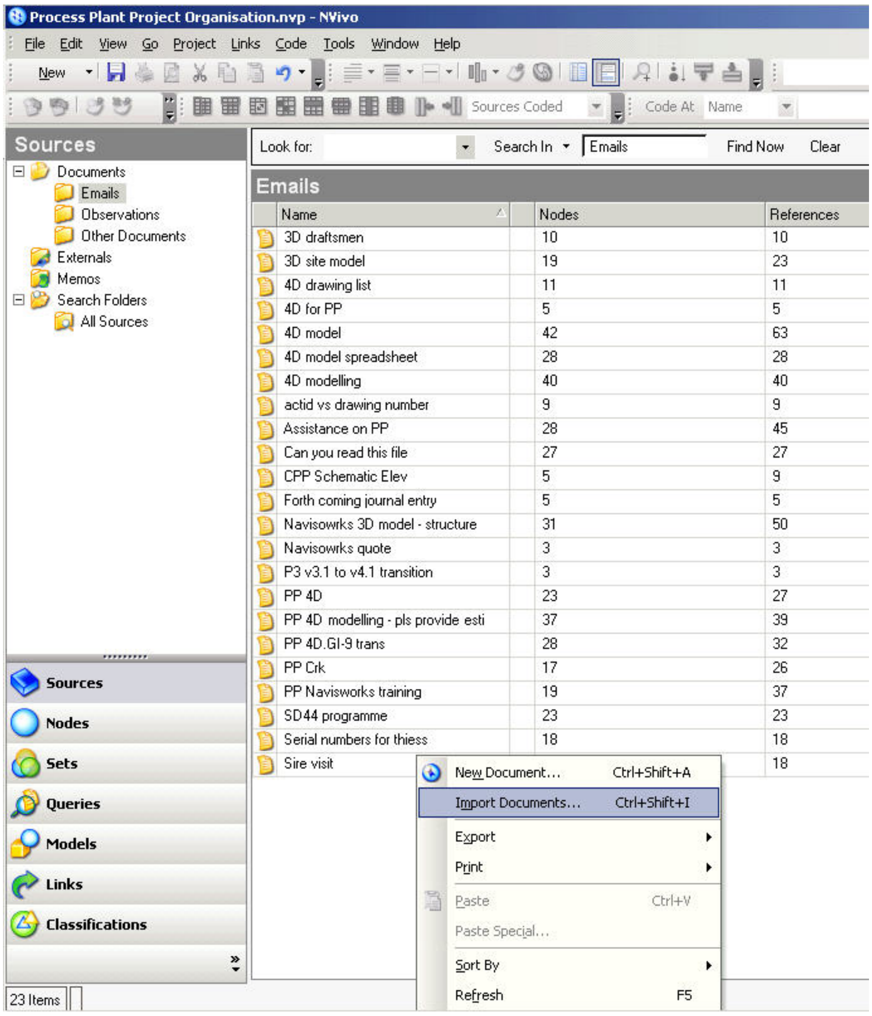

Figure 5-10: NVivo7 Documents Import and Naming

Figure 5-10 also shows the emails that were imported to the Process Plant Project Organisation (PP_{PO}) NVivo7 analysis file. They have been named by the subject line from the email conversation[43]. The names for the documents initially come from the names of the imported files but they can be changed once imported. NVivo7 can accept a small range of different text file formats (e.g. .txt, .doc)

[43] This convention of naming the thread of emails using the subject line was carried right through all of the NVivo7 analysis files for each of the project organisations in both the middle and final research phases.

however the most user-friendly format was .rtf (rich text format). Once all the documents were imported to the four NVivo7 analysis files, the initial coding structure could be applied to the data in each.

Applying the P-I_1 coding structure

The process by which the initial coding structure was applied to the data in NVivo7 was disciplined and methodical. The NVivo7 coding display (Figure 5-11) is activated by taking the *Code Selection at Existing Nodes* option after highlighting a passage of text[44] from the imported data and right-clicking (as shown above in Figure 5-6). By working this way through every imported document or linked item to find the passages of text with evidence of the P-I_1 model constructs, the coding structure was applied to the data in each of the four NVivo7 analysis files in the middle research phase.

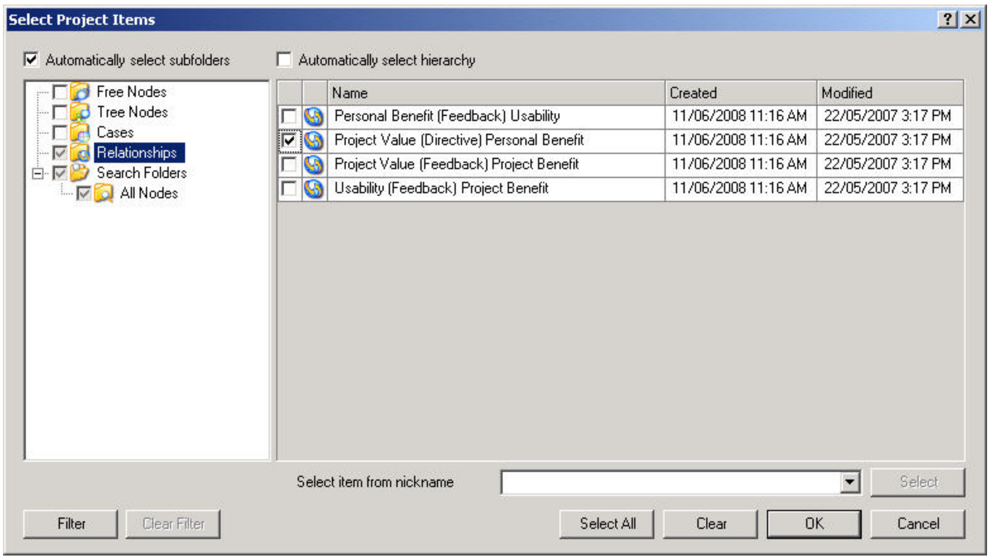

Figure 5-11: NVivo7 coding display – P-I_1 model structure

The NVivo7 coding display in Figure 5-11 presents all the coding structure elements as 'tick box' options so that any passage of text can be coded to any coding structure element. By ticking the box in the *Relationships* tab shown by Figure 5-11, the text previously highlighted for that coding instance would be

[44] Regarding the size of the passages of text coded: rather than code the specific individual sentences that were the exact evidence of, say, an expressed opinion, the entire paragraph or email was coded so that when retrieved later it could be more quickly comprehended in context.

coded as representing a management directive. This is an influence of the manager's perception of *Project Value* on the user's perception of *Personal Benefit* in the $P\text{-}I_1$ model (see Figure 5-9). A typical example of this is a manager instructing a particular user via email to learn how to interrogate a 4D CAD model. Similarly, if the highlighted passage of text was evidence of any of the contributing factors, and hence a participant perception, then the *Tree Nodes* 'tick box' on the left (in Figure 5-11) would be chosen to activate the list of all tree nodes (as in Figure 5-8) on the right. In this instance, the type of contribution would also be coded using one of the three options in the list of *Free Nodes* (i.e. positive, negative or indifferent). The coding structure was also developed by adding new elements as part of the NVivo7 analysis process.

Developing the coding structure by adding new elements

As in the initial research phase, new ideas and patterns emerged from the data processed in this middle research phase. These developments were facilitated by the way in which NVivo7 was used to code the data and then search through the coded data. This iterative process facilitated the theory-generation methods of the middle research phase (see 3.3.2). The coding operation allowed new propositions to be added to the coding structure as new primary and secondary elements (see Figure 5-6 above). Both the coding and search operations allowed for as many tracked iterations as was necessary to identify simple patterns and code all data completely.

A separate NVivo7 analysis file, *Coding Structure Master – Middle Phase.nvp*, was kept up to date with any changes to the coding structure. This acted as a template and was able to be merged across the four NVivo7 analysis files so that any changes to the developing coding structure were able to be transferred consistently.

5.3 Outcomes from Early Analysis Iterations

The early analysis iterations in the middle research phase embodied the proposed $P\text{-}I_1$ model with empirical evidence. In other words, the uncertainties that came out of the initial research phase were investigated. At the outset of this part of the analysis, the $P\text{-}I_1$ model was a preliminary set of related theoretical constructs representing the research propositions to date. Therefore the identification of the evidence within the empirical data sets that supports these constructs was the first significant outcome. In addition to this, a better understanding of each P-I_1 model construct was developed throughout the early analysis iterations and the definition of some constructs could be added to or adjusted according to what the data were suggesting. This outcome leads to developments to the proposed bank of contributing factors (secondary constructs) for each of the perception (or primary) constructs in the P-I_1 model. In the context of the wider thesis, two more propositions regarding the theoretical constructs in the literature are formed. These are in addition to the two that resulted from the initial research phase. As noted previously, these propositions are built into the theory of the P-I model for further investigation and so that the first revision of the P-I_1 model might better explain and map the lifecycle of an innovation implementation.

The explanation of these outcomes and how they were achieved also contains descriptions of the functional ways NVivo7 permits the researcher to navigate coded data. This information becomes more important later in the thesis when the method for compiling a P-I model is addressed.

5.3.1 Embodiment of the P-I_1 Model Constructs

Any passage of text that embodied a P-I_1 model construct was coded to it via the parent-child tree nodes in NVivo7. A results summary of this coding procedure for each primary construct in the P-I_1 model is shown as four partial NVivo7 screenshots in Figure 5-12. The contribution component for each coded passage of text (i.e. positive, negative or indifferent) was coded using the free nodes, however it was less relevant in the middle research phase. This is because the emphasis was on the embodiment of the constructs that the P-I_1 model proposed. In other words, to embody the propositions in the P-I_1 model, the existence of the proposed project-participant opinions and concerns and the connection they have with the relevant perception had to be evident in the data regardless of the type of contribution being made. The positive, negative and indifferent coded contributions of each passage of text are used to surmise each perception as part of the outcomes from the final research phase which is documented by chapter 6.

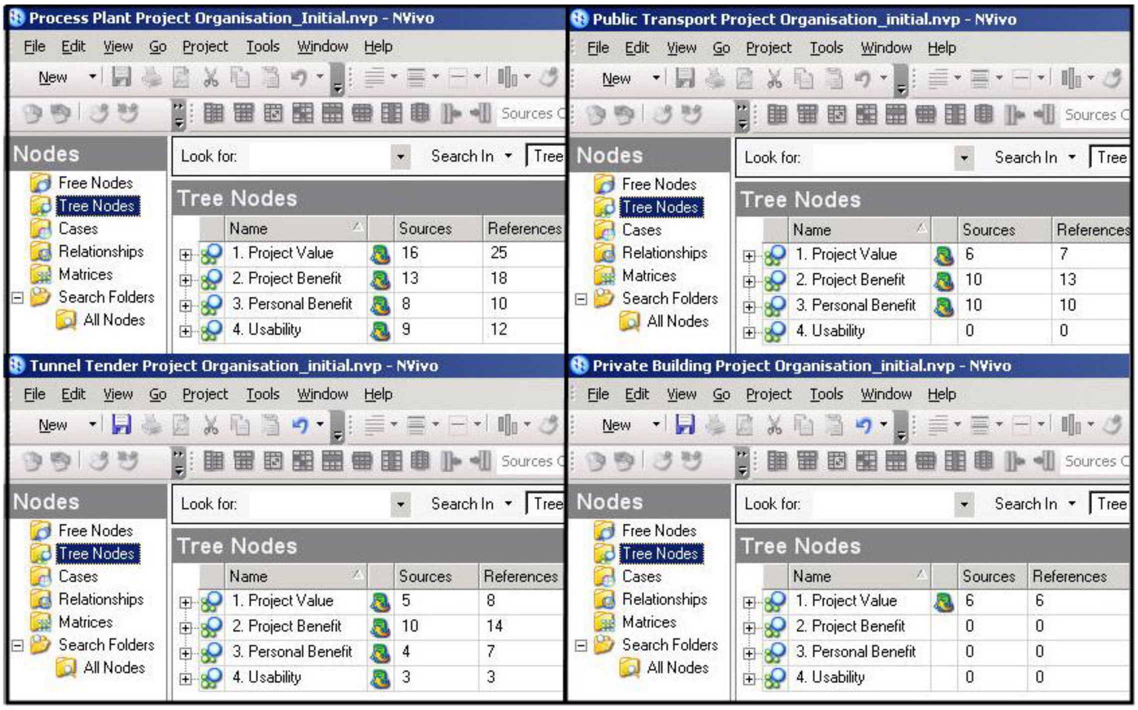

Figure 5-12: Summary of evidence coded to P-I_1 model primary constructs

The summaries of each of the four project organisation (PO) analyses in Figure 5-12 show the number of textural passages that were coded to perceptions. The number of times a passage of text was coded as contributing something to each perception is shown in the *References* column and the number of imported documents that the passages came from is shown in the *Sources* column. Prima facie, the ineffective implementation outcomes that occurred at the PT_{PO} and PB_{PO} can be seen. Because the implementations at the PT_{PO} and PB_{PO} did not progress far enough for the project-participants to actually use the innovation, there was no evidence of opinions or concerns about the usability of 4D CAD modelling (samples of data and excerpts from the PP_{PO}, TT_{PO}, PT_{PO} and PB_{PO} analyses can be found in Appendices B, C, D and E, respectively). Figure 5-13 shows a screenshot of the expanded tree nodes for the case of the PP_{PO} NVivo7 analysis file. It summarises the number of passages of text collected at the PP_{PO} that were coded to each contributing factor for each perception during the early iterations.

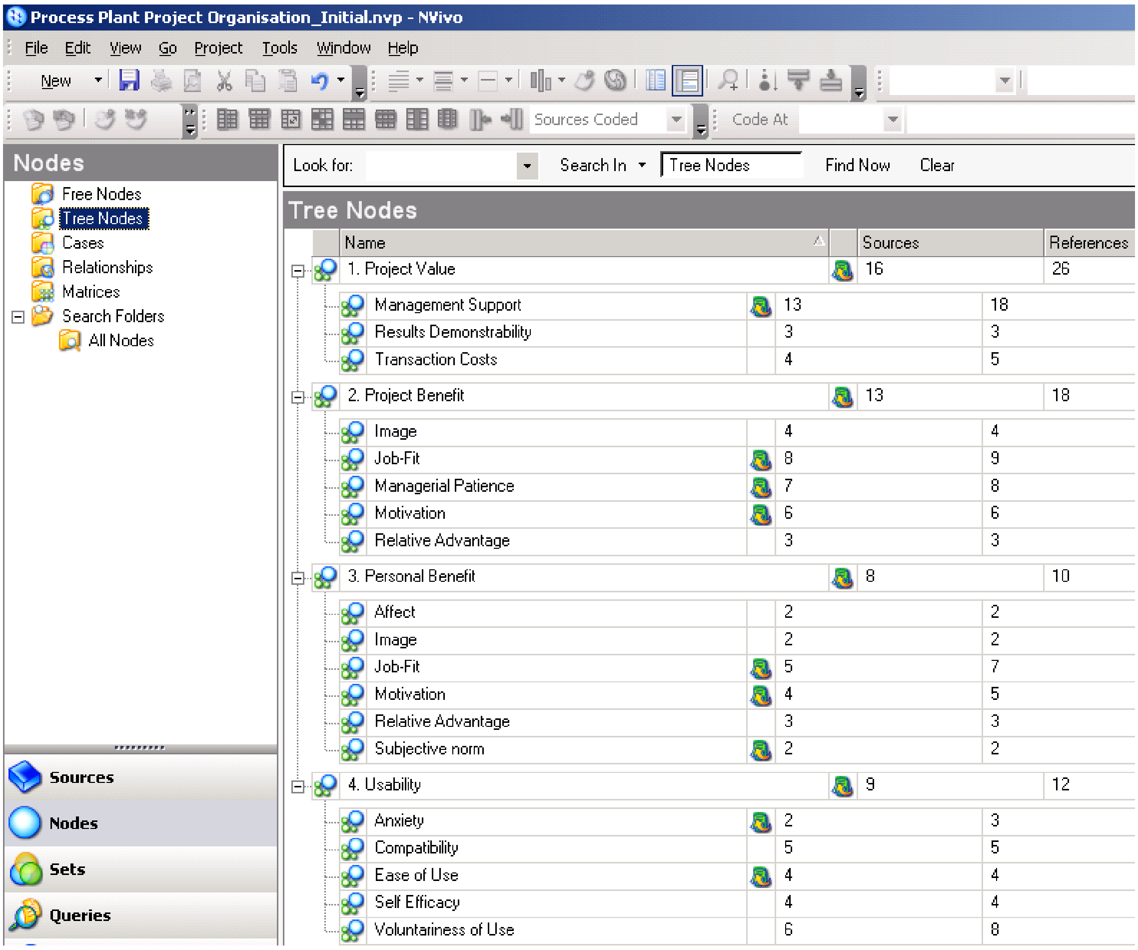

Figure 5-13: Summary of PP_{PO} evidence coded to P-I_1 model secondary constructs

Two important functional aspects to an NVivo7 analysis can be seen in Figures 5-12 and 5-13 above: 1) an indication of which nodes have linked memos[45]; and 2) the use of the *Node Navigation View.* Those nodes with a green icon next to the number of sources coded to that node have an attached memo that can be accessed by double-clicking the icon. The *Node Navigation View* not only tracks and summarises the amount of coded data but it gives immediate access to it. By double-clicking on any of the parent or child tree nodes, the text that has been coded to that node can be retrieved. This enables the accuracy of the coding to be checked and like or related passages of text to be compared. Figure 5-14 demonstrates this by showing a partial screenshot made after a double-click on the 'Results Demonstrability' secondary construct in the screen shown in Figure 5-13 above.

[45] Memos are notes linked to the data source or NVivo7 node that they are relevant to.

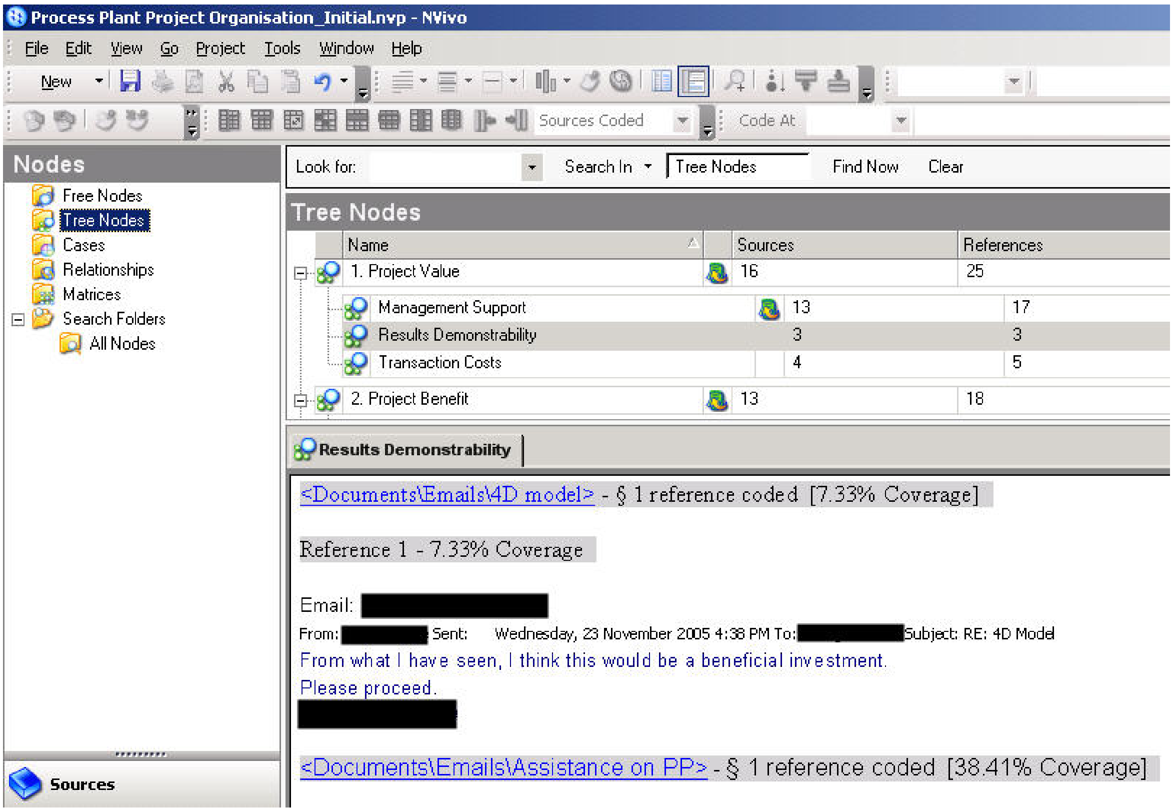

Figure 5-14: Coded data retrieved using the *Nodes Navigation View* (PP_{PO} NVivo7 analysis file)

The email in Figure 5-14 is a concise example of empirical evidence that embodies the ‘Results Demonstrability’ opinion construct as a contributing factor to a positive perception of project value. Even though the project manager uses the term ‘beneficial’ this email was sent at a time before the commitment decision was made; in fact, it also provides concise evidence of the commitment decision being confirmed. Therefore with respect to the value perception, this passage of textural data embodies the two theoretical constructs with the primary-secondary (i.e. perception-opinion) and encompassing relationships that the P-I_1 model proposes to exist between them.

Figures 5-11, 5-12, 5-13 and 5-14 exhibit some of the most important post-coding navigational functions that NVivo7 brought to the analysis in this thesis. Performing the process stepped out in these four figures, that is, coding the data then revisiting them through the coding structure as well as linking memos to particular passages along the way, is the essence of the iterative nature of the qualitative analysis in this thesis. The researcher is always connected to the data and checking and rechecking the coding that has been done. These functions allowed the evidence supporting both the primary and secondary P-I_1 model constructs to be isolated, thus embodying them. As a result, the early NVivo7 analysis iterations supported the P-I_1 model as a plausible synthesis (further to Figure 5-14, see Appendix B.1 for an NVivo7 coding summary report of the PP_{PO} emails coded to project value contributing factors).

5.3.2 Secondary Construct Developments

The most tangible outcome of the content analyses that began with the P-I_1 model coding structure was a significant revision to the bank of contributing factors. The changes are namely the creation of five new contributing factors (secondary constructs) and the inclusion of more-related constructs for some of the existing ones. These developments and expansions eventuated by thinking critically about the research propositions and P-I_1 coding structure while the data were being coded. Tables 5-2, 5-3 and 5-4 collectively show the revised bank of contributing factors. These three tables highlight the five contributing factors new to the P-I model with a shaded grey background. Table 5-2 lists the contributing factors associated with the project management perceptions while Tables 5-3 and 5-4 present those for the two individual user perceptions in personal benefit and usability respectively. The three tables together are a more detailed and extended version of the initially proposed bank of contributing factors shown in Table 4-4.

Table 5-2: Contributing factors for project management perceptions

Perception		Contributing Factors	Description – References – Related Theoretical Constructs
Project Management	VALUE	**Transaction Costs**	A positive or negative opinion about the costs associated with implementing an innovation (Williamson 1975; Moore and Benbasat 1991). Encompasses 'Availability of financial resources' (Nord and Tucker 1987; Klein and Knight 2005).
		Results Demonstrability	An opinion about how amenable to demonstration an innovation is and how visible its advantages are (Zaltman, Duncan et al. 1973; Karahanna, Straub et al. 1999; Rogers 2003; Jebeile and Reeve 2008).
		Suitable Resources	An opinion or concern about the ability of the project to implement the innovation or about the facilitating conditions at the project organisation (Peansupap 2004; Peansupap and Walker 2005a). Encompasses 'Management support' (Leonard-Barton and Deschamps 1988; Sharma and Yetton 2003; Klein and Knight 2005; Peansupap and Walker 2005b), 'Tight timeframes' (Stewart, Mohamed et al. 2004) and 'Climate for implementation' (Klein and Sorra 1996). Parallels 'Behavioural control' (Ajzen 1991; Taylor and Todd 1995).
	PROJECT BENEFIT	**Job-Fit**	An opinion or concern about how the capabilities of a new innovation will enhance (or otherwise) the project organisation's performance (Thompson and Higgins 1991). Parallels 'Innovation-Values Fit' (Klein and Sorra 1996; Holahan, Aronson et al. 2004) and 'Usefulness' (Davis 1989; Peansupap 2004).
		Relative Advantage	An opinion or concern about how an innovation might improve (or otherwise) existing systems and workflows at the project organisation (Ramiller 1994; Dooley 2001; Rogers 2003). Division of 'Motivation' (Griffith 1996). Exemplar of 'Intrinsic Motivation' (Davis, Bagozzi et al. 1992).
		Image	An opinion about how the use of an innovation might enhance (or otherwise) the managers' status or image (Moore and Benbasat 1991; Rogers 2003). Division of 'Motivation' (Griffith 1996). Exemplar of 'Extrinsic Motivation' (Davis, Bagozzi et al. 1992).
		Managerial Patience	An opinion that shows patience (or lack thereof) in project management (Repenning and Sterman 2002; Klein and Knight 2005).
		Suitable Resources	*As for the perception of value above* – BUT in the ongoing sense of an implementation. AND Encompasses 'Technical support' (Peansupap 2004; Stewart, Mohamed et al. 2004; Peansupap and Walker 2005a).
		Transaction Costs	*As for the perception of value above* - BUT in the ongoing sense of an implementation.

Table 5-3: Contributing factors for individual-level perceptions – personal benefit perception

Perception		Contributing Factors	Description – References – Related Theoretical Constructs
Individual User	PERSONAL BENEFIT	**Job-Fit**	An opinion or concern about how the capabilities of a new innovation might enhance (or otherwise) an individual's job performance (Thompson and Higgins 1991). Parallels 'Innovation-Values Fit' (Klein and Sorra 1996; Holahan, Aronson et al. 2004) and 'Usefulness' (Davis 1989; Peansupap 2004).
		Affect	An opinion or concern about a liking (or otherwise) for the behaviours associated with using an innovation (Thompson and Higgins 1991). Division of 'Motivation' (Griffith 1996). Exemplar of 'Intrinsic Motivation' (Davis, Bagozzi et al. 1992).
		Relative Advantage	An opinion or concern about how an innovation might improve (or otherwise) relevant workflows and existing systems (Ramiller 1994; Dooley 2001; Rogers 2003). Division of 'Motivation' (Griffith 1996). Exemplar of 'Intrinsic Motivation' (Davis, Bagozzi et al. 1992).
		Image	An opinion or concern about how the use of an innovation might enhance (or otherwise) the individual user's status or image (Moore and Benbasat 1991; Rogers 2003). Division of 'Motivation' (Griffith 1996). Exemplar of 'Extrinsic Motivation' (Davis, Bagozzi et al. 1992).
		Subjective Norm	An opinion or concern in an individual user about people important to them and whether they believe they should or should not use the innovation (Venkatesh and Davis 2000). Division of 'Motivation' (Griffith 1996). Exemplar of 'Extrinsic Motivation' (Davis, Bagozzi et al. 1992).
		<u>Suitable Resources</u>	An opinion or concern about the facilitating conditions at the project organisation (Peansupap 2004; Peansupap and Walker 2005a). Encompasses 'Management support' (Leonard-Barton and Deschamps 1988; Sharma and Yetton 2003; Klein and Knight 2005; Peansupap and Walker 2005b), 'Tight timeframes' (Stewart, Mohamed et al. 2004) and 'Technical support' (Peansupap 2004; Stewart, Mohamed et al. 2004; Peansupap and Walker 2005a). Parallels 'Behavioural control' (Ajzen 1991; Taylor and Todd 1995).
		<u>Use Intention</u>	An opinion that shows an intention to use a new innovation (or otherwise) in an individual user (Agarwal and Prasad 1997; Karahanna, Straub et al. 1999). Parallels and re-labels 'Behavioural Intention' (Taylor and Todd 1995; Legris, Ingham et al. 2003; Lippert and Forman 2005). Parallels 'Attitude towards use' (Fishbein and Ajzen 1975).

Table 5-4: Contributing factors for individual-level perceptions – usability perception

Perception		Contributing Factors	Description – References – Related Theoretical Constructs
Individual User	USABILITY	**Compatibility**	An opinion or concern about whether or not an innovation is consistent with the individual user's existing values, needs and past experiences (Ramiller 1994; Rogers 2003).
		Ease of Use	An opinion or concern about whether or not actually using an innovation would be free from physical and/or mental effort (Moore and Benbasat 1991; Lucas and Spitler 2000; Rogers 2003; Yuandong, Zhan et al. 2005; Peansupap and Walker 2005a; Jebeile and Reeve 2008). Parallels 'Complexity' (Rogers and Shoemaker 1971; Davis 1989).
		Voluntariness of Use	An opinion or concern about the use of an innovation and whether or not it is voluntary (Moore and Benbasat 1991; Karahanna, Straub et al. 1999; Green and Hevner 2000; Rogers 2003; Green, Collins et al. 2004).
		Self-Efficacy	An opinion or concern that represents one's judgment of their ability to use an innovation to accomplish a particular job or task (Davis 1989; Compeau and Higgins 1995; Venkatesh, Morris et al. 2003; Yuandong, Zhan et al. 2005; Peansupap and Walker 2005c).
		Anxiety	An opinion or concern that shows anxious or emotional reactions (or otherwise) when it comes to performing the behaviours associated with using an innovation (Compeau and Higgins 1995; Venkatesh, Morris et al. 2003; Peansupap 2004; Beaudry and Pinsonneault 2005; Yuandong, Zhan et al. 2005; Peansupap and Walker 2005c). A suitable positive connotation is *Confidence.*

Tables 5-2, 5-3 and 5-4 present the developmental results of the early analysis iterations. They show the updated propositions in terms of the contributing factors for each previously proposed perception listed with other constructs from the literature that were suggested by the data as being related and worthy of inclusion in the theory behind the P-I model. Furthermore, accounts of the more prominent propositions of 'encompassed' and 'paralleled' relationships between user acceptance theoretical constructs (vis-à-vis those that exist more tacitly as part of the P-I model) were consistently identified throughout the early analysis iterations. The iterative analysis also revealed another plausible relationship, expressed by the third prominent proposition in this thesis:

3. ***Dividing*** – With regards to perception-based constructs in implementation research, a theoretical construct divides another if its definition clearly fits within the wider scoped definition of another theoretical construct and it is an exemplar of the construct for which it appears to be a division.

The key aspects of the data analysis that lead to the outcomes presented in this section so far (5.3.2) are now explained by the remainder of it.

New contributing factors for project management perceptions

Any passage of text showing evidence of a project-participant perception that could not be coded to an existing contributing factor needed a new coding element to be created. In this scenario, an interim node was created via the *Code Selection at New Node* option (shown in Figure 5-6) or a Memo or annotation was made and linked to that passage of text to enable further development of the idea. With a clear and established frame of reference to interpret each piece of data, those that did not fit the P-I_1 model or the theory behind it were reasonably obvious. The process of creating new P-I model constructs was constantly informed by implementation research literature. Before a prospective theoretical construct was included in the model, it was compared against similar constructs and existing theories. In most cases, the literature helped provide a suitable term and definition thus shaping its place in the evolving P-I model.

'Suitable Resources' was added as a contributing factor for the perception of project value after finding anecdotal evidence of each theoretical construct that it is proposed to encompass. It was thought that because the instances of most resource/conditions-based factors were somewhat infrequent, combining them under the broader scoped definition of the 'Suitable Resources' construct (Peansupap 2004; Peansupap and Walker 2005a) would provide more substance for a disparate implementation factor in the P-I model. This meant 'Management Support' which was previously proposed as a contributing factor in its own right became an encompassed construct along with the others listed and referenced in Table 5-2 above.

Making the proposition that the 'Suitable Resources' construct adequately encompasses a number of similar concerns and opinions involved thinking critically about the coded data. Opinions and concerns about 'Management Support' were already being coded during the early analysis iterations because this construct was part of the P-I_1 model coding structure. When coding this construct, the researcher's thoughts were oriented toward what the project managers were thinking about the facilitating conditions for the implementation at the project. These particular thoughts were informed by the parts of the literature that present related theoretical constructs, namely 'Suitable Resources' (Peansupap 2004; Peansupap and Walker 2005a), 'Behavioural Control' (Ajzen 1991) and the 'Climate for Implementation' (Klein and Sorra 1996). As such these constructs were noted in a memo during the analysis as possible new constructs. This memo, a critical excerpt from which is in Figure 5-15 below, enabled the notion of developing this particular aspect to be captured and returned to after that coding iteration. In returning to the notion, post-coding reflective thinking processes then concluded that 'Suitable Resources' should be proposed as an encompassing contributing factor.

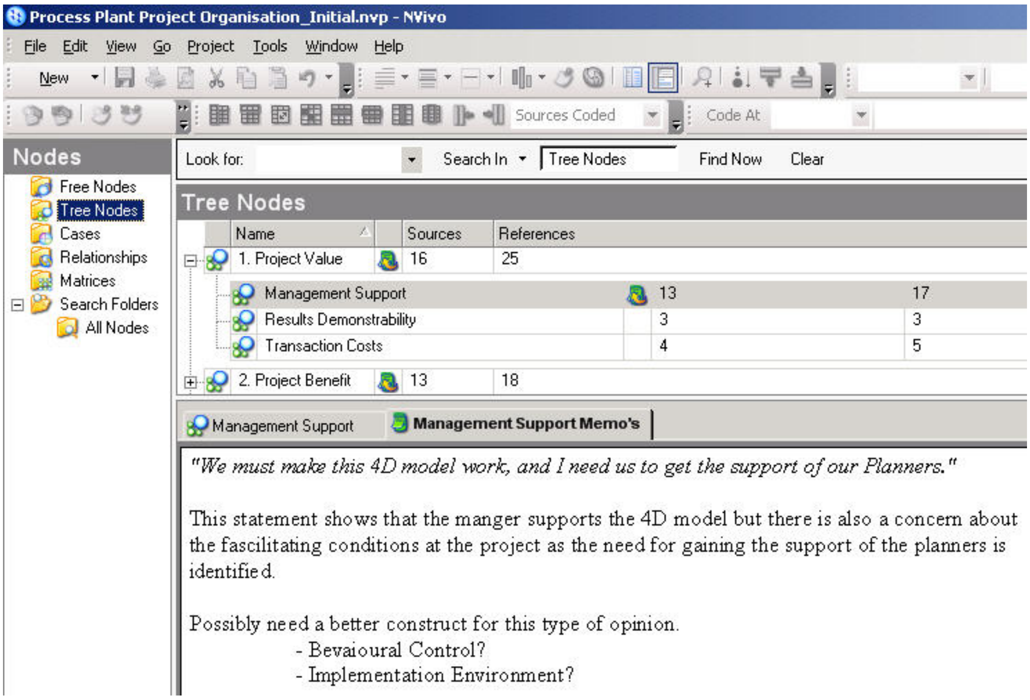

Figure 5-15: Excerpt from a Management Support construct memo made in the PP_{PO} analysis

Similarly the data analysis also suggested 'Suitable Resources' as a contributing factor for the more longitudinal perception of project benefit in management. The perception of project benefit involves both types of contributing factors, that is, those formed before an implementation has been committed to and those formed during one that has commenced (Drury and Farhoomand 1999a). This means that some of the opinions and concerns a project manager might have before committing to an innovation implementation are also relevant during a commenced and ongoing implementation. The identification of the need for the P-I model to include ‘Suitable Resources’ as a contributing factor for the project benefit perception in the P-I model was typified by the addition of an annotation in the PP_{PO} NVivo7 analysis. This annotation is shown below in Figure 5-16. It follows on from Figure 5-15 because it was linked to the data coded as evidence of the ‘Management Support’ secondary construct.

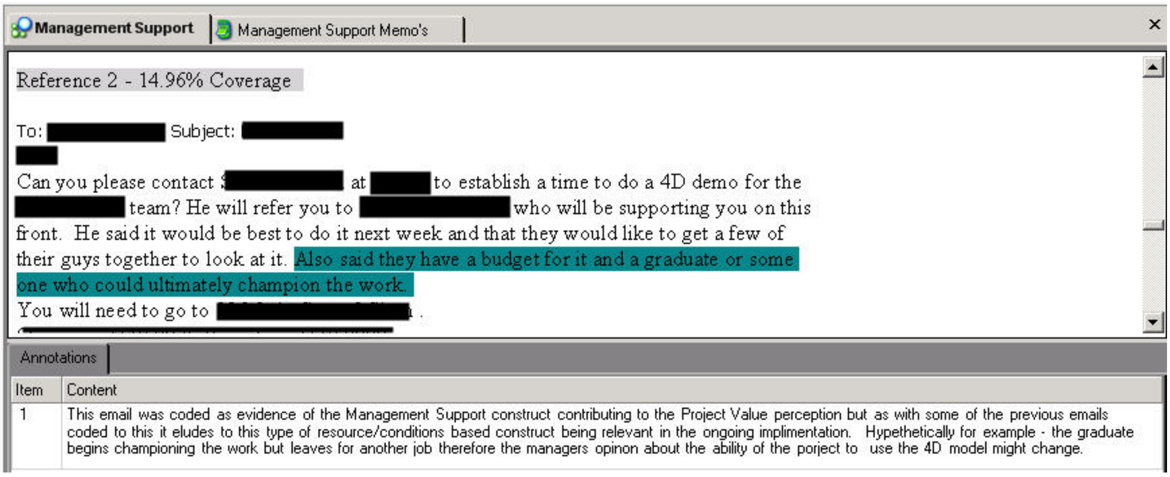

Figure 5-16: Annotation added to PP_{PO} NVivo7 analysis

Realising that the resource-based opinions and concerns of project managers would also influence the ongoing implementation helped identify and add some more theoretical constructs to the $P\text{-}I_1$ model as well as the theory behind it. Logic as well as the data suggested that the ‘Suitable Resources’ construct would encompass other factors when considered in the context of the project benefit perception. Via similar means to those shown in Figures 5-14 and 5-15, ‘Technical Support’[46] was identified as one such encompassed construct. In the same sense, ‘Transaction Costs’ was added as a contributing factor for the perception of project benefit. The influence of ‘Transaction Costs’ as a contributing factor for the perception of project benefit is best illustrated by an excerpt from the data collected at the PT_{PO} (see Appendix D.1). The data shows that project management saw the transactions costs of the 4D CAD implementation as being realistic at the time it was committed to but two months into the implementation, they decided to discontinue it because of cost concerns (Appendix D.2 shows a

[46] An opinion or concern about Technical Support includes any training-related concerns or opinions.

coded email with the details of the transaction costs for the PT_{PO} 4D CAD implementation).

The change regarding the ‘Motivation’ construct in the bank of contributing factors associated with the perception of project benefit is another significant development. The previous additions and changes were aligned with propositions 1 and 2 (i.e. encompassing[47] and paralleling[48] relationships between constructs) whereas the ‘Motivational’ theoretical construct was identified as being too broadly defined and that some of the other contributing factors were actually examples of motivations. This became clear while coding the data because most passages of text that could be coded to ‘Relative advantage’ and ‘Image’ could also be coded to ‘Motivation’. This discovery caused proposition 3 to be included in the thesis as part of the theory behind the P-I model. The thinking was that the inclusion of this relationship and garnering of further empirical evidence of it would add another useful facet to the synthesis of theoretical constructs.

The similarities between the two benefit perceptions in the $P\text{-}I_1$ model allowed the change to how the ‘Motivation’ construct was being included in the theory to be transferred directly. The separation is their association with different decision-making levels (i.e. project and individual) in the implementation process but they each have a similar set of contributing factors. There were some changes to the bank of contributing factors that were unique to the individual decision-making level perceptions however.

New contributing factors for individual user perceptions

‘Use Intention’[49] was identified by the early analysis iterations as a contributing factor for the perception of personal benefit (as in table 5-3 above). This outcome

[47] With regards to perception-based constructs in implementation research, a theoretical construct encompasses another in a primary-secondary or parent-child like relationship if the encompassed construct is a contributor to the formulation of the encompassing construct.

[48] With regards to perception-based constructs in implementation research, a theoretical construct is paralleled by another if it has a significantly similar or synonymous definition but is labelled using a different term or terminology.

[49] ‘Use Intention’ is a simplified term for the theoretical construct ‘Behavioural Intention’ (Taylor and Todd 1995; Legris et al. 2003; Lippert and Forman 2005) – the opinions or concerns about the specific individual behaviour of using a new innovation. It is paralleled by ‘Attitude Towards Use’ (Wixom and Todd 2005).

is another result of the iterative NVivo7 coding technique that helped establish the new contributing factors at the project management level. During the analysis, emails were often annotated with suggestions that a theoretical construct which defines whether or not an individual intends to use the innovation being implemented should be included in the P-I model. An example of an email and annotation that makes reference to this is in Figure 5-17.

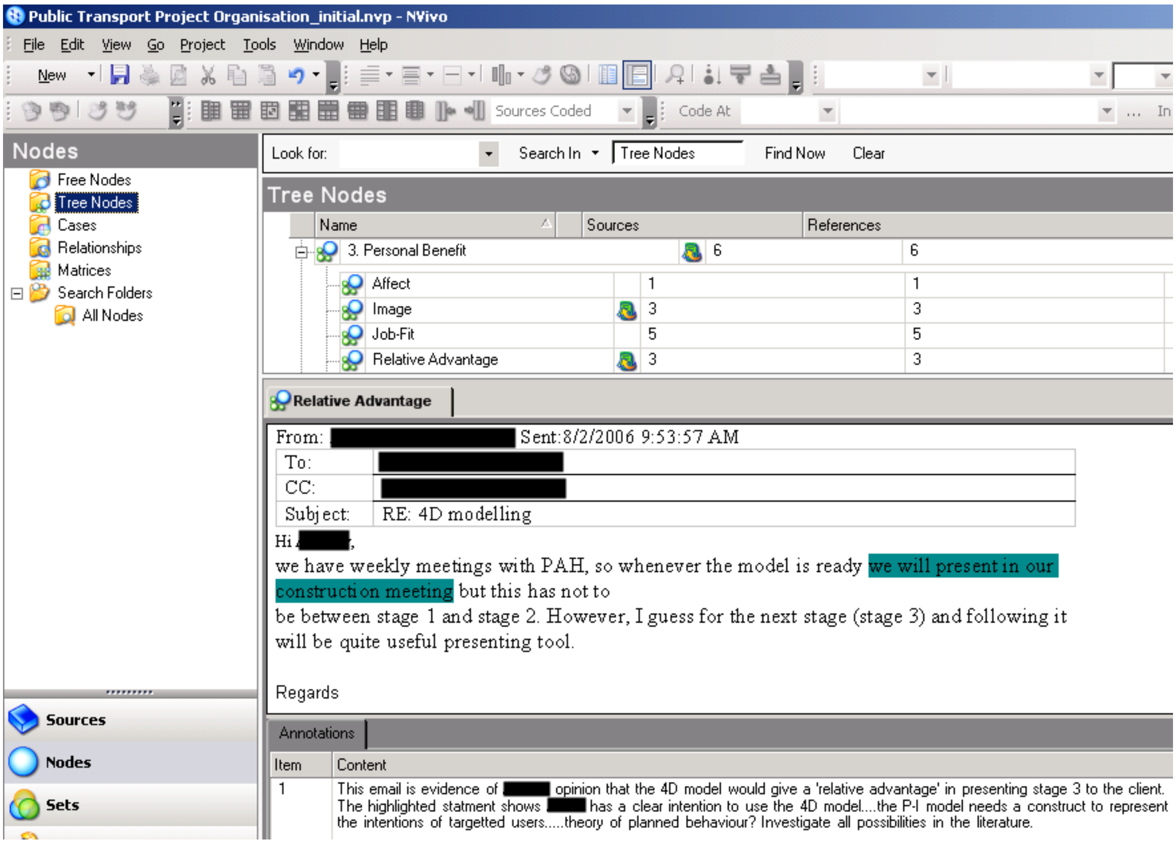

Figure 5-17: Annotation added to PT_{PO} NVivo7 analysis

Two theoretical constructs regarding an individual's intentions to use an innovation were found in the implementation research literature: 1) 'Behavioural Intention' (Taylor and Todd 1995); 2) 'Attitude Towards Use' (Ajzen 1991). The first is an adaptation of the second (Venkatesh, Morris et al. 2003) but both use confusing terms or labels for essentially the same theoretical construct (Karahanna, Straub et al. 1999) that can be defined as: *the opinions or concerns about the specific individual behaviour of using a new innovation*. Therefore these constructs provide support for proposition 2 in this thesis because they are an example of two theoretical constructs from implementation research with a paralleling relationship.

Nevertheless they are each labelled with terms that are not very self-explanatory and perhaps confusing.

The discovery of another particular case of confusion presented another opportunity for the synthesis that the development of the P-I model was working towards. Karahanna et al. (1999) consistently refer to 'user intentions' without explicitly proposing them as a theoretical construct during their investigation that involved some scrutiny of the 'Behavioural Intention' construct. As a resolution to the confusion, the singular form of the term that was clearly and consistently used by Karahanna et al. (1999), that is 'Use Intention', was chosen as the contributing factor to include in the P-I model and 'Behavioural Intention' and 'Attitude Towards Use' were included as paralleling constructs. This also fits better with requirement for an effective implementation adhered to by this thesis (productive use). In referring back to the TC_{PO} data from the initial research phase, further justification for this inclusion exists with the notion that an individual's 'Use Intention' could be used to explain the reasons behind the reluctance found in the TC_{PO} project-participants (Appendix D.1 shows an interesting example of raw data about which some field notes were made that show how the opinion of 'Use Intention' can be positive and negative at different times throughout an implementation).

Another outcome was the proposal of 'Suitable Resources' as a secondary construct for the personal benefit perception. The notion for it to be included in the bank of contributing factors (table 5-3 above) was arrived at similarly to the way in which it was proposed for the project management perception of benefit. This is because it became apparent that there was no contributing factor to account for the individual user's resources/conditions-based concerns and opinions. As a result of this discovery, and also the recognition that this contributing factor could be found in data coded to the individual decision-making level in the NVivo7 analysis, it was proposed as a new construct. This construct along with the other four contributing factors added to the theory behind the P-I model were able to be further embodied with empirical data during the later analysis iterations.

Critical and reflective thoughts during and just after the coding that occurred during the early analysis iterations was centred on the constructs that the $P\text{-}I_1$ model proposed and the ways in which they could be developed. To this point the only primary constructs in the P-I_1 model were perceptions which are contended to be formed by a set of encompassed secondary constructs (or contributing factors). While this may seem logical, there was a need for more theoretical support for this approach. Examples of studies that involve people's perceptions were sought, particularly those that involve an individual's beliefs and perceptions being inferred by another using textural data.

5.4 The Project-Participant Perception Construct

By referring to more literature, this section provides support for the method by which the P-I_1 model proposes perceptions to be inferred and documents some theories about the outcomes that can be expected from an individual's perception. The background for the construct of a project-participant perception was established in chapter 2 from implementation theory, and in particular, user acceptance research. While this provides an adequate theoretical grounding for this construct in the P-I_1 model, some knowledge at a more general level from studies that involve the interpretation of particular social contexts will serve to strengthen its foundations. To this end, this section builds a new understanding that exists as an input to the developed P-I model, the P-I_2 model. It has been located here in the dissertation to be consistent with the chronology of how the P-I model was developed by the researcher.

5.4.1 Inferring Perceptions

Textural data have been used to infer how people think in particular social contexts (Jensen 2007). Hermeneutics is a good example of a method of analysis and textural interpretation (Jamieson 2007) and it can be succinctly stated as 'the theory of understanding' (Jensen 2007). In the research project conducted by Jamieson (2007), the aim was to build an understanding of a particular context using an iterative hermeneutic process, and the result was the development of a theory. As a further similarity to this research, Jamieson's approach was aligned with Eisenhardt's (1989) recursive analysis and theory-building process. The methodological stance of this thesis was in place at the time I became aware of hermeneutics however, so it is not stated as the specific method used. Nevertheless, it is worth noting the strong parallels that exist in related studies that have used hermeneutic analyses because they lend support to the approach and findings of this thesis. A study performed by Lee (1994) involving hermeneutic interpretation of electronic mail (email) found that it was an appropriate and meaningful medium of communication for managers in the organisational context. Hermeneutics has also been used to find and explain the reasons for the failure of information system (IS) implementations (Harvey and Myers 1995) and to explore the factors contributing to decisions involving change (e.g. Whitley 1993). Furthermore, it was used by Heracleous and Barrett (2001) to analyse an innovation implementation whereby the underlying factors that drove observed decisions and actions were inferred from textural data.

Interestingly, few studies make specific reference to the act of inferring the perceptions of others. A likely explanation for this is that researchers have simply chosen other terms for what they are inferring in these types of analyses. The following quote from a hermeneutic-like analysis by Ramiller (2001) supports this claim:

> *We want to interpret the story in light of what it is reasonable to infer about the social context in which it arises and is told. Accordingly, we will weave between text and context, examining the interplay of characters, their actions and interactions, their goals and motives, their means, the setting, and ultimately the outcomes, as we endeavour to extract the meaning of the story.* (Ramiller 2001)

One of the few studies that presents a method that specifically infers the perceptions of others was by Herrmann (1988). His work exists as a theory of international relations that aids an investigator endeavouring to draw inferences about the perceptions of international leaders. The method or strategy has foundations in attribution theory[50] and balance theory,[51] both developed by Heider (1958). Herrmann's strategy targets four perceptions that international leaders have: 1) threat; 2) opportunity; 3) capability relationships; and 4) cultural differences as the perceptions that define a situation. He contends that the evidence is in public and private statements and that the observation of patterns in

[50] Attribution theory states that people explain (or attribute) behaviour to something else (e.g. 'he aced the test because he is very intelligent').
[51] Balance theory suggests that people often connect images with things they like or dislike, for example, if one person dislikes another their cognitive image associated with that person will be a negative item or image.

a subject's behaviour also provides some indicators for the underlying perception. These indicators are gauged from positive to negative and with a degree of intensity. The result is a data-driven method for inferring perceptions.

5.4.2 Outcomes from an Individual's Perception

An observable and influential outcome from an individual's perceptions is their actions (Hofstadter and Dennett 1982) and they exist with an interdependent relationship (Hurley 2001). An individual's perception about a particular situation or issue causes them to act in response to it (Heider 1958). These actions are the individual's influential behaviours in the context that originally inspired the perception (Ajzen 1991). Their interdependence becomes clear by considering them in an ongoing functional sense because an individual's preceding actions can influence how they perceive the relevant issue within that context. This can be to the extent where the perception in question changes and a different course of action is subsequently assumed (Hurley 2001).

An important facilitator in the relationship between perception and action is decision. An individual's perceptions are the precursors to their decisions and before a particular action is performed, a decision must be made to carry it out (Jamieson 2007). Further to the background presented in chapter 2 regarding decision-making levels in PBE and implementation decisions, a statement by Dean and colleagues (1990) shows the interdependence of decisions and actions:

> *Each implementation decision (e.g. to provide extensive training for operators) must itself be implemented through some sort of action (planning the training). This action will create still more decisions (should training be modular?), which in turn are implemented through action (presenting the modules). Thus, implementation consists of a series of decisions and actions in which each decision necessitates actions which involve still more decisions.* (Dean, Susman et al. 1990)

In summary and for the context of an innovation implementation in PBE, a project-participant's actions are influential behaviours and an observable outcome of their perceptions. They can help determine whether the implementation is effective or not (Heracleous and Barrett 2001). A requisite antecedent of observable human action is perception, the interpreting of sensory information (Heyes and Huber

2000), therefore without perception, action would be unguided; but without action, perception would be fruitless (Gibson 1979). This logic succinctly explains the interdependent relationship between the actions and perceptions of a project-participant and it was built into the P-I_2 model prior to the later analysis iterations.

5.5 Formulation of the P-I_2 Model

The result of the literature reviewing work before the later analysis iterations in the middle research phase was the proposition of a new P-I model revision, the P-I_2 model (Figure 5-18). In the same way the P-I_1 model required the early analysis iterations, the establishment of the P-I_2 model necessitated the later analysis iterations. The P-I_2 model includes an added dimension for interpreting an innovation implementation. The revising change to the P-I_1 model is the addition of another primary construct in resultant 'actions' for each perception, one positive and one negative. This section explains the thinking behind their proposition as new constructs in the P-I_2 model as well as the functional purpose they serve in helping to map the flow of an implementation. The way in which these constructs were built into the NVivo7 coding structure is also explained.

5.5.1 Another Primary Construct

Actions were proposed as another type of construct in the P-I_2 model in order to help confirm the positive or negative nature of each project-participant perception. Their proposition followed on from the return to the literature (documented by the previous section 5.4) which further strengthened the foundations of the perception construct. The idea was that an observable construct, in addition to an inferable one, may help in a similar way and bring a sense of internal triangulation or crosschecking ability to the P-I_2 model. Similar to the secondary constructs (i.e. expressed opinions and concerns), an individual's actions are observable in both their animate behaviour and in written communications (Bandura 1986) which means that the actions of the project-participants would be evident in the collected data. Furthermore, because an individual's actions can be interpreted as the result of their perceptions (Chadwick, Diamond et al. 2006) they exist as an indicator of whether a perception is positively or negatively orientated toward the innovation implementation being investigated. In this way they are the outcomes of a perception and can be used to work backwards from, vis-à-vis working forwards from, the perceptions' contributing factors. The basic notion was that the addition of this construct might enhance the interpretive power of the evolving P-I model.

The term 'action' was chosen for the new construct to help with the simplification of germane constructs that the grounding theory behind the P-I model intends to provide. Other terms suggested in the literature that could have been used were 'decision' and 'behaviour'. In considering all three terms, the concepts they describe are all closely related. The decisions an individual makes are the causes of their behaviours which can also be described as their actions. In the context of an innovation implementation in PBE it is reasonable to assume that decisions that are made get followed through and carried out, therefore these three terms are synonymous in that context. However, when considering how they fit in wider contexts, the terms 'decision' and 'behaviour' can be loosely applied and used to describe concepts that aren't as explicitly observable as actions. In other words, everything an individual does can be described as their behaviour or behaviours, and even though an individual may make a decision, it may not be observable and it may not be carried out. An action, on the other hand, is something that has an implied purpose and has actually happened therefore it is clearly observable. This type of logic led to the formulation of the P-I_2 model in Figure 5-18 that proposes two actions for each project-participant perception as new primary constructs.

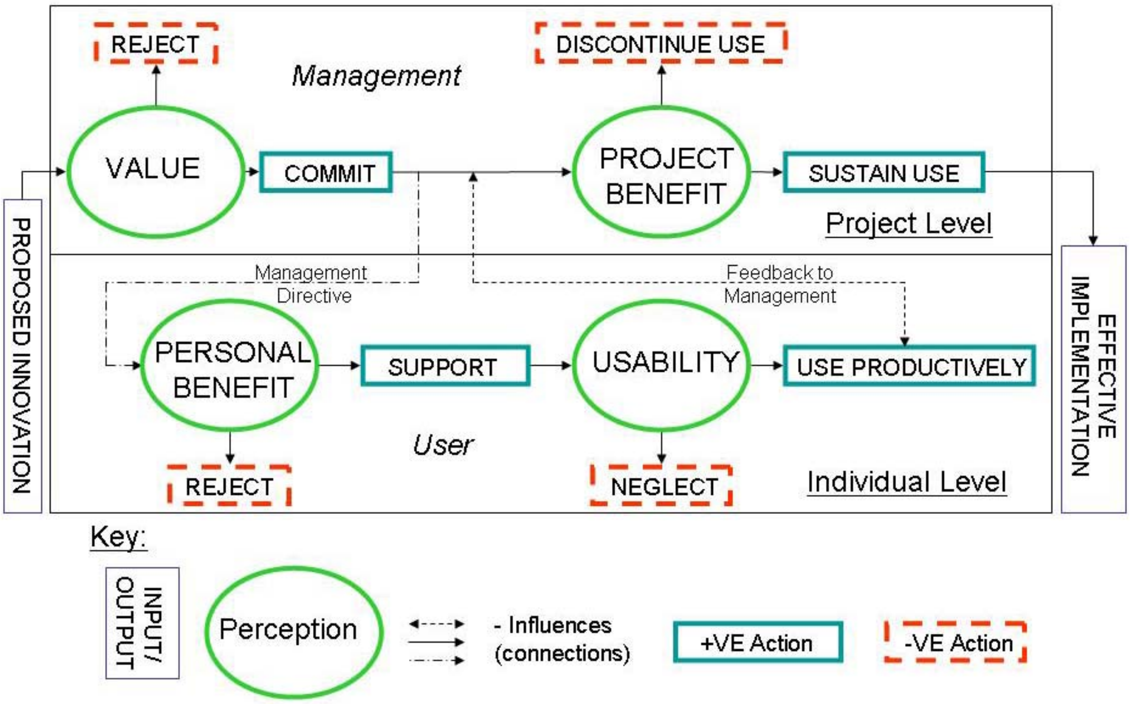

Figure 5-18: The Developed Perception-Influence Model: P-I_2 Model

The action constructs added to the P-I_1 model to give the P-I_2 model (Figure 5-18) were also named to maintain simplicity. Project-participants' actions are telling indications of what they are thinking, for example, if a project manager believes and decides that there are insufficient or no suitable resources for an innovation implementation to continue, he or she will act accordingly so that its use is discontinued. This scenario could only arise once an implementation had been committed to (see 2.3.2) and the innovation may or may not have been supported and used productively by potential users. The clear description of this example alludes to the term chosen for each positive and negative action in the P-I_2 model.

Each action was proposed as a primary rather than secondary construct because they could conceivably stand alone in mapping an innovation implementation. Given that the actions of project-participants are clearly observable, even if over an extended period of time rather than as a discrete event (e.g. neglect), they are actual happenings and are similar in this regard to the proposal of an innovation implementation and the outcome, effective or otherwise. With this in mind and at the same time removing the perception constructs from the implementation map, it can be seen how an innovation could be mapped by these observable events or actions. Understandably this development led to a new coding structure to be applied during subsequent analysis iterations.

5.5.2 The P-I_2 Model Coding Structure

Each of the eight actions in the P-I_2 model was included in the new coding structure as children to the one parent *Tree Node* in NVivo7. As before, this change was made in the *Coding Structure Master – Middle Phase.nvp* analysis file. Using this file the new P-I_2 model coding structure could be distributed to the four analysis files corresponding to each of the project organisations. The tree nodes in the P-I_2 model coding structure are shown by Figure 5-19 below.

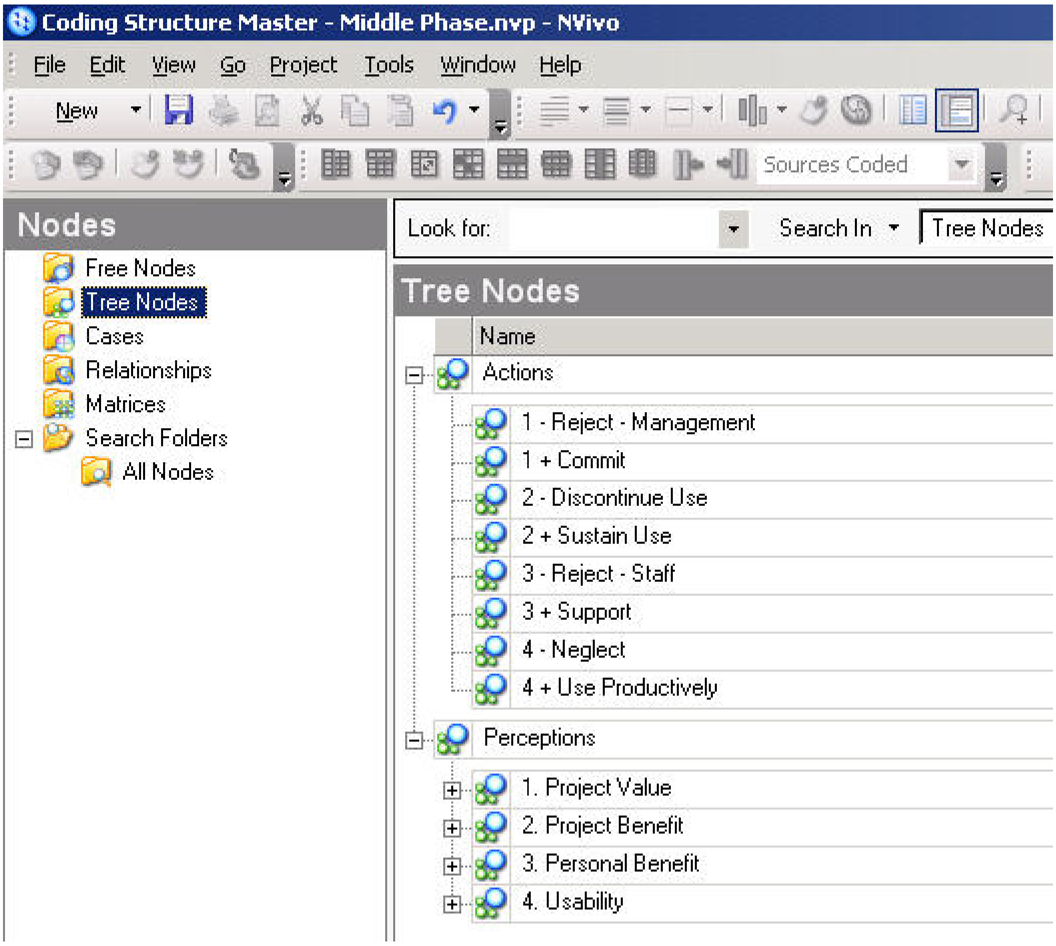

Figure 5-19: P-I_2 coding structure tree nodes

Figure 5-19 shows how each of the primary constructs in the P-I_2 model exists in the new coding structure. With two types now proposed, the perception constructs are as before (Figure 5-8) but grouped in NVivo7 for clarity. The secondary constructs also changed (as shown in Tables 5-2, 5-3 and 5-4) so the coding structure under each of the four perceptions was edited accordingly (as in appendix F). The P-I_2 model coding structure was applied the data from each of the four projects during the later analysis iterations of the middle research phase.

5.6 Outcomes from Later Analysis Iterations

The same coding methods used in the early analysis iterations (see section 5.2.2) are used to re-code the data to the new P-I_2 model coding structure during the later iterations. The P-I_2 model represents a significant revision of the P-I_1 model so leading into these iterations the emphasis was on the embodiment of the new constructs with empirical data. Therefore, with less development to the development of the theory behind the P-I model occurring, the analysis and critical thought processes begin to consider what is being achieved by the analysis. By assuming this more reflective perspective for this part of the theory-generation research phase, thoughts relating to the functional structure of the P-I_2 model are able to be explored and a series of small changes are made in proposing the P-I_3 model. In addition the actual NVivo7 analysis method that has evolved is identified as a finding itself: the so-called P-I model compilation method.

5.6.1 Embodiment of P-I_2 Model Constructs and the P-I_3 Model

The data representing evidence of each action added in the P-I_2 model were identified and isolated during the later coding iterations of the middle research phase. This was carried out by reanalysing[52] the data in each of the four NVivo7 analysis files using the new coding structure. Figure 5-20 shows some examples of data coded in this regard; two emails sent to an ACL technology champion by two different project-participants and coded as evidence of positive actions from the TT_{PO} implementation. The first email was from an individual user and was coded as evidence of actioned ‘Support’ for the 4D modelling implementation. The second was from a project manager and was coded as evidence of a ‘Sustain Use’ action with respect to the 4D model. This type of evidence supports the inherent proposition that the capabilities of the P-I_2 model are enhanced by the inclusion of actions as new primary constructs.

[52] It is important to realise that the previously applied codes common to both the P-I_1 and P-I_2 coding structures did not need to be recoded so that the findings from later iterations systematically built on the previous work.

From: [redacted] Sent: Sunday, 4 December 2005 11:43 PM To: [redacted] Subject: [redacted], 4D modelling

[redacted],
For our [redacted] bid submission we require some data from your 4D model.
Would you please give [redacted] a call [redacted] Monday Morning to discuss further.
Thanks [redacted]

From:	[redacted]
Sent:	Monday, 5 December 2005 5:54 PM
To:	[redacted]
Cc:	[redacted]; [redacted]

Subject: RE: 4D model
Hi [redacted]
It's ok with me that it wasn't ready...it would have been an unexpected bonus.
However, [redacted] was just at my desk and said he is keen to see it by next Tuesday in order for any changes to be made by final deadline of Friday.
We would like to have it for our rehearsals leading up to the oral presentation on Monday 19 December!
Regards [redacted]
-----Original Message-----From: [redacted] [mailto:[redacted]] Sent: Monday, 5 December 2005 6:48 PM To: [redacted] Subject: 4D model
Hi [redacted],
My apologies for the delay in getting back to you this afternoon. Unfortunately, the 4D model is not in any state to present. We are yet to bring in the construction programme (the 'time' element of the model) and there's still a lot of CAD work required. We hope to have a draft model ready in about a week, but this is
obviously way beyond your schedule.
Regards,
[redacted]

Figure 5-20: Two TT_{PO} emails coded to actions (new primary constructs)

Even though these two emails only show examples of data coded to two of the four positive actions in the P-I_2 model, they indirectly show that the other two have occurred. This can be seen by considering the progression of an implementation that the P-I_2 model proposes to map (refer to Figure 5-18). The first email in Figure 5-20 was coded to 'support' at the individual level but logically if the implementation had not commenced by being 'commit'[ed] to, this could not have occurred. It's the same situation in the second email. The innovation needs to be 'use[d] productively' before the use of it can be 'sustain'[ed]. Nevertheless, data were coded to each of the four positive actions ('Commit', 'Support', 'Use Productively' and 'Sustain Use') during the TT_{PO} analysis (see Appendix C.2 NVivo7 screenshot coding summary). Only the PB_{PO} and PT_{PO} data analyses produced evidence of some of the negative actions proposed by the P-I_2 models (excerpts from which are in appendices D and E).

During the garnering of empirical evidence for each of the new primary constructs, some additions were able to be made to the structure of the P-I_2 model. These include one more feedback connection and three new linking connections. These changes were included in the P-I model evolution by proposing the P-I_3 model shown in Figure 5-21 below. The best way to visually distinguish them in the refined model is to refer back to the previous version of the P-I model in Figure 5-18.

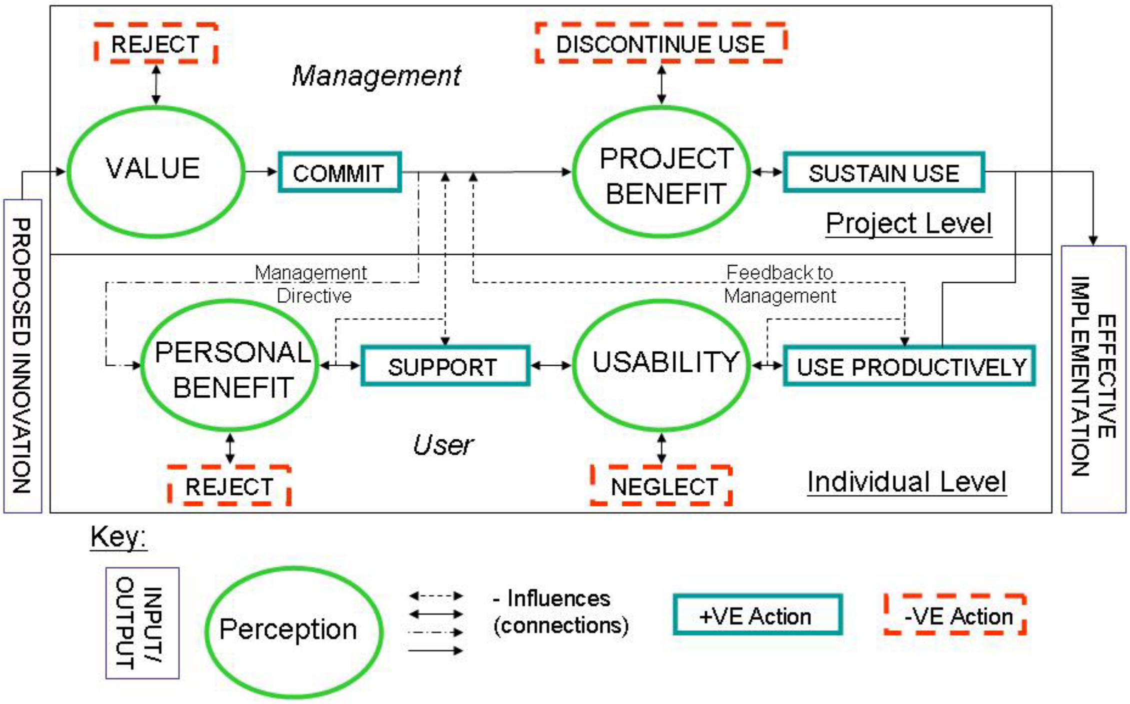

Figure 5-21: Refined perception-influence model, P-I_3 Model

The refinements presented in Figure 5-21 were made so that the P-I_3 model could better map most if not all possible innovation implementation scenarios. The new feedback connection was added to represent the notion that an individual user who actions any 'Support' of an innovation can have an effect on a project manager's perception of benefit. This is clearly evident in the field notes excerpt from the PT_{PO} data in Appendix D.1 – the text component and 'actions' coding densities for which are shown by Figure 5-22 below.

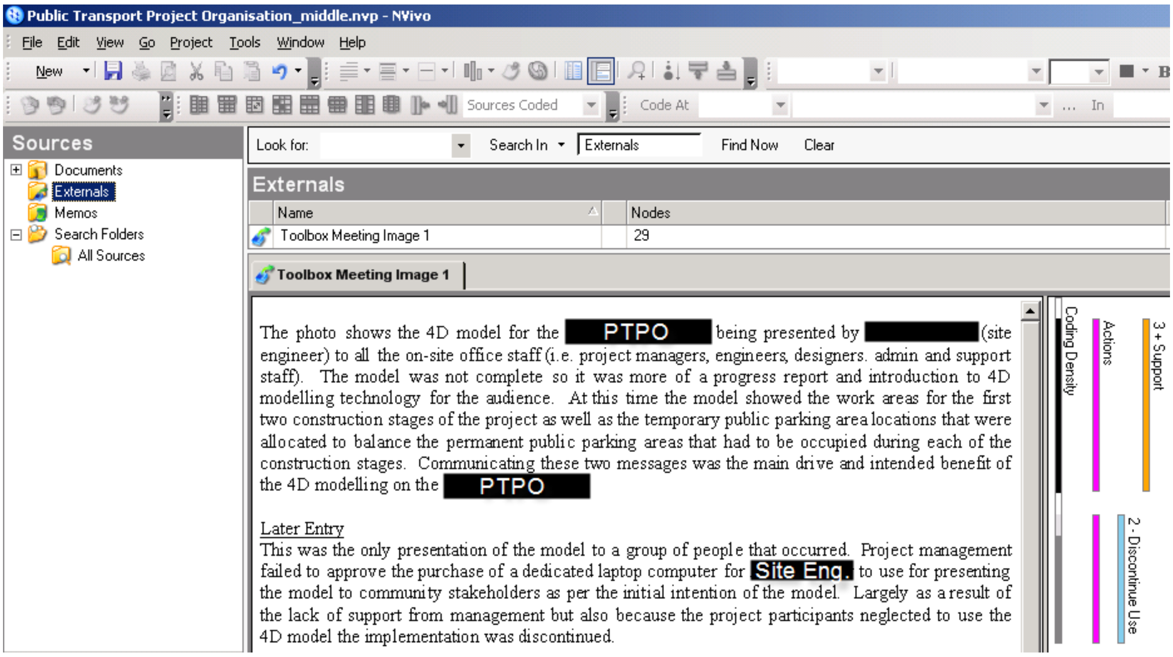

Figure 5-22: Coded PT_{PO} field notes identifying a deficiency in the P-I_2 model

This data helped identify a deficiency in the P-I_2 model's ability to fully represent a particular feedback scenario that can exist in an innovation implementation. As a result, it inspired further critical thoughts about what other conceivable implementation scenarios might arise and need to be catered for by the model, such as the transfer of influences from negative actions. This resulted in the addition of two more connectors in the P-I model at the individual level and the changes to some arrowheads within the model so that those influences were bi-directional. Figure 5-22 and appendix D.1 also provide a good example of the need for the connector that bypasses the action of 'Support'. These changes are included in the P-I_3 model revision (Figure 5-21), which is the extent to which this thesis developed the P-I model's structure and makeup. The analysis performed in the final research phase and documented in chapter 6 of this thesis seeks to deduce the meaning of, and messages embedded within, the P-I model following its inductive development.

5.6.2 Establishment of a Method for Compiling a P-I Model

A more subtly achieved finding (actually from the entire middle research phase rather than just the later iterations) was the establishment of a method for compiling a P-I model from project data. Interestingly, it could only exist as a finding after having conceived the basic theory of the P-I model, embodied the propositions it contains with empirical data and thought about the applicability of the model. While the applicability of the model is considered in detail during the final research phase (chapter 6), the potential significance of, and therefore finding in, the establishment of the compilation method was recognisable towards the end of the middle research phase. The method is transferable because NVivo7 content analysis software is commercially available and most if not all innovation implementations produce more than adequate amounts of qualitative data from which a P-I model can be compiled. Identifying this as a finding from the middle research phase enabled it to be explored further during the theory-confirmation (or final) research phase.

5.7 Chapter Summary

The theory-generation (or middle) research phase developed a synthesis of user acceptance theoretical constructs for implementation research using the P-I model as a paradigm. The model was taken from the first revision, the P-I_1 model, and developed through two more revisions into the P-I_3 model (Figure 5-21) using an iterative NVivo7 content analysis of textural data from four separate construction project organisations each implementing the same innovation, 4D CAD modelling. The most important details of the developed synthesis are captured by the bank of contributing factors (Tables 5-2, 5-3 and 5-4) which is the theory behind the P-I model that evolved. While the paradigm of the P-I model contends a number of tacit propositions as part of its structure, the most prominent are the three relationships identified between perception-based theoretical constructs in implementation research (Encompassing, Paralleling, and Dividing).

The middle research phase was extensive by virtue of the fact it covered many data analysis iterations that required constant reference to the literature. Both implementation research and qualitative research methodology literature played a significant role in guiding the middle research phase. Along with the inclusion of four innovation implementations as opposed to one, a clear aspect of difference vis-à-vis the data analysis in initial research phase was the ongoing ‘comparison with known theoretical constructs’ rather than its occurrence as an explicit part of the analysis. While an important part of the middle research phase was the expansion of understanding with respect to human perceptions (section 5.4), it was effectively a side-bar to the analysis with a specific purpose of firming up the literary grounding for the theory behind the P-I model. Similarly, section 5.2 provides the necessary background to how NVivo7 was used to deliver the qualitative methods.

The P-I models compiled for each of the four project organisations studied are further outcomes from the later analysis iterations that help provide a sense of closure to the middle research phase. Firstly, because each model could be compiled, it meant a functional model had been proposed, iteratively developed and, to a certain extent, established thus emphasising a milestone for the research. Secondly, the four models are clear and simple accounts of what transpired during each of the implementations expressed in terms of theoretical constructs from the literature. Therefore they each present summaries of what is evident in the data sets collected at each project organisation with respect to the perceptions and actions of the project-participants as well as the outcome of the 4D CAD implementation (or the extent it progressed to). The four models are shown in Figure 5-23 (note that the TT_{PO} and PP_{PO} implementations embodied identical P-I models).

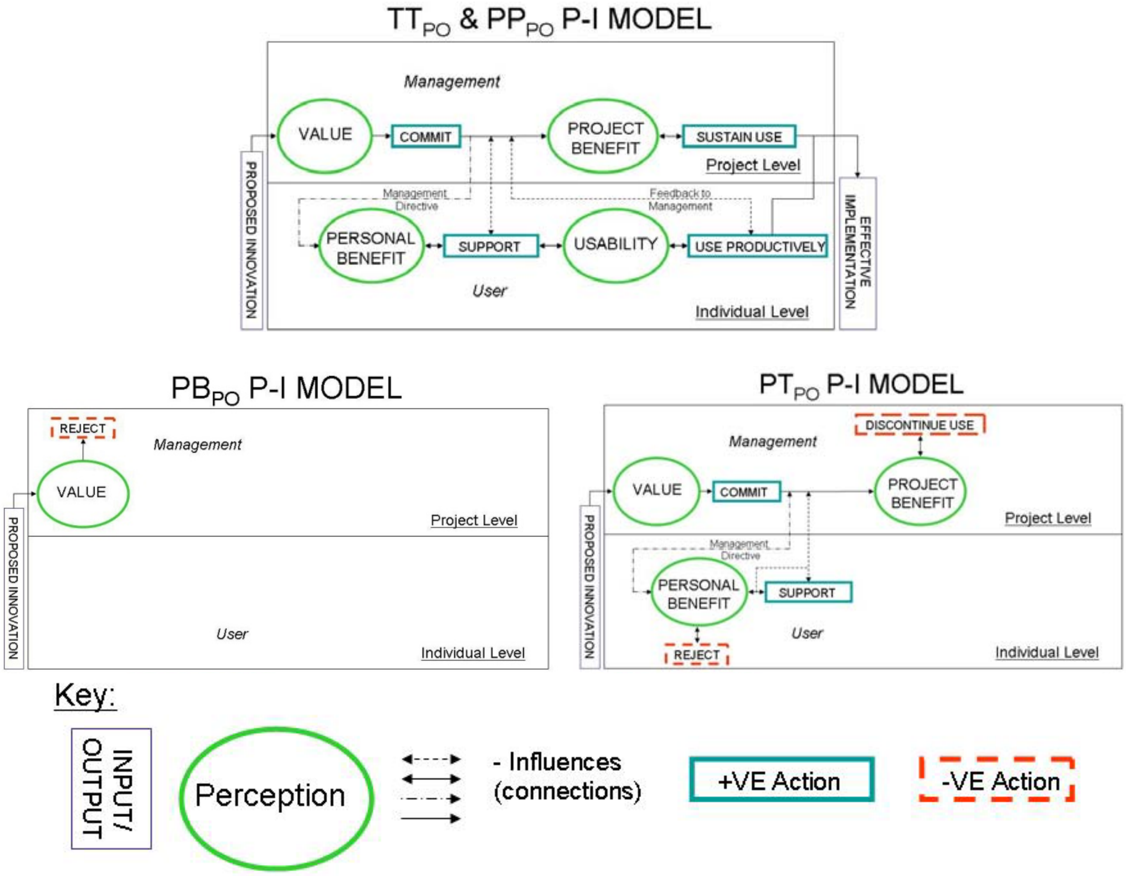

Figure 5-23: P-I models for the TT_{PO}, PP_{PO}, PB_{PO} and PT_{PO} implementations

The four models in Figure 5-23 are illustrative examples of the P-I model being applied to four completed innovation implementations. While this first NVivo7 analysis phase set out to find evidence of, and develop the propositions represented by the P-I_1 model in order to find a synthesis, carrying out this process also provides examples of the P-I model being applied to real sets of data. Their reduced size (vis-à-vis previous figures in this thesis with P-I models) shows how the coloured and shaped symbols can be easily used to interpret what happened in each innovation implementation. Nevertheless, at this point of the research two unknowns became obvious: 1) the ways in which the P-I model could plausibly be applied; and 2) the relationship between an innovation implementations lifecycle and the application of the P-I model. Therefore, the final research phase seeks to further the exploration of the method for compiling a P-I model and provide an evaluation of its potential applications.

6 Evaluation of the P-I Model

> *Clearly, top management cannot close the book on an innovation after they have decided to adopt it. To ensure targeted users' sustained and skilful use of innovative technologies and practices, managers must devote great attention, conviction, and resources to the implementation process. In the absence of effective implementation, the benefits of innovation adoption are likely to be nil.* (Klein and Knight 2005)

The theory-confirmation or final analysis phase of the research is presented in this chapter. After having established the theory behind the P-I model and embodied it with empirical evidence, the meaning embedded within the model can be explored. The rationale of this research phase in general terms is to evaluate the temporal and functional aspects of the P-I model with a view to how it can be applied to an innovation implementation. Data from two more implementations of 4D CAD modelling were studied and, in a similar way to before, the collection was guided by the P-I_3 model's theoretical constructs. The data were again analysed in NVivo7 to produce a P-I model for each innovation implementation, however this time the way in which the P-I models form over time during each implementation is examined as well as the resulting models. The outcomes serve as additional support for the P-I model's plausibility as a useful theory and they provide illustrative empirical examples of its application at different stages of progression for an innovation implementation. Figure 6-1 below presents an overview of this phase of the research design.

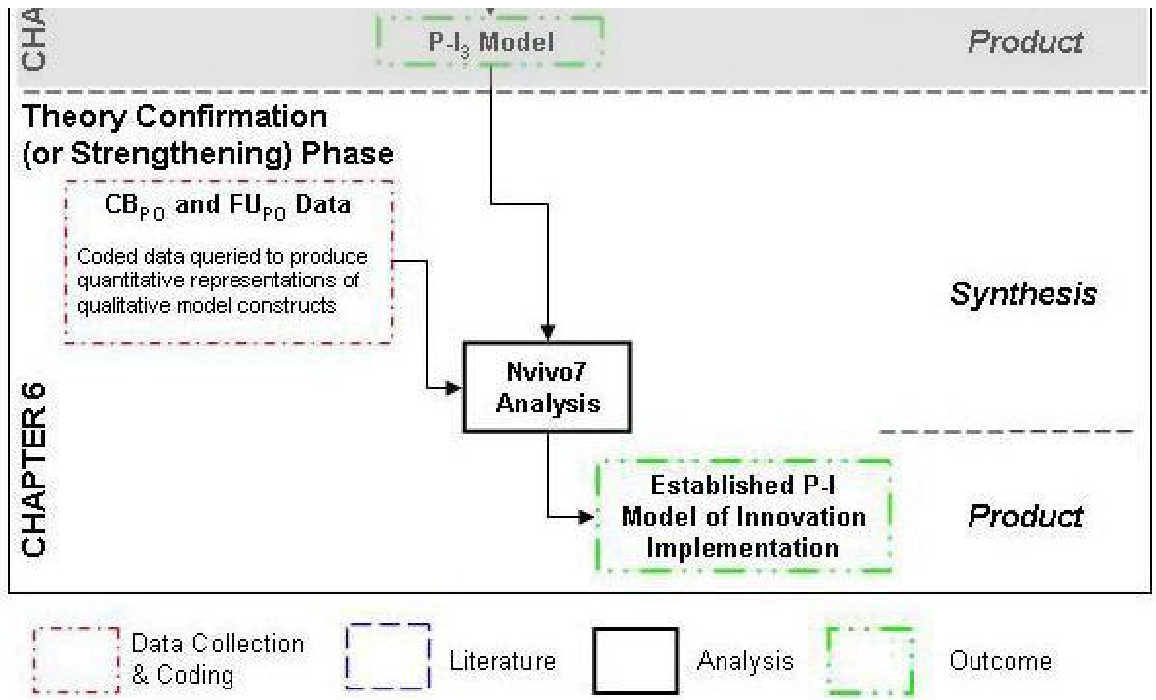

Figure 6-1: Research design – final research phase

6.1 Two more Innovation Implementations Studied

This section introduces each project organisation studied by the final analysis phase, gives an overview of the 4D modelling undertaken at each and summarises the data gathered. The data collected for the final analysis phase of the research was focused and the collection process was thorough. At this advanced stage of the research, my improved aptitudes in qualitative methods enabled more longitudinal data. This was instrumental in facilitating an analysis that explored what the P-I model for a given implementation looks like at different times throughout a progressing innovation implementation. As a result, two more implementations' worth of data embodying the theory behind the P-I model are added to the thesis. More importantly, it provides a basis for the explanation and illustration of how P-I models can be formed at any stage of progression during an innovation implementation and that new data from an ongoing implementation will often cause the P-I model to change dynamically.

6.1.1 The CB_{PO}, FU_{PO} and each 4D CAD Implementation

The scope of works for the two (2) project organisations and the 4D CAD modelling performed as part of each implementation is described below.

Commercial Building Project Organisation (CB_{PO})

The CB_{PO} tendered for and won the contract for the construction of an A$300–400 million city-high rise building. ACL was the primary construction contractor. At the tender stage of the project, the technology group presented 4D CAD modelling to the CB_{PO} as a potentially beneficial innovation, but it was not implemented at that time. At the design and construct (D&C) stage of the project, the technology group was employed by the CB_{PO} to create, implement on-site and maintain a 4D CAD model showing: 1) the construction cycle for one modular floor of the building; 2) the typical cycle for the cladding[53] installation of one floor; and 3) the overall building construction schedule. The objectives of the model were to stimulate creative communications between project office and on-site employees regarding how the building was to be built and to assist in presenting the planned construction to external stakeholders. The data collected show that while the implementation was ultimately effective, a negative perception of value during the tender stage of the project caused project management to initially 'reject' rather than 'commit' to the innovation.

Freeway Upgrade Project Organisation (FU_{PO})

The FU_{PO} was delivering an A$400–500 million upgrade to an existing city freeway. ACL was one of the primary construction contractors and the technology group was employed by the FU_{PO} to implement a 4D CAD model showing the planned construction works and temporary traffic management. The model was implemented at the design and construct (D&C) stage of the project at both the main office and two site offices. The data from the FU_{PO} shows evidence of some negative opinions and concerns at the individual decision-making level at times during the course of the implementation along with the occurrence of some negative actions by particular individual users. However, these instances within the collected data are outweighed by evidence of more longitudinal positive influences that show the implemented 4D CAD model was used productively and the anticipated benefits were realised by the majority of potential adopters – therefore the implementation was effective.

[53] Each floor of the building was clad with glass panels.

6.1.2 Data Gathered

Similar to the data collection for the middle research phase, the emphasis was on data that embodied any of the existing constructs in the P-I_3 model. The prior addition of actions to this final revision of the P-I model provided a new aspect of project-participant behaviour to focus on. The time or stage of progression at which each piece of data were created was also of importance. A summary of the data collected at the CB_{PO} and FU_{PO} is shown in table 6-1.

Table 6-1: Data gathered from the CB_{PO} and FU_{PO}

Project Org.	Data Set	Item/Source
Commercial Building Project Organisation (CB_{PO})	Project Documentation	Emails regarding the 4D CAD implementation (68 emails) Other Documents (16 pages)
	Observations	Researcher field notes from the 4D CAD implementation (26 pages – 12 pages when transcribed)
Freeway Upgrade Project Organisation (FU_{PO})	Project Documentation	Emails regarding the 4D CAD implementation (51 emails) Other Documents (12 pages)
	Observations	Researcher field notes from the 4D CAD implementation (28 pages – 11 pages when transcribed)

The data sets were larger and more comprehensive than those from the first five implementations studied. This was not only a result of being able to collect the data with a more developed theory in place or the fact they were the sixth and seventh implementations studied, but because they were implementations that were longer in duration. This meant that the data were more longitudinal thus ideal for exploring and evaluating possible applications of the P-I model in conjunction with the temporal (time-dependent) aspects. This endeavour was helped by the nature of both data sets because the time at which each data item was created is clearly evident for the project documentation, for example emails, and captured as part of the field notes recording process for the observations. Even so, it was helpful to build this aspect into the coding structure within the NVivo7 data analysis.

6.2 NVivo7 Data Analysis

The data analysis performed during the final research phase required fewer iterations to complete than those from prior analyses. Because the model had reached a sufficiently developed stage the research and the objective had shifted to more deductive interpretations, there was not as much reprocessing of the data. The emphasis was rather to code each passage of data accurately the first time so that it could be retrieved as evidence of the constructs it was coded to when required. This meant that there was no change to or development of the P-I_3 model coding structure during the final research phase. However, the final analysis phase was broadly similar to the middle one as it involved interpreting the new data in terms of the theoretical constructs and structure of the P-I_3 model. This section explains in detail how the NVivo7 data analysis in the final research phase was carried out.

6.2.1 The P-I_3 Model Coding Structure

A new NVivo7 template file was created for the coding structure applied during the final research phase, the *Coding Structure Master – Final Phase.nvp* file. This template file revised the previous one to include those constructs that were added to the P-I_2 model coding structure in making the P-I_3 model (see Figures 5-18 and 5-19). Another element was also added to allow for coding the time at which a piece of data was created at the respective project stage. The new influences and connections in the P-I_3 model were added as 'relationships' in NVivo7 to the existing elements of that type, and project stage timing elements were defined in NVivo7 as three different 'cases' (refer Figures 5-4 and 5-5). These new elements are shown in Figures 6-2 and 6-3 below.

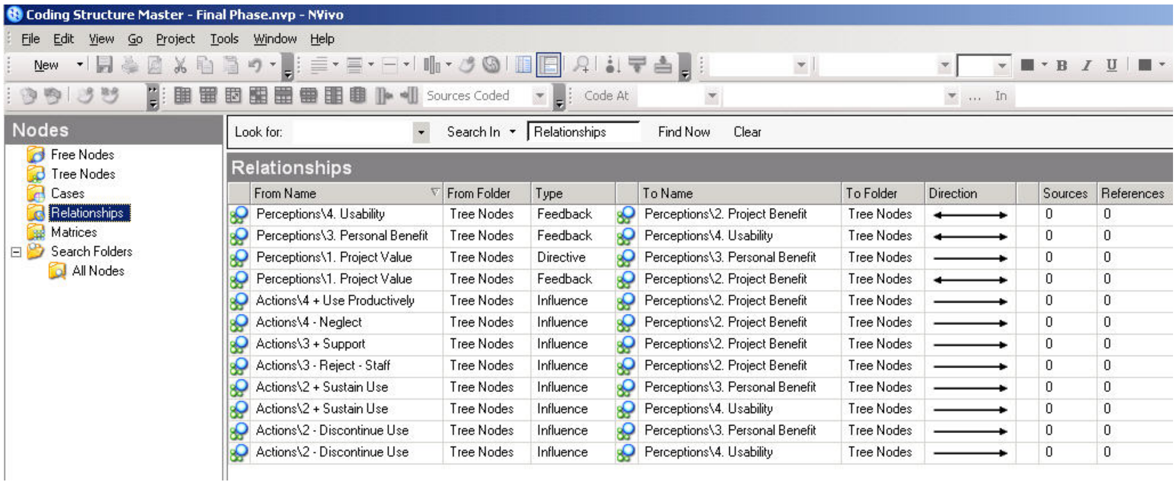

Figure 6-2: NVivo7 ‘Relationships’ node elements in P-I_3 model coding structure

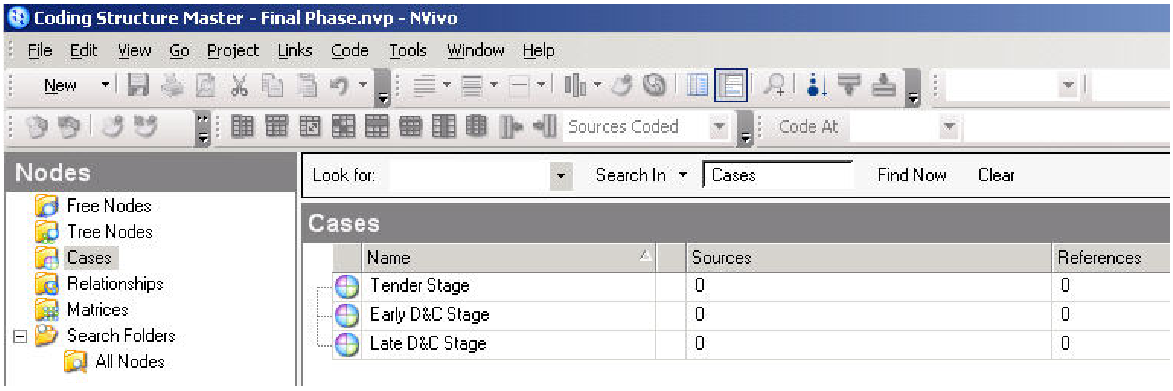

Figure 6-3: NVivo7 ‘Cases’ node elements in P-I_3 model coding structure

It was important to be able to code the new influences or connections in the P-I_3 model as well as the time at which a piece of data were created. This was to maintain the integrity of the P-I model and the compilation method. In other words, by creating each of the elements in Figures 6-2 and 6-3, the ability of the P-I model to cater for all possible scenarios for these implementation variables was maintained. Because the innovation implementation is different, it is not conceivable that any one implementation would provide evidence of each influence and it may occur at only one of the project stages. This means that in order for the P-I model to be able to map each scenario, all combinations need to exist in the model and also in the NVivo7 coding structure. Testimony to this can be seen in the data coded from the two project organisations featured in this final research phase (section 6.2.2 below).

Because the primary constructs in the P-I_3 model are consistent with those in the P-I_2 model, they were coded the same way (refer sections 5.5.1 and 5.5.2). The high importance of the corresponding elements in the NVivo7 coding structure for compiling a P-I model also remained consistent. That is, the *Tree Nodes* representing the perceptions, actions and contributing factors. The new influence elements in the P-I_3 model coding structure were also applied via the same 'select and right-click' functional coding method, however their purpose was more to catalogue, arrange and make for easy access to the data vis-à-vis to interpret it. The purpose was the same for new time-dependent elements in the P-I_3 model coding structure and they too were able to be coded using the same procedure. However the easiest way to code the project stage from which a whole piece of data (e.g. an email) had come was when importing it to NVivo7. Figure 6-4 shows a partial screenshot from the NVivo7 'import' function that allowed this to be done. To summarise the revisions through which the coding structure passed in arriving at the P-I_3 model coding structure, Appendix F – NVivo7 Coding Structure Evolution has been included.

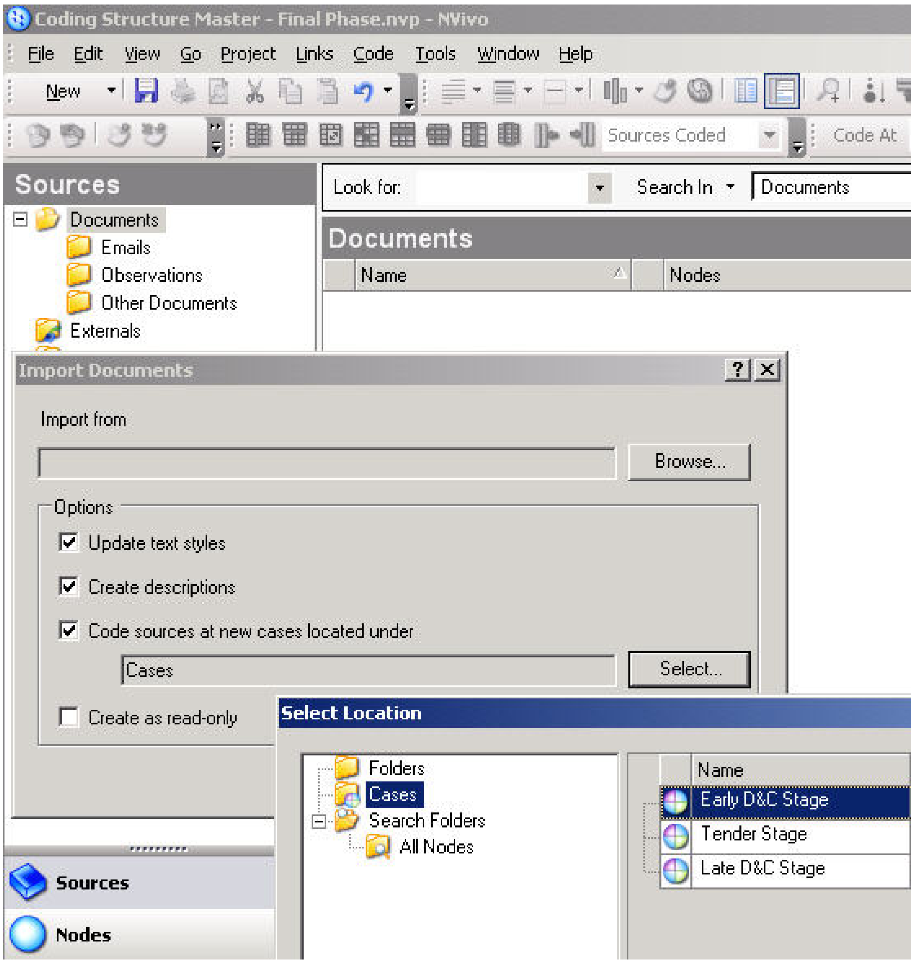

Figure 6-4: Coding documents to NVivo7 'Cases' node elements at import

An interesting aspect of the coding procedures completed during the final phase analysis was the actual timing of their execution. Data were often coded soon after it was collected so that at times the analysis and implementations occurred in parallel. In this way the coded data were deductively explored in real time as well as post event. The exploration performed during the final research phase analysis made extensive use of *Queries* based on combinations of coding elements in NVivo7.

6.2.2 Querying the Coded Data

The way in which the data were explored during the final research phase was deductive vis-à-vis the inductive exploration of the initial and middle phases. *Queries* were set up in NVivo7 (refer Figure 5-7) and applied or ‘run’ as part of each NVivo7 analysis of the CB_{PO} and FU_{PO} data. They could be set by any combination of criteria from the coding structure or imported text, but the most useful Queries for the compilation of a P-I model searched for the quantities of data coded to each of the primary constructs. That is, the four perceptions and eight actions. By using NVivo7 ‘Queries’ the weight of evidence for each $P\text{-}I_3$ model primary construct found within the data sets from the two 4D CAD implementations could be gauged (or deduced). This so-called ‘weight’ is logically dependent on three main variables, each of which is used as pivotal criteria in the key NVivo7 Queries explained in this section:

1. The extent to which the implementation has progressed – in terms of the project stage at which a piece of data were created (NVivo7 *Cases* element);

2. The type of contribution (i.e. positive, negative or indifferent) for a piece of data (NVivo7 *Free Node* element); and

3. The number of pieces of data coded as evidence (visible in NVivo7 GUI summaries and Query results).

A number of Queries were trialled but those using the three criteria above proved to be the most useful in quantifying the data coded as evidence of the primary P-I model constructs. Ultimately the trial and error establishment of the key Queries resulted in one for each of the four perceptions and one that covered the eight actions. Therefore there are 'Five Key Queries' in the particular NVivo7 analysis method arrived at in the final research phase. Figure 6-5 highlights the five key Queries and shows some of the other Queries that were trialled but produced results that weren't as meaningful.

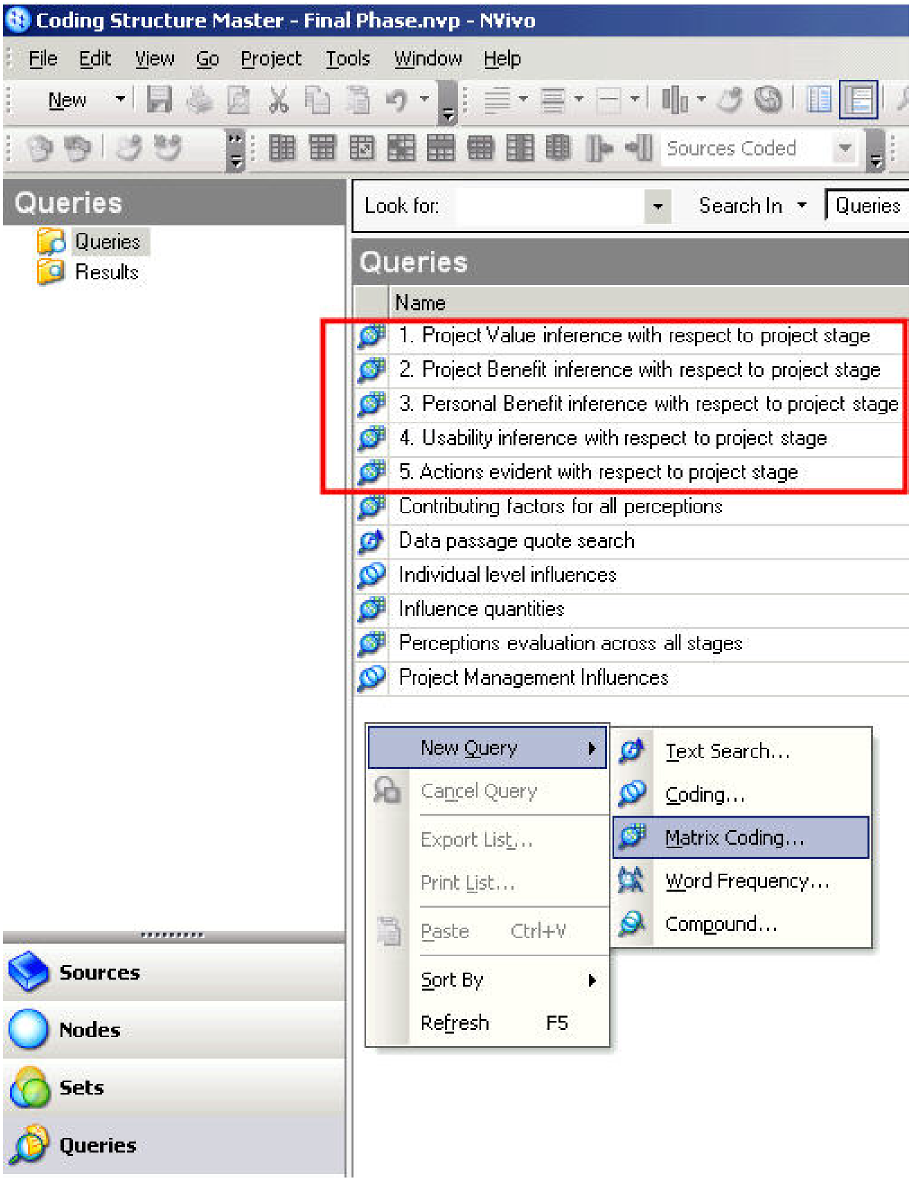

Figure 6-5: Five key NVivo7 Queries and right-click options

The five key Queries were found to be the quickest way of isolating and clearest way of summarising the data that embodied the primary P-I model constructs for each implementation. This section explains how they were established and applied in NVivo7. The five key Queries provide direct access to the coded data they summarise which means the influential secondary constructs for a particular primary construct were able to be quickly determined if required. The addition of these five Queries to the *Coding Structure Master – Final Phase.nvp* NVivo7 analysis template file is an important expansion of the compilation method for a P-I model.

Key Queries 1 to 4 – *Perception* inference with respect to project stage

Figure 6-6 shows the NVivo7 screens used to establish key Query number 1 – Project Value inference with respect to project stage.

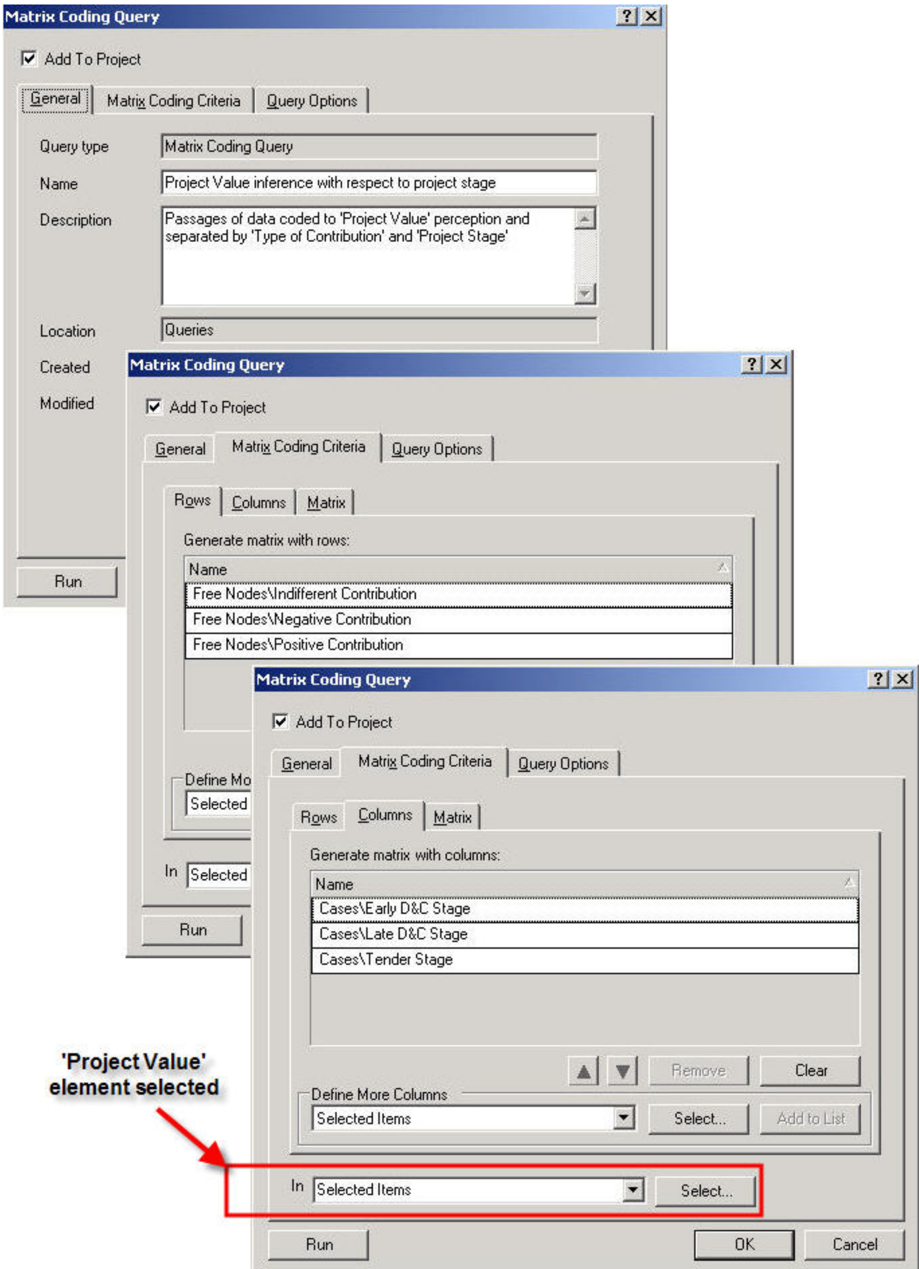

Figure 6-6: NVivo7 screens used to establish Query 1

The NVivo7 screens shown in Figure 6-6 appear after selecting 'Matrix Coding…' as shown in Figure 6-5. They were used in a similar way to create key Queries 2, 3 and 4 with the only difference between them being the 'In' setting which was set to the three other perceptions in the P-I model (i.e. Project Benefit, Personal Benefit and Usability). Each of the Queries was applied regularly during the analysis, often as the data were being coded, by clicking 'Run' for the selected Query. This activated the summary screens shown in section 6.3 of this chapter. Key Queries 1, 2, 3 and 4 allowed the coding already performed to be checked but more importantly, it streamlined and increased the reliability of the inference process for each P-I model perception. The fifth key Query allowed the actions evident in each implementation to be evaluated.

Key Query 5 – 'Actions' evident with respect to project stage

Figure 6-7 shows the NVivo7 screens used to establish the key Query number 5. While a Matrix Coding Query was also used to create key Query 5 there was no need to select a coding element at the 'In' setting. This is because the actions already indicate the type of contribution they are providing to the implementation. The summarising matrices activated by running each of the five key Queries are presented as part of the final research phase findings.

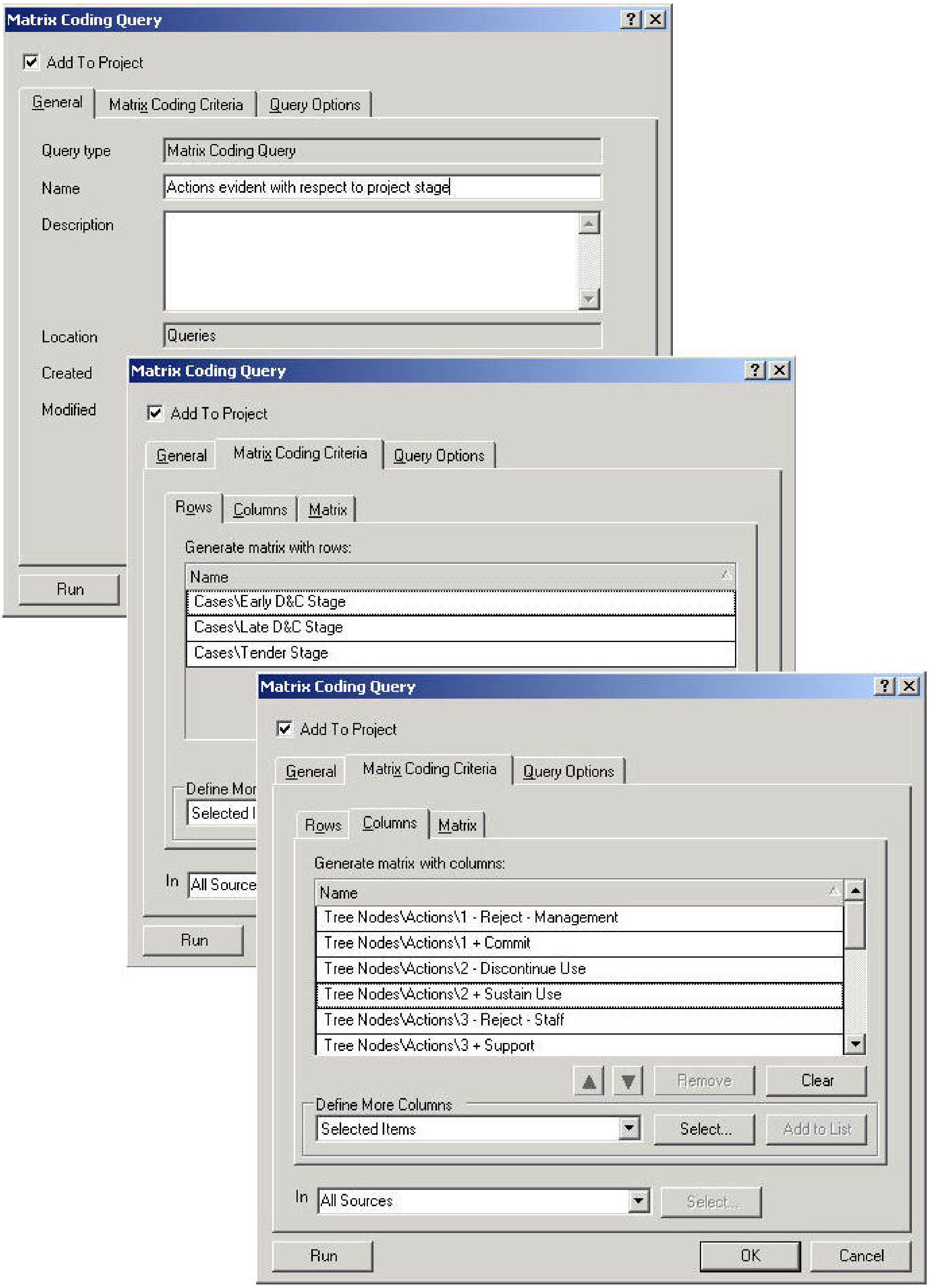

Figure 6-7: NVivo7 screens used to establish Query 5

6.3 Final Research Phase Findings

The main findings from the final research phase came largely from running the five key Queries within the coded data. The data were coded to the P-I_3 model coding structure via the same NVivo7 process as in the previous research phase however as a contrast, the main findings were not developments to the theory behind the P-I model produced during the actual coding procedure. They were produced by applying the five key NVivo7 Queries once all the CB_{PO} and FU_{PO} data were coded. These Queries are also used throughout the analysis to access the data and check that they had been coded correctly. The results of running each of the five key Queries provided immediate access to the data embodying the primary P-I model constructs and produced a succinct summary of them. Figure 6-8 shows an NVivo7 screenshot with the results of the five Queries open and the tab for Key Query 5 active. The physical results of running the five key Queries in each of the CB_{PO} and FU_{PO} NVivo7 analysis files at a time when each implementation had concluded and all data were coded follows immediately in Figure 6-9.

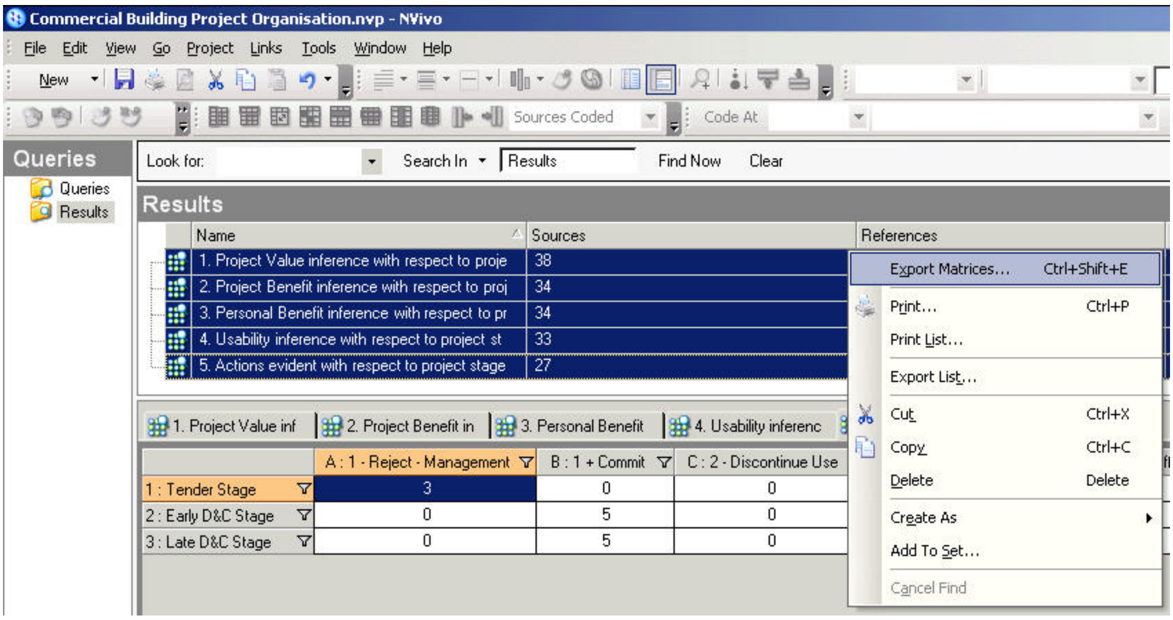

Figure 6-8: NVivo7 Query results screenshot

Project Value inference (Query 1 results)

CBPO	Tender Stage	Early D&C Stage	Late D&C Stage
Indifferent Contribution	7	11	5
Negative Contribution	3	0	0
Positive Contribution	2	9	4

FUPO	Tender Stage	Early D&C Stage	Late D&C Stage
Indifferent Contribution	2	7	0
Negative Contribution	0	0	0
Positive Contribution	6	8	0

Project Benefit inference (Query 2 results)

CBPO	Tender Stage	Early D&C Stage	Late D&C Stage
Indifferent Contribution	0	11	5
Negative Contribution	0	0	0
Positive Contribution	0	13	6

FUPO	Tender Stage	Early D&C Stage	Late D&C Stage
Indifferent Contribution	0	7	1
Negative Contribution	0	0	3
Positive Contribution	0	11	4

Personal Benefit inference (Query 3 results)

CBPO	Tender Stage	Early D&C Stage	Late D&C Stage
Indifferent Contribution	0	10	5
Negative Contribution	0	0	0
Positive Contribution	0	16	4

FUPO	Tender Stage	Early D&C Stage	Late D&C Stage
Indifferent Contribution	0	8	1
Negative Contribution	0	1	3
Positive Contribution	0	11	4

Usability inference (Query 4 results)

CBPO	Tender Stage	Early D&C Stage	Late D&C Stage
Indifferent Contribution	0	10	5
Negative Contribution	0	0	0
Positive Contribution	0	14	5

FUPO	Tender Stage	Early D&C Stage	Late D&C Stage
Indifferent Contribution	0	6	1
Negative Contribution	0	1	3
Positive Contribution	0	10	4

Evidence of actions with respect to project stage (Query 5 results)

CBPO	1 - Reject: *Management*	1 + Commit	2 - Discontinue Use	2 + Sustain Use	3 - Reject: *Staff*	3 + Support	4 - Neglect	4 + Use Productively
Tender Stage	3	0	0	0	0	0	0	0
Early D&C Stage	0	5	0	6	0	17	0	10
Late D&C Stage	0	5	0	6	0	6	0	6

FUPO	1 - Reject: *Management*	1 + Commit	2 - Discontinue Use	2 + Sustain Use	3 - Reject: *Staff*	3 + Support	4 - Neglect	4 + Use Productively
Tender Stage	0	5	0	0	0	0	0	0
Early D&C Stage	0	4	0	0	0	13	0	11
Late D&C Stage	0	0	0	3	4	3	4	3

Figure 6-9: NVivo7 analysis results of the five key Queries[54]

The coding summaries shown in Figure 6-9[55] were used during the analysis to compile P-I models for each of the three project stages: 1) Tender; 2) Early D&C; and 3) Late D&C. They were generated as Microsoft Excel spreadsheets using the right-click function shown in Figure 6-8. Also shown in this Figure is an example of the function that allowed direct access to the coded data – that being the highlighted top left-hand cell of the matrix. A double-click on any of the cells in each matrix retrieved the data that had been coded to the corresponding row *AND* column elements of the coding structure – thereby performing the simple logic function. This allowed me to check like against contrasting data and in

[54] CBPO and FUPO in this figure are the same as CB_{PO} and FU_{PO} (i.e. just not formatted with the PO as subscript).

[55] Note that every tally in the ten matrices shown by Figure 6-9 is the number of 'Sources' in NVivo7 coded to the combination of P-I_3 coding structure elements that is set out by the criteria for each matrix. A single NVivo7 source could be any of six things: 1) a single email, 2) a group (or thread) of emails, 3) a page of transcribed field notes, 4) an NVivo7 memo, 5) a linked external item of data that has had notes made about it (such as an image), or 6) an imported document (such as meeting minutes).

combination with any associated supporting information[56] in order to make an inference about a project-participant perception or conclusion regarding the existence of a particular action. It is important to note that this was done constantly throughout the analysis and amidst increasing quantities of coded passages of text, thereby making for traversable data sets and an iterative data analysis. As a result the compiled CB_{PO} and FU_{PO} P-I models at each of the three different project stages correspond with the two sets of Five Key Query results shown in Figure 6-9. This correlation and the way in which the compiled P-I models symbolise the findings of the final research phase are explained in this section.

6.3.1 P-I Models Compiled at the Beginning of an Implementation

This thesis contends that an innovation implementation begins at the time the implementation of it is proposed. This definition was alluded to while interpreting the data as part of the PB_{PO} NVivo7 analysis in the previous research phase and this suggestion was echoed by the data from the CB_{PO} and FU_{PO}. The compiled PB_{PO} P-I model (in Figure 5-21) shows an implementation that hadn't progressed far at all because the management decided not to use 4D modelling. However in a sense, an implementation of 4D modelling had begun because it had been formally proposed. The decision to reject a potential innovation implementation can be overturned at any time therefore a P-I model such as the one for the PB_{PO} shows the simplest 'state' for an innovation implementation – proposal rejected. A similar trend was evident in the CB_{PO} data coded to 'tender stage' while in contrast, the tender stage data from the FU_{PO} illustrates the other possible beginning 'state' for an implementation – proposal accepted (i.e. a commitment to the innovation implementation is made by project management).

The most revealing data from the time when 4D modelling was first proposed as a value-adding tool to the CB_{PO} management came from a single meeting. The meeting, between the ACL technology group and the CB_{PO} managers, had two purposes: first to introduce them to the technology, thus raise awareness; and second to discuss the requirements for implementing it at the tender stage (i.e.

[56] The associated supporting information is the data coded as having an indifferent contribution to the model constructs it provided evidence of or information about.

cost, resources and targeted benefits). This meeting was the only pre-tender submission meeting regarding 4D modelling and the first between the ACL technology group members and the CB_{PO} managers. A Microsoft Outlook Calender search was used to summarise all scheduled meetings held between the ACL technology group and CB_{PO} management involving 4D modelling (Figure 6-10).

Calendar (Search Results) [redacted]

Click here to enable Instant Search

Subject	Location	Start	End	Recurrence ...	Catego...
Recurrence: (none) (13 items)					
Mtg [redacted], [redacted], et.Al re CBPO tender 4D Modelling	[redacted]	Mon 24/04/2006 4:00 PM	Mon 24/04/2006 5:00 PM		
CBPO - 3D/4D Modelling re Jump Form/Typical Floor/etc	[redacted]	Mon 4/06/2007 3:00 PM	Mon 4/06/2007 5:00 PM		
CBPO-3D Modelling	[redacted]	Mon 18/06/2007 3:00 PM	Mon 18/06/2007 4:30 PM		
Updated: CBPO 3D/4D Modelling	[redacted]	Tue 17/07/2007 9:30 AM	Tue 17/07/2007 10:30 AM		
CBPO-4D Modell	[redacted]	Tue 31/07/2007 4:00 PM	Tue 31/07/2007 5:00 PM		
CBPO presentation	[redacted]	Thu 16/08/2007 2:00 PM	Thu 16/08/2007 3:00 PM		
[redacted] mtg re CBPO safety & training model	[redacted]	Tue 4/09/2007 3:00 PM	Tue 4/09/2007 4:00 PM		
CBPO 4D workshop	[redacted]	Wed 5/09/2007 9:00 AM	Wed 5/09/2007 12:00 PM		
Mtg CBPO re hyperlinks	[redacted]	Tue 18/09/2007 2:00 PM	Tue 18/09/2007 4:00 PM		
Mtg [redacted]	[redacted]	Wed 23/01/2008 1:00 PM	Wed 23/01/2008 2:30 PM		
[redacted] visiting	[redacted]	Wed 30/01/2008 1:00 PM	Wed 30/01/2008 3:00 PM		
Prepare images for CBPO	[redacted]	Wed 14/05/2008 9:30 AM	Wed 14/05/2008 10:30 AM		
[redacted] - join in safety & site walk	[redacted]	Fri 27/06/2008 11:00 AM	Fri 27/06/2008 2:00 PM		

Figure 6-10: Summary of ACL technology group – CB_{PO} management formal meetings

The gap of nearly 14 months between the first and second meetings shows a clear period of inactivity. This evidence is quite revealing even without knowing exactly what transpired at the meeting because it is reasonable to assume that had 4D modelling been implemented as a result of the first meeting, more meetings would have occurred soon after. Despite this, the minutes from this meeting and associated NVivo7 memos (see Appendix G.1) are what provided the coded data supporting the CB_{PO} tender stage P-I model. These account for two of the three sources of data coded as negative contributions to the perception of project value at a tender stage (as indicated in Figure 6-9)[57]. The CB_{PO} tender stage P-I model compiled as an outcome of the analysis in the final research phase is shown by Figure 6-11 below along with the FU_{PO} tender stage model.

[57] The two (2) sources coded as positive contributions to the tender stage perception of project value relate to the fact that the CB_{PO} managers recognised the 'relative advantage' that the 4D modelling innovation could provide. This was not sufficient enough to cause an overall positive perception of project value however and this was confirmed by the evidence of actioned 'rejection' within the data.

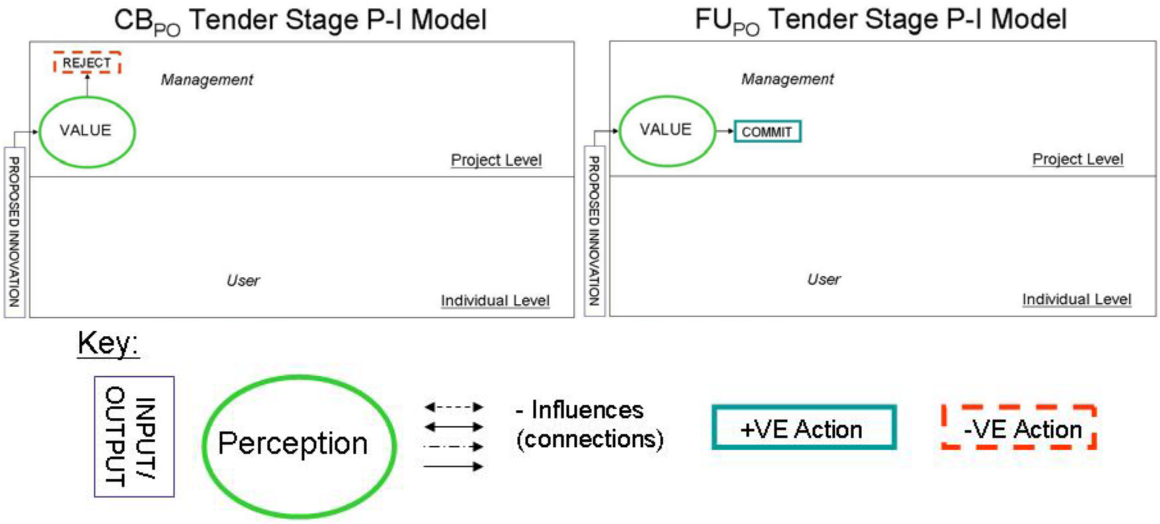

Figure 6-11: Illustrative tender stage P-I models

The FU_{PO} tender stage P-I model exhibits the state of acceptance of, or commitment to, the proposed innovation implementation. This is the initial positive scenario with respect to the progression of an implementation and for this case, it can be identified in the summary of the coded data that support or embody it. At the top right-hand corner of Figure 6-9 it shows there were six sources in the FU_{PO} NVivo7 analysis coded as providing evidence of positive contributions to the tender stage perception of project value and none as negative contributions[58]. It can also be seen that no sources were coded to the tender stage for any of the other three perceptions in the P-I model which indicates the innovation implementation was committed to at the tender stage but carried out after the tender was awarded. While this captures the correlation between the compiled P-I models and the coding summaries, it is important to realise they are both metadata (data about data) created by previous interpretation of the underlying physical data. When used in this way, the coding summaries are a clarifying link between the physical data and the implementation 'state' presented by a P-I model.

[58] The six sources were an email conversation consisting of three emails, three different pages of transcribed field notes and the minutes from one meeting that had an associated NVivo7 memo.

6.3.2 P-I Models Compiled Midway through an Implementation

In compiling a P-I model of each of the two 4D modelling implementations for a stage when they were both in progress, the data coded as coming from the early D&C stage were used. An innovation implementation that has commenced produces data relevant to all four perceptions in the P-I model as well as evidence of any actions performed by the project-participants. Therefore all five key NVivo7 Queries were used to access and quantify the relevant data as part of the process of inferring the four perceptions and determining which actions had been performed by the project-participants. Both the CB_{PO} and FU_{PO} early D&C stage P-I models are shown in Figure 6-12.

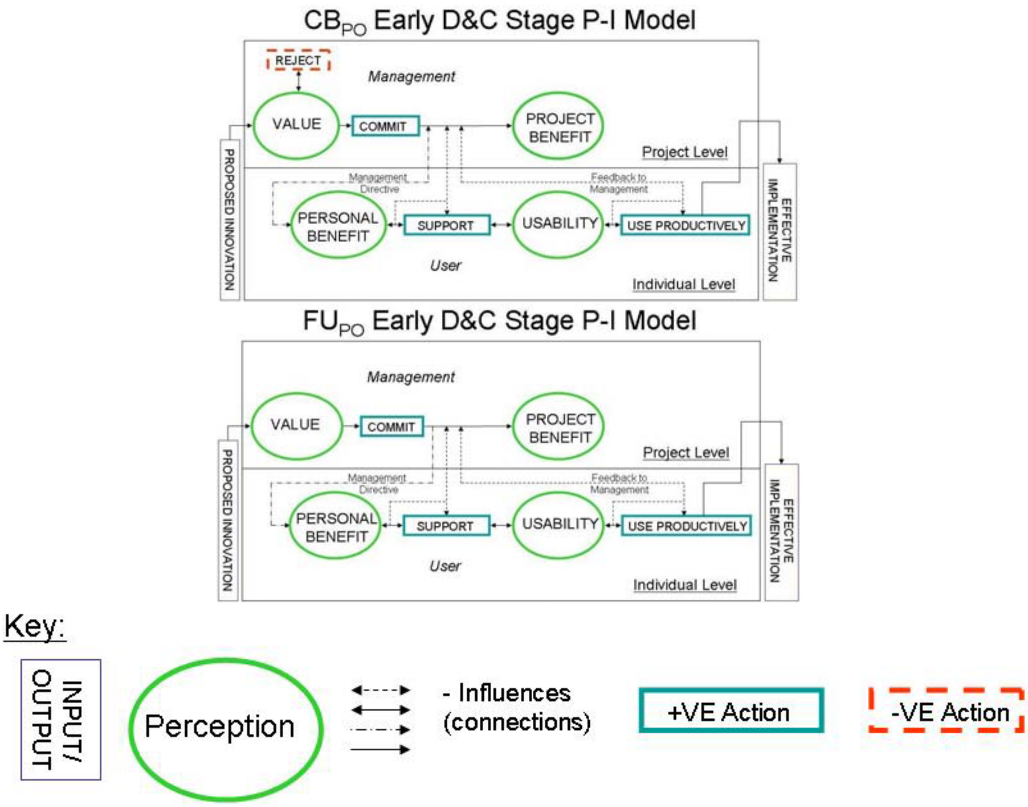

Figure 6-12: Illustrative early D&C stage P-I models

The P-I models in Figure 6-12 present two innovation implementations that have progressed to actioned 'productive use' – hence the ultimately desired 'effective' state. As with the tender stage data, the number of coded sources supporting the two primary constructs from the early D&C stage is shown in Figure 6-9 for both project organisations. The results of Key Query 5 show that neither of the CB_{PO} or FU_{PO} analyses returned any data that were coded to both the early D&C stage

AND either of the negative actions. On the other hand, they show that convincing quantities of data exist as evidence of the positive actions. This indicates the two implementations were well accepted by the project-participants and they had progressed via their positive actions. Similarly, the results for key Queries 1, 2, 3 and 4 indicate that almost all contributions to each perception were positive – therefore they were inferred as such.

The physical data embodying the two P-I models in Figure 6-12 included most if not all the different types of data source. This is because the bulk of activity associated with the 4D modelling at each project organisation occurred during the early D&C stages of both projects and large quantities of data were able to be gathered during this time. The coding summaries in Figure 6-9 can also be used to determine this. As an indicative cross-section of this data, Appendices G and H have been included and they present some of the more revealing evidence that was gathered from the CB_{PO} and FU_{PO} and generated via participant-observation.

6.3.3 P-I Models of Completed Implementations

A significant functional advantage in compiling a P-I model of an innovation implementation that has been completed is that the data need not be categorised by when it was obtained. This is because a final P-I model should indicate everything that occurred up until the time the implementation is said to be complete. This finding, as might intuitively be expected, became apparent as part of the analysis performed during the final research phase and is considered further in the following chapter when the various applications of the P-I model are discussed in more detail. Nevertheless, coding the data gathered towards the end of the CB_{PO} and FU_{PO} 4D modelling implementations to 'late D&C stage' helped emphasise when some negative actions occurred at the FU_{PO}. Figure 6-13 shows the two late D&C stage P-I models.

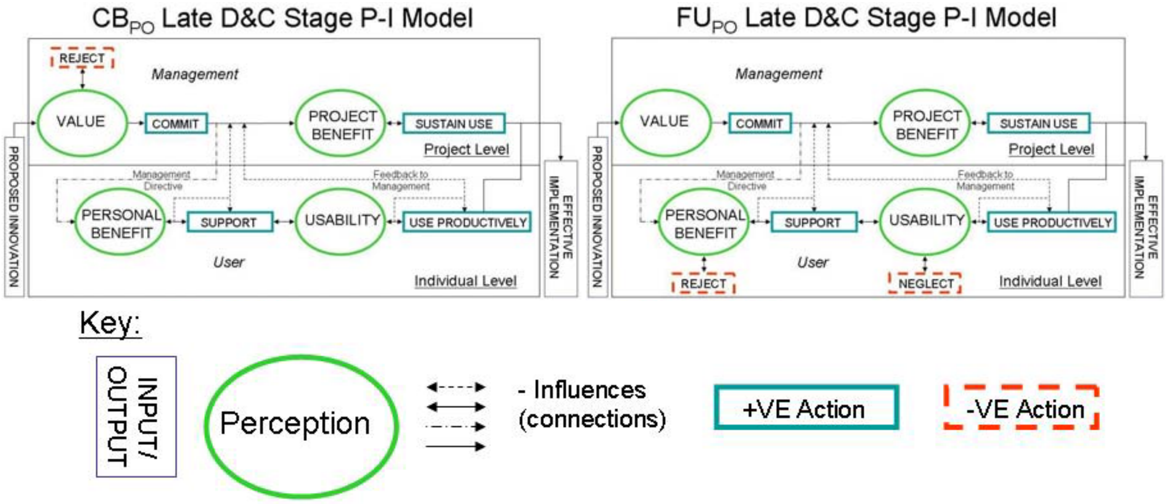

Figure 6-13: Illustrative late D&C stage P-I models

The way in which the two implementations advanced from mid- to completed phase can be determined by comparing the late D&C stage P-I models in Figure 6-13 with those in Figure 6-12. Both models in Figure 6-13 show that project management supported sustained use of 4D modelling through their actions but it can be seen that the FU_{PO} implementation experienced some negative actions from individual users. Again, Figure 6-9 summarises the coded data behind each of these primary P-I model constructs that had not previously occurred. For example, four sources provided evidence of each negative action at the FU_{PO} during the late D&C stage. It's also apparent in Figure 6-9 that the previously identified positive actions were ongoing during this time. However, the instances of each negative action were isolated and did not have a significant influence on the implementation (see Appendix H). Moreover, the insignificant influence of the negative actions becomes much clearer by including the weight of evidence for the positive actions from the early D&C stage[59].

It is important to note that the data used to compile a P-I model of a completed implementation do not need to be coded to any temporal aspects of the implementation. Because the implementation is complete there can be no new data so the compiled P-I model should be embodied by the entire data set. Therefore the CB_{PO} and FU_{PO} P-I models in Figure 6-13 were compiled using the contributions from all the coded data summarised in Figure 6-9. In this way they

[59] Had the negative actions been more significant and occurred without productive use being actioned, then the implementation would not have been effective.

illustrate two completed innovation implementations in terms of the project-participant perceptions and actions that occurred throughout each entire implementation.

6.3.4 Furthering the P-I Model Compilation Method

The method for compiling a P-I model was developed further by the analysis in the final research phase. The final revision of the NVivo7 template file, *Coding Structure Master – Final Phase.nvp,* is a tangible outcome at the heart of the developed P-I model compilation method and it captures the coding structure to be applied in order for someone to compile a P-I model. The most notable advancements brought by the final research phase are the establishment and use of ‘the five key Queries’ to help determine the weight of evidence behind each P-I model construct. Few if any changes were made to the way a template file was applied to textural data in NVivo7 between the analyses of the middle and final research phases. The CB_{PO} and FU_{PO} P-I models provide illustrative examples of P-I models compiled with the aid of the five key Queries.

A simple summary sheet was developed so that the results of the five key Queries could be presented together. The need for this widget was identified by assuming a post-analysis, reflective perspective, similar to that which helped identify the establishment of a P-I model compilation method as a finding from the middle research phase. By thinking about what was missing in the P-I model compilation method or what could simplify its replication, it became apparent that a scorecard-like summary of a coded data set would help the final conversion of it into a graphical model. Figure 6-14 shows the summary sheet for the case of the final CB_{PO} P-I model.

	Contributing Factors (Secondary Constructs)	Weight of Evidence +VE	Weight of Evidence -VE	Perceptions (Primary Const.)	Weight of Evidence +VE	Weight of Evidence -VE	Actions (Primary Constructs)	Weight of Evidence
Project Management	Transaction Costs	7	3	VALUE	15	3	COMMIT	10
	Results Demonstrability	14	1				REJECT	3
	Suitable Resources	9	3					
	Job-Fit	11	0	PROJECT BENEFIT	19	0	SUSTAIN USE	12
	Relative Advantage	16	0					
	Image	7	0					
	Managerial Patience	5	0				DISCONTINUE USE	0
	Suitable Resources	17	0					
	Transaction Costs	7	0					
Individual User	Job-Fit	16	0	PERSONAL BENEFIT	20	0	SUPPORT	23
	Affect	7	0					
	Relative Advantage	17	0					
	Image	9	0				REJECT	0
	Subjective Norm	6	0					
	Suitable Resources	16	0					
	Use Intention	9	0					
	Compatibility	8	0	USABILITY	19	0	USE PRODUCTIVELY	16
	Ease of Use	13	0					
	Voluntariness of Use	7	0				NEGLECT	0
	Self-Efficacy	6	0					
	Anxiety	7	0					

Figure 6-14: Summary sheet used to compile the final CB_{PO} P-I model

Presenting a coded data set using the summary sheet brings to the fore an important aspect of the compilation method: making judgments where both positive and negative evidence exists. In these unclear situations, unlike the case of the CB_{PO} data in Figure 6-14, common sense must be applied when making judgment calls and they must be based on the actual content of the evidence (i.e. the textural passages). For example, a particular implementation may produce three pieces of data coded to a negative action and only one coded to the associated positive action. This does not mean that the negative action outweighs the positive action. The four pieces of data should be retrieved and compared to determine which action is more compelling and what followed each action in the sequence of events. A number of circumstantial variables could be used to determine this, such as the authority held by the source of the data (e.g. manager or user). Judgments about project-participant perceptions should be approached in the same way. The advantage here is that the evidence of associated actions can also be used to help determine if the perception is positive or negative.

6.4 Chapter Summary

The theory-confirmation (or final) research phase explored the functional and temporal aspects of applying the P-I model to an innovation implementation. The specific outcomes were advancements to the method for compiling a P-I model, namely, the addition of the Five Key Queries to the NVivo7 template file and also the creation of a separate summary sheet (see Figure 6-14). These two findings assist in making inferences about the perception and action constructs in the P-I model from a coded data set. The other changes were additions to two of the coding element categories: 1) *Cases* elements for temporal coding of data to implementation stage, and 2) *Relationships* elements so as to include the new influence connections from the P-I_3 model. The general significance of the final phase data analysis is the provision of a better understanding of how the P-I model could be applied to help improve the effectiveness of an innovation implementation. The CB_{PO} and FU_{PO} P-I models compiled from data created at different stages of progression for each 4D modelling implementation help summarise the outcomes that are also inputs to the discussion chapter of this thesis that follows. As a more complete graphical summary, Figure 6-15 (overleaf) compares the progression of the CB_{PO} and FU_{PO} implementations and the lifecycle of the projects themselves using the P-I models that were compiled.

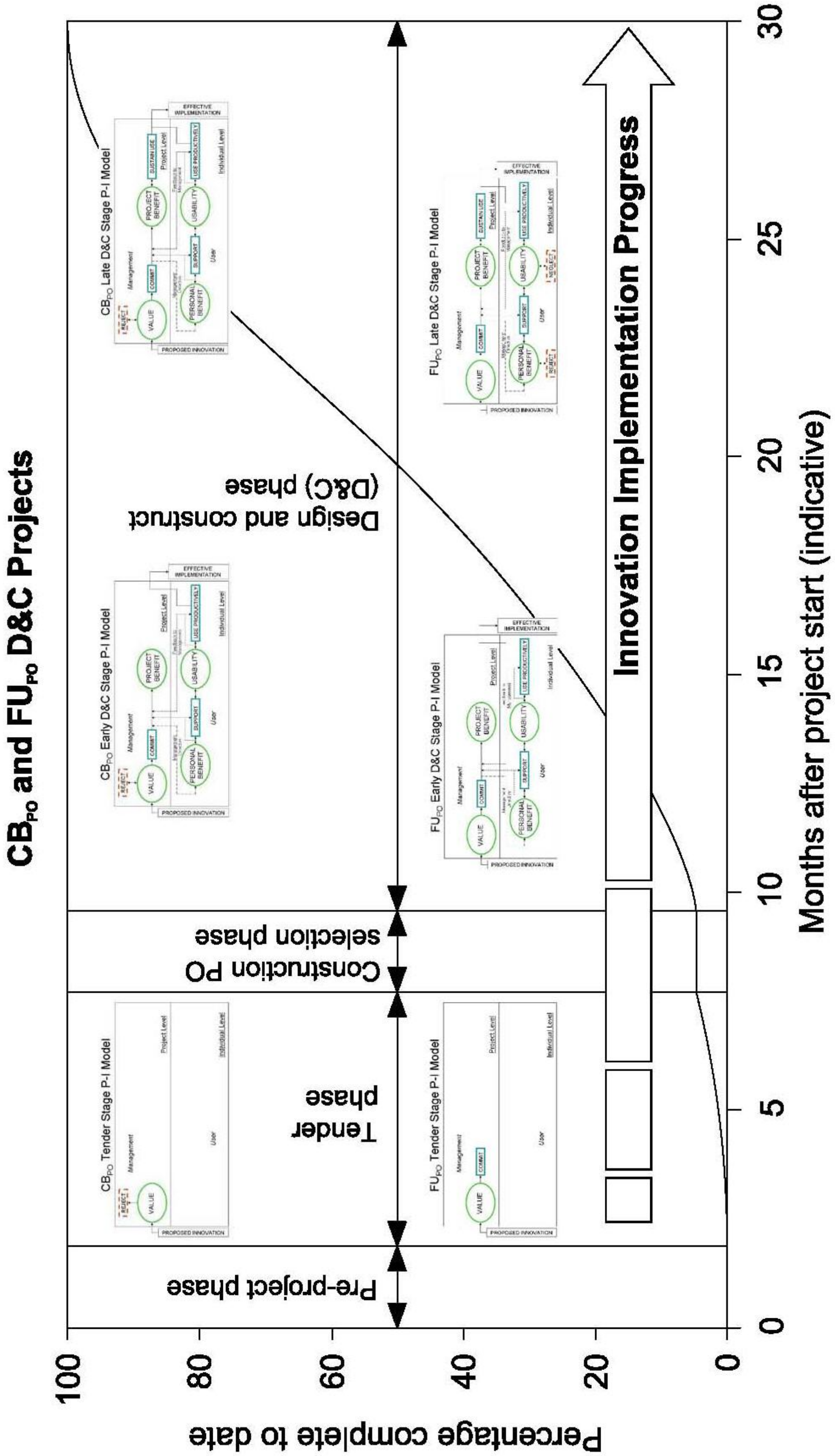

Figure 6-15: Implementation progress vs project lifecycle using the P-I model

Compiling the CB_{PO} and FU_{PO} P-I models at three different points in time with respect to the project lifecycle helped identify a useful concept – implementation states. An implementation can be considered to be in one of six ‘implementation states’ depending, first, on the actions the management have taken and, second, on the actions of the individual users. The six implementation states identified as a result of the evaluation of the P-I model are:

1. Implementation Proposed – Neither a commitment nor rejection decision/action by project management has been made.

2. Proposal Rejected – Implementation proposal rejected by project management (e.g. the CB_{PO} at a tender stage as in Figure 6-15).

3. Implementation Commitment - Implementation proposal accepted and committed to by project management (e.g. the FU_{PO} at a tender stage as in Figure 6-15).

4. Neglected Use – Individual users have either rejected the innovation entirely or it has been seldom used.

5. Discontinued Use – The project management decision to stop using the innovation has been made.

6. Productive Use/Implementation Effectiveness – The innovation has been or is being used productively. (e.g. the CB_{PO} and FU_{PO} during the D&C phase as in Figure 6-15). Note that the decision to sustain use does not have to have come from project management for this implementation state to exist.

The notion of implementation states complements the theory behind the P-I model and simplifies the map of an innovation implementation’s progress even further. Each of the six states align with a small number of possible P-I modes, in some cases only one. Therefore for a P-I model that has been compiled and is being used to clarify what has happened or is happening in an innovation implementation, the explanation can begin with a single concept that is expandable. This newfound expandability is brought by the synthesis of theoretical constructs from implementation research that is the theory behind the P-I model.

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7 Discussion

> *The importance of successful implementation of IT investment poses a fundamental question: "How can a company improve the chances of an IT implementation being successful?" While factor research has identified various elements of the corporate environment that are likely to lead to successful implementation, the end result is a fragmented summary of disparate factors that have been tested in various situations at different points along the implementation process. It is important for researchers to integrate these fragments into a holistic approach that will allow companies to coordinate efforts in the most effective way.* (Edington and Shin 2006)

The introduction of a new way of things, such as the implementation of an innovation, is one of the most difficult tasks that can be undertaken (Machiavelli 2006). The work of many researchers has been devoted to trying to help simplify this challenge (Klein and Knight 2005) and meaningful findings often contribute as small pieces to the intricate global conundrum (e.g. Drury and Farhoomand 1996).

This thesis explores the individual decision-making level, or micro context of inquiry, of an innovation implementation in Project-based Engineering (PBE) – the macro context of inquiry. As a result, the findings originate from the micro context of inquiry and make contributions within the wider, macro context. There are some implications that stem from the approach that was undertaken and how this technique enables the study to be tuned to the influence that the perceptions of individuals can have on an innovation implementation. Others relate directly to the Perception-Influence (P-I) model in terms of the synthesis it represents and the possible applications for it in industry. Therefore in addition to providing the most tangible thesis outcome, the P-I model's conception and development as an integral part of the research design also represent significant findings.

Accordingly, this chapter discusses the research findings in terms of their significance for implementation theory and project-based engineering (PBE) practitioners. Firstly, the implications of the thesis for the field of innovation implementation research are considered. This is followed by some reflections of the research design. Two specific applications of the P-I model in industries involving PBE are then considered. Finally, some possible future directions are noted.

7.1 Implications for Implementation Research

The individual decision-making level is an important aspect inherent to all innovation implementations (Linton 2002; Jebeile and Reeve 2008). Despite this, authors have largely ignored this context in implementation research (Edington and Shin 2006; Jamieson 2007). Therefore the significance of this thesis is the new perspective on innovation implementation that it provides. The theoretical implications of these findings for the macro context are discussed in this section along with the way in which they relate to the wider field of implementation research. While the findings were derived from innovation implementation in PBE, some can be transferred to other contexts.

7.1.1 Investigation of the Individual Decision-making Level

This thesis demonstrates how an exploratory implementation research project can establish a focused investigation context at the individual decision-making level. Previous research often frames the problems of slow diffusion rates and ineffective implementations against organisation and project-level decisions without considering the influence of decisions made at the user level (e.g. Stewart, Mohamed et al. 2004; Taylor and Levitt 2005b; Taylor and Levitt 2007). Unlike this thesis, these studies included broad spectrum variables such as ‘country’ and ‘innovation type’ which make it difficult to include aspects from the individual level. Because these variables are fixed in this thesis[60] and explored within a nominated industry, the individual decision-making level becomes accessible and some influential implementation factors therein are exposed. The innovation implementation environment that was explored by this thesis is shown by Figure 2-12 (reproduced below).

[60] The variables set in refining the scope of the thesis were: 1) Country = Australia; 2) Industry context = project-based engineering (PBE) – with construction used as the typical example; and 3) Innovation type = incremental innovation – 4D CAD in PBE used as the typical example.

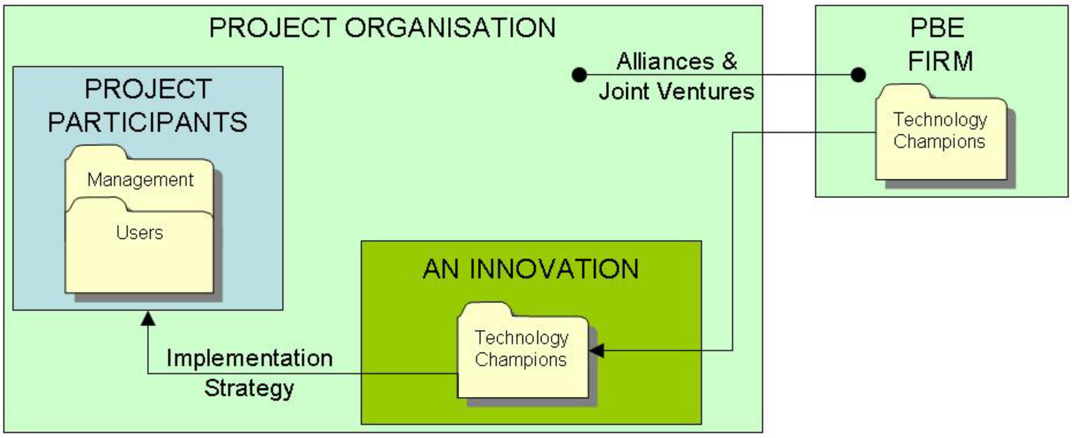

Figure 2-12 (Reproduced): Stakeholders in an innovation implementation by a PBE firm

The findings in this thesis are based on a proposed model that uses the perceptions of individual project-participants to map the progression of an innovation implementation. In contrast, Taylor and Levitt (2007) posit a 'two-stage model for innovation [implementation] in project networks' built with constructs such as 'Interests' (i.e. of the implementing firm and project organisation) and 'Boundary Permeability' (i.e. how open each project organisation is to implementing new innovation). They also used 'Innovation Alignment' (i.e. alignment with the firms existing work flows) as a construct at the organisation and project decision-making levels in their model. It corresponds to the type of innovation (see Figure 2-2) in this thesis. At the individual decision-making level this construct is referred to as 'Job-fit' (Thompson and Higgins 1991) or 'Innovation Values-fit' – a factor that was included by Klein and Sorra (1996) in their model of innovation effectiveness. However, it is only one of many influential factors at the individual level, and their model (Figure 2-9), as with most others in the literature, predominantly applies to the higher levels in the PBE decision-making hierarchy[61].

By using a bottom-up (vis-à-vis top-down) approach, any apparently significant factors existing at the individual level were able to be included. The findings propose four perception constructs, each of which cumulatively account for other relevant theoretical constructs from the literature that were evident in the empirical

[61] Nevertheless, both Taylor and Levitt (2007) and Klein and Sorra (1996) provide instances of model-based findings that map processes in innovation implementation and clarify obscurities from previous research to lend support to the findings from this thesis on a functional level.

data. Exploring a particular innovation implementation setting to this extent enables a study in implementation research to induce and suggest contributions for the wider associated contexts.

7.1.2 Innovation Implementation in PBE

The results of this study as well as those from previous studies (Klein and Sorra 1996; Drury and Farhoomand 1999a; Legris, Ingham et al. 2003; Venkatesh, Morris et al. 2003; Yuandong, Zhan et al. 2005) have shown that the perceptions of project-participants can have significant impacts on the effectiveness of an innovation implementation. In PBE, because there is a consultant-like relationship between firms that have adopted an innovation and the implementing project organisation (PO), (as shown in Figure 2-12 above), implementation effectiveness is predominantly determined by the decisions of management and users at the PO. These decisions are a direct result of associated project-participant perceptions. This is consistent with an implementation style of social interactionism[62] (Campbell 1996). The findings also illustrate how it is critical in implementation research to separate innovation effectiveness from implementation effectiveness, as noted by Klein and Knight (2005). There are many circumstantial factors that can cause an innovation to fail, however its implementation is a controllable process and effective if productive use of the innovation is achieved (Klein and Knight 2005). Therefore disregarding innovation effectiveness helps give clarity to the scope of empirical studies that seek to improve implementation effectiveness.

The findings suggest plausible reasons why a project manager might decide not to implement an innovation. If project management form significant negative opinions such as concerns about ‘Transaction Costs’, and/or the suitability of the PO’s ‘[Suitable] Resources’ and/or a lack of ‘Results Demonstrability’, they may decide not to commit to the implementation (Moore and Benbasat 1991; Rogers 2003; Peansupap 2004). Grouping these theoretical constructs into one parent perception of ‘Project Value’ by identifying the relationship between them is a

[62] The implementation style of social interactionism, vis-à-vis technological determinism and managerial rationalism, is a process governed by the social interactions between the technology and a particular organisational context (see Table 2-1).

simplified perspective. It also highlights them as important and related aspects of the commitment decision process. For this process to be successful, the communications between the PBE firm proposing the innovation and the potentially adopting PO need to be attuned to the particular circumstances of *that* innovation combined with *this* PO. This can be done if technology champions are mindful of how project managers might perceive the value of the proposed innovation. If a positive perception of value can be encouraged, the likelihood of gaining a commitment to the implementation increases.

Thesis proposition 1, the 'Encompassing'[63] relationship, is the basis for the grouping of the three constructs as contributing factors in the formation of a project manager's perception of 'Project Value'. The other three perceptions in the P-I model (i.e. 'Project Benefit', 'Personal Benefit' and 'Usability') exhibit the same grouping characteristic with respect to theoretical constructs from the literature. Thesis propositions 2 and 3, the 'Paralleling'[64] and 'Dividing'[65] relationships, relate to theoretical constructs identified as contributing factors to the four perceptions in the P-I model. The model and the theory behind it, as well as the three prominent propositions, are all interrelated and integral parts of the implications for innovation implementation in PBE. Therefore the section 7.1 subsections that follow expand further on these aspects of the thesis findings by discussing the synthesis of existing theory, the P-I model and, ultimately, by stating some recommendations.

7.1.3 A Synthesis of Existing Theory

The discovery that project-participant perceptions can be interpreted in terms of theoretical constructs from the literature was an important finding for the thesis. This realisation is complemented by the association of these perceptions with barriers to innovation implementation. As a general finding this is well aligned with the objectives of the research which are central to the outlined knowledge gaps.

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[63] The descriptor for the inclusive, multi-faceted, contribution-style relationship existing between certain secondary constructs (e.g. contributing factors) and certain primary constructs (e.g. perceptions).

[64] The descriptor for the relationship between two theoretical constructs of similar or synonymous definition that are labelled with different or confusing terms.

[65] The descriptor for the relationship between a theoretical construct with a broadly scoped definition and one or more other theoretical constructs with narrower scoped definitions that exist as divisions but also as examples of the parent construct.

Regarding the evolved qualitative research design, the discovery can be considered a significant shaping event. As a result the notion of a synthesis between the empirical data and implementation research and the suggestion that it would be useful in implementation theory as well as practice was built on.

This thesis provides a unique synthesis of disparate theoretical constructs associated with implementation effectiveness and user acceptance in implementation research. In some ways it assumes a reflective perspective with respect to innovation implementation research not dissimilar to that of Klein and Knight (2005) or Linton (2002) because the research findings take stock of existing theories. Naturally, there are strong similarities with studies that combine and review existing theory by analysis, such as Venkatesh et al. (2003) and Karahanna (1999). However, these previous studies often sought to discredit those existing theoretical constructs that the analysis findings suggested were of lesser significance. This thesis contends that overlaps in the terminologies and definitions[66] of the theoretical constructs create confusion and that the best way to address this problem is to identify, combine and explain them via constructive synthesis. The theoretical constructs synthesised by this thesis are concisely summarised in table 7-1.

[66] These overlaps most likely result from the way individual authors interpret the data they analysed.

Table 7-1: Theoretical constructs synthesised by the P-I Model[67]

	Actions (Primary)	**Perceptions** (Primary Const.)	**Contributing Factors** (Secondary Constructs)	**'Encompassed', [Paralleled] and Divided Theoretical Constructs**
Project Management	**COMMIT / REJECT**	**VALUE**	**Transaction Costs**	'Availability of financial resources'
			Results Demonstrability	*None found*
			Suitable Resources	'Management support', 'Tight timeframes', 'Climate for implementation' [Behavioural control]
	SUSTAIN USE / DISCONTINUE USE	**PROJECT BENEFIT**	**Job-Fit**	[Innovation-Values Fit, Usefulness]
			Relative Advantage	Motivation - Intrinsic
			Image	Motivation - Extrinsic
			Managerial Patience	*None found*
			Suitable Resources	*As above plus* 'Technical support'
			Transaction Costs	'Availability of financial resources'
Individual User	**SUPPORT / REJECT**	**PERSONAL BENEFIT**	**Job-Fit**	[Innovation-Values Fit, Usefulness]
			Affect	*None found*
			Relative Advantage	Motivation - Intrinsic
			Image	Motivation - Extrinsic
			Subjective Norm	Motivation - Extrinsic
			Suitable Resources	*As above plus* 'Technical support'
			Use Intention	[Attitude towards use, Behavioural Intention]
	USE PRODUCTIVELY / NEGLECT	**USABILITY**	**Compatibility**	*None found*
			Ease of Use	'Complexity'
			Voluntariness of Use	*None found*
			Self-Efficacy	*None found*
			Anxiety	*None found*

Table 7-1 presents the constructs that are the theoretical foundation of the P-I model. Together they are the essential elements of the synthesis that this thesis provides. The constructs are arranged in the table to show the hierarchical relationships that the data analysis suggested exists between them. The P-I model was developed in order to generate as well as capture the synthesis so that it would exist in a useful format. Because the degree of prominence for each

[67] This table is the combination of Tables 5-2, 5-3 and 5-4, omitting the definitions and including the other form of primary construct, actions. '*None found'* in the far right column indicates that no encompassed, paralleled or divided constructs were found for that contributing factor.

construct in the model decreases the further right it is in the table, the two forms of primary constructs are located on the left. Another left-to-right interpretation of the column arrangements in table 7-1 relates to outcomes, that is, a perception is the outcome of its contributing factors and an action is the outcome of its perception.

The proposed 'Dividing' relationship is the only right-to-left interpretation intended by table 7-1. It is similar to the 'Encompassing' relationship but in the context of the P-I model it is important the two are separated. The concepts of the 'Paralleling' and 'Dividing' relationships allow the secondary constructs and other related theoretical constructs to be distinguished in terms of the scope of their definitions. The motivation construct is a good example of one that is divisible and needs to be divided in order to separate a number of important contributing factors that can provide influences in their own right (see Appendix J.1 for a concise definition of each contributing factor in the theory behind the P-I model).

The relationships identified between the contributing factors and other theoretical constructs from the literature is the lower of two layers that make up the synthesis. This layer was established by the exposure of any encompassed, paralleled and divided theoretical constructs for the secondary constructs (as shown in Table 7-1). The findings in this regard help highlight two interesting characteristics to the implementation research literature and particularly that concerning user acceptance: 1) where authors have established a theoretical construct that is a subset or more detailed part of a parent construct; and 2) where authors have established similar or the same theoretical constructs but used a different terminology or standpoint. An important aspect that is part of the lower layer to the synthesis built into the P-I model is the simplification of ambiguous terminologies where such overlaps in definitions were found. The more self-explanatory terms were chosen for the secondary constructs in the cases where a choice needed to be made and the more ambiguous terms were included as paralleled constructs[68]. Of course, some of the theoretical constructs were found to be referenced

[68] The notable exception where this was not possible was in the case of 'Subjective Norm' - *an opinion or concern in an individual user about people important to them and whether they believe they should or should not use the innovation*. The definition for this construct will need to be regularly footnoted alongside the P-I model in order to maintain the built-in simplification and clarity of terminologies.

consistently in the literature without any such ambiguities or overlaps. Accordingly, to identify them as those that were empirically observed with clear distinction, these constructs are shown with ‘none found’ registered in the appropriate column in Table 7-1. As a result they form part of only the upper layer to the synthesis.

The ‘Encompassing’ relationship existing between the perceptions and contributing factor constructs in Table 7-1 is the upper of the two layers to the synthesis established by the thesis findings. This is a unique perspective because few if any other published research group theoretical constructs from the individual decision-making level of an innovation implementation in this way. A perception (primary construct) is inferable by means of observing evidence of the encompassed project-participant opinions and concerns, or contributing factors (secondary constructs). An action (primary construct) in the model is observable in reality therefore it is autonomous but, more importantly, it is linked as an outcome of the relevant perception.

The two-layer synthesis of existing theory is the supporting knowledge behind the network-like foreground of the P-I model. The structure of the P-I model connects and assembles each of the primary constructs theoretically expanded above. The functions of the network aspects of the P-I model are now discussed in the following section.

7.1.4 The P-I Model

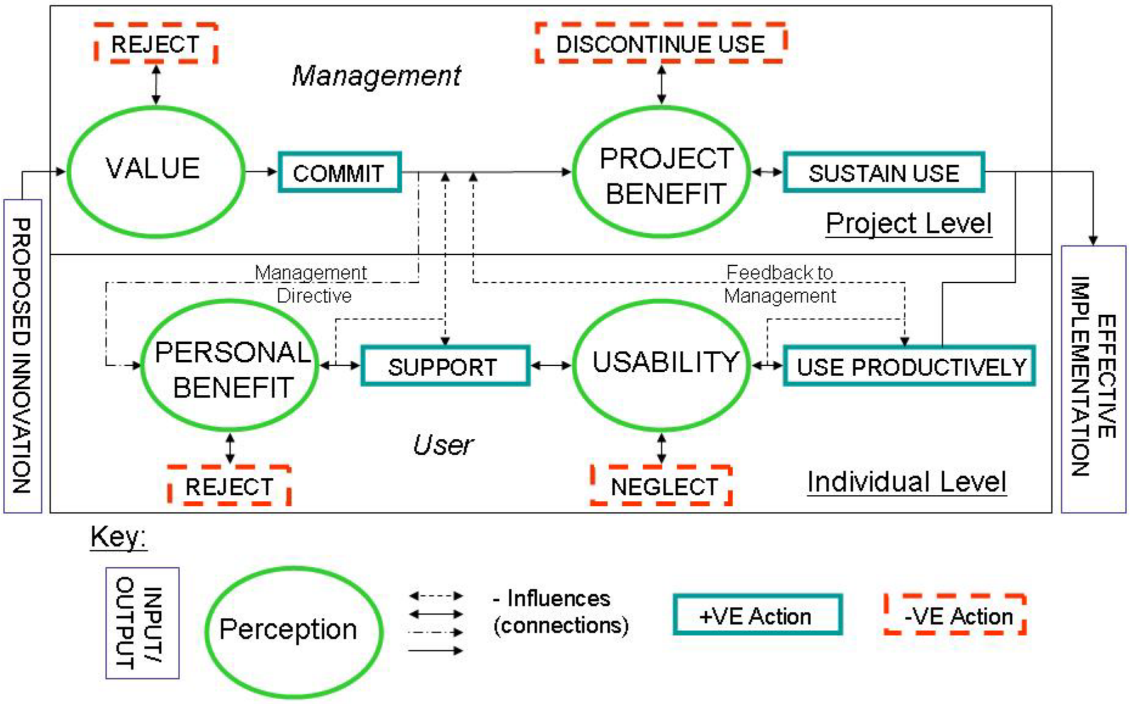

Figure 5-21 (Reproduced): P-I_3 Model – the final P-I model

The P-I model (Figure 5-21) is effectively an instrument that can be used to suggest what might happen, explain what is happening, or record what happened in an innovation implementation. In this sense, the instrument consists of four predictive or summarising gauges – the four perceptions of the project-participants. Depending on the particular circumstances of the innovation implementation, these gauges will have either a positive or negative reading. The negative actions are warning lights and the positive actions are normal or acceptable operating lights. If the empirical inputs to the instrument (observable evidence of contributing factors and actions) cause any of the gauges to display a negative reading or make one of the action warning lights come on independently of the perception gauge it is connected to, the implementation will be tending towards being ineffective. In literal terms this means, for an in-progress or completed implementation, an inferred perception is able to be cross-checked using the observed actions. Furthermore, for an implementation in planning, desirable readings for the gauges can be targeted by understanding how the instrument processes the inputs. In other words, the actions and perceptions that may be encountered can be assumed or predicted using the P-I model.

A useful concept that can help to explain and demonstrate how the P-I model maps the progression of any given innovation implementation is the concept of 'implementation states'. As mentioned above, a positive perception of 'Project Value' by project management participants in an implementation is required for a PO to commit to it, or in other words, for it to progress to a state of commitment. Once an implementation is in progress it is subject to influences from the perception of 'Project Benefit' in project management and the two user level perceptions of 'Personal Benefit' and 'Usability'. If these perceptions are initially positive and remain so, such that productive use occurs, the implementation will have progressed to a state of effectiveness. Further to the progression of an implementation, the 'Project Benefit' perception is more ongoing and reflective in comparison to the explicit nature of the two user level perceptions. This is because the possible events at the user level will have an influence on the manager's perception of benefit as a result of normal organisation hierarchies (Williamson 1975).

Should any of the four project-participants perceptions be negative at any time, that implementation is likely to be in a state of rejected, neglected or discontinued use. Two of the four 4D CAD implementations studied in the theory-generation (middle) phase of this thesis (the PT_{PO} and PB_{PO}) provide examples of two such negative implementation states (respectively): 1) Discontinued use; and 2) Proposal rejected. These two states are recognisable in the P-I models compiled for each implementation (see Figure 5-21). Although they represent implementations that have finished, it is important that they be referred to in terms of their current state. This is because the current state could change as the circumstances of the PO change and it may only take something as simple as a new manager for the implementation to be resumed, for example, the new manager may be more supportive of the implementation and allow it to progress further. This was the case with the CB_{PO} 4D CAD implementation from the final research phase where a change in the project-participants (or targeted adopters) at the project coincided with a change in the stage of the construction project.

The P-I Model and Construction Project Stage

The theory-confirmation (or final) research phase produced some temporally-based findings regarding the progression of an innovation implementation in relation to the construction stage. Because major infrastructure projects in the Australian construction industry utilise the Design-Build delivery system, the prominent construction stages are the tender and design and construct (D&C) stages – this is evident in the empirical data from the seven projects considered in this thesis. A change in project stage can bring about changes in the individual project-participants for an implementation and this can affect the progress of an implementation. In addition, the priorities of the PO will also change, as will the priorities and perceptions of those project-participants common to both the prior and current project stages. In the case of the CB_{PO}, for example, an implementation can be stifled at the tender stage of a construction project when the priority is winning the job, but it may progress more effectively during the D&C stage when delivering the project is the priority. Moreover, as in the case of the FU_{PO}, an implementation may proceed effectively during the early construction stages but then as it approaches completion, negative influences can become more significant. Collectively, the six CB_{PO} and FU_{PO} P-I models, compiled at one of three different times during the construction project lifecycle, highlight the need for technology champions to be aware of changing PO priorities (see Figure 6-15) and how the implementation might be affected. The following section provides some concise recommendations from the above discussion.

7.1.5 Recommendations for Implementation Strategies in PBE

Some specific points of advice can be made based on the findings and experience from the 3.5 year industry immersion, for technology champions and researchers involved in innovation implementation in PBE. The following recommendations should improve implementation strategies in PBE as well as innovation diffusion rates in general.

- *The potential benefits or results an innovation can provide to a project need to be clearly demonstrated when it is being proposed.* This is critical for gaining a commitment to the implementation. Project managers generally have little time, funds or resources to try new ideas therefore the benefits of an innovation need to be compellingly proposed. If a positive opinion of 'Results Demonstrability' is not inspired in project management by the technology champions, they will more than likely have serious concerns about allocating the proposed 'Transaction Costs' and other project '[Suitable] Resources' required. Where possible, pilot applications of the innovation should be carried out as part of the proposal using data specific to the circumstances[69].

- *An implementation strategy should introduce the innovation as incrementally as possible with respect to the workflows it needs to fit within.* This means identifying the aspects of the project's current workflows that will be affected and managing the characteristics of the innovation to reduce adverse effects. If specific circumstances permit, a scaled or phased approach over time, in terms of the extent to which all functions of the new innovation are used on a project, can help instil and maintain positive perceptions in targeted adopters. This means exploiting the innovation characteristics of divisibility (Gopalakrishnan and Damanpour 1994) and pervasiveness (Wolfe 1994) (by limiting it) as much as possible. An approach that can help is to initially limit the number of intended benefits to only include the most obvious, perhaps just one, and then in later phases of the implementation expand the applications of innovation for that particular project (in terms of both benefits and usability).

- *An implementation strategy needs to be responsive to the changing priorities of a project organisation (PO).* The wider objectives and priorities of a PO change depending on what stage the project is at (i.e. tender or D&C). While the nature of the innovation being implemented is always a dependent implementation variable, interpreting these implementation specifics in terms of the effects they have on the influential individual-level

[69] For example, in a 4D CAD modelling implementation, a pilot model might show milestone construction activities for the main structures of the particular project it was being proposed to.

factors in the P-I model will improve the chances of an implementation strategy accommodating all possibilities.

- *Technology champions should be open-minded and avoid fixations in both the planning and delivery of implementation strategies – especially those fixations that arise from their enthusiasm for the innovation.* In order to improve the chance of effective uptake, implementations need to be approached from a flexible stance by those in charge of its transferral, particularly where social interactionism and technology-push scenarios are concerned[70]. Focusing on the clear demonstration of the benefits an innovation can provide is a useful way of helping to establish such objectivity (as above).

- *A technology champion should be as embedded as possible in the day-to-day workings of the project and take on extra responsibilities where possible.* Ideally an innovation that is being implemented will become a part of the normal project workflows over time. A catalyst that can help this happen is the individual technology champion becoming a part of the normal project workflows during the times when targeted adopters are still speculating about the worth of the innovation (i.e. forming their perceptions of benefit and usability). The influence of negative opinions and concerns such as 'Job-fit', 'Managerial Patience' and 'Suitable Resources' may be reduced if the termination of the implementation removes an extra helping hand. This would mean a diversification of the technology champion role so that it adds value to the project via outputs other than those that are direct results of the innovation[71].

- *An increased empathy for the opinions and concerns of implementation participants makes implementation strategies more user-friendly.* A better

[70] In a technology-pull scenario, the drive is provided by the enthusiasm of the targeted adopters and there is little if any need for technology champions to plan for flexibility (Von Hippel 1976).
[71] This was recognised in most of the seven project organisations studied in this thesis. For a 4D CAD modelling implementation, a logical helping hand the technology champion can provide is associated with data management and distribution (both CAD and schedule data). This is because these data need to be collected and kept up to date in order to deliver an accurate 4D model.

awareness and allowance for potential influences of the significant individual-level aspects to an innovation implementation highlighted by the P-I model and theory behind it should increase the chances of achieving effectiveness.

7.2 Reflections of the Research Design

This thesis set out to explore the context of innovation implementation in project-based engineering (PBE) with some basic motivating questions. In the initial phase of the design it identified a research question that asked about the influence of project-participant perceptions. This question evolved during the course of the research; a logical and common approach where qualitative methods are being used to explore human or individual-level aspects of a particular social system (Eisenhardt 1989; Creswell 1998). The results of doctoral theses by Peansupap (2004) and Robertson (2007) are good examples of findings produced by similar explorations and with implications for a wider context.

The catalyst that helped shape the research design and define a more specific, manageable research question during the initial phase was the conception of the P-I_1 model. This involved combining the basic motivating questions with observed consistencies between the empirical data and the theoretical constructs that had been identified as being relevant. The value of this approach is emphasised by Eisenhardt (1989):

> *A priori specification of constructs can also help to shape the initial design of theory building research. Although this type of specification is not common in theory-building studies to date, it is valuable because it permits researchers to measure constructs more accurately. If these constructs prove important as the study progresses, then the researchers have a firmer empirical grounding for the emergent theory.*

Including this level of flexibility during the initial phase along with the theory-generation emphasis of the research design appeased the limitation of there being no guarantee of investigating a critical case. Illustrative cases are usually chosen on expectations about what they will bring to the study (Flyvbjerg 2006), however this research was designed to make the most of the various innovation implementations and project organisations that I had access to. This means the research design maximised the opportunity to extract meaningful findings from a unique research opportunity. An associated and common weakness of similar studies has been including only a small number of cases or illustrative empirical examples (Eisenhardt 1989) – another pitfall avoided by the research design's inclusion of empirical evidence from seven separate project organisations.

The research design used in this thesis provides some advantages that stem from it being based on a researcher immersed in the industry environment under investigation. This allowed data to be gathered unobtrusively via participant-observation. Collecting data from emails, meeting minutes and any textural data created as part of the natural workflows of the projects made for a high degree of authenticity. Surveys and questionnaires can create useful qualitative data (Yin 2003) but these are data captured outside the daily context with respect to normal workflows (Webb 1981). Therefore it is considered an advantage that this type of data were not included and that sufficient amounts of data could be gathered without the need for obtrusive data collection. The strength of an industry-immersed research design is reinforced by the inherent ability to, where possible, use the more objective forms of unobtrusive data to lead an exploration[72]. Because researcher observations have an increased potential to be subjective, they were primarily used for triangulation of the patterns emerging from the more-authentic forms of data (i.e. the emails and project documentation). Nevertheless, they have been suggested as being as valuable and sufficiently reliable a source of data – a point made by Bem (1972) as part of a self-perception theory (Kim and Malhotra 2005):

> *Individuals come to "know" their own attitudes, emotions, and other internal states partially by inferring them from observations of their own overt behaviour and/or the circumstances in which this behaviour occurs. Thus, to the extent that internal cues are weak, ambiguous, or uninterpretable, the individual is functionally in the same position as an outside observer, an observer who must necessarily rely upon those same external cues to infer the individual's internal states.* (Bem 1972)

[72] By not using surveys and questionnaires to maintain the unobtrusiveness of the data a useful method of validation was excluded. This was balanced by the nature of an immersed participant-observation technique permitting everyday conversations between the researcher and subjects. The data collected as part of these conversations ultimately served as a method of validation.

Regarding the analysis methods, the application of triangulation where possible and the parent method of cross-case analysis are also strengths of the research design (Eisenhardt 1989; Love, Holt et al. 2002). Triangulation is a robust technique that increases the reliability of research efforts, particularly those involving construction (Love, Holt et al. 2002). Despite the wide support for such methods however, Eisenhardt (1989) notes the danger of making premature or even inaccurate inferences when using these methods. An example of a measure taken to avoid this danger was the diversification of the P-I_2 model to include actions. Because this development was made to the P-I model, an additional aspect involving triangulation was included in the research design. Therefore the concept of triangulation was not only used as a technique for cross-checking between data sources as part of the analysis but it was built into the findings.

The iterative way in which the research design evolved and the interconnectedness between the analysis and data collection in the theory generation (middle) and theory confirmation (final) phases are also strengths. Eisenhardt (1989) captures the leverage this aspect can provide to a research design:

> *Overlapping data analysis with data collection not only gives the researcher a head start in analysis but, more importantly, allows researchers to take advantage of flexible data collection. Indeed, a key feature of theory-building case research is the freedom to make adjustments during the data collection process. These adjustments can be the addition of cases to probe particular themes which emerge.*

It is important, however, to maintain and work towards a cohesive structure for a research design from the outset and at all times (Strauss 1987). Even though the overlaps between data analysis and collection became apparent as part of an iteratively evolving research design, there was an established and ongoing skeletal structure that assimilated all developments (Figure 3-3). Of course, the benefit of hindsight allows it to be explained much more easily, but had this not been in place throughout, the likelihood of achieving clarity in this regard would have been slim. This alludes to a common peril of exploratory qualitative research associated with poor results due to a lack of direction (Neuman 2003). An integral part of the guidance in this thesis was the P-I model and its conception, development and evaluation which correspond to the three research phases: 1) initial; 2) theory-generation; and 3) theory-confirmation. An aspect of the structure to the research design that works in parallel with the phasing is the P-I model's iterative establishment across three separate revisions (i.e. the P-I_1, P-I_2 and P-I_3 models). This also maximised the opportunity for theoretical constructs to be interpreted with respect to one another.

A defining feature of the three phases to the research design, in terms of the analyses performed as part of each, was the ways in which the data were explored and interpreted via coding. In the initial phase the scope was at its broadest and the main intention was to sharpen it progressively. Therefore only a simple, manual coding procedure was used. This allowed for a number of aspects (or themes) of an innovation implementation to be considered. Completing this phase (i.e. analysing the TC_{PO} data) not only sharpened the focus of the thesis but it helped me gain a better grounding in qualitative methods, particularly textural analysis. As a result the decision was made to use a more formal and accountable textural analysis method during the two subsequent phases. The difference between the coding procedures in these two phases relates only to the intention of each analysis method and not the technique. The theory-generation (or middle) phase developed the P-I model from the first revision through to the third (and final) revision. The theory-confirmation (or final) phase was reflective with the main objective to evaluate the temporal and functional aspects of the P-I model with a view to how it could be applied to an innovation implementation.

The different analysis objectives of the three research phases allow the research design to provide a sense of closure to the thesis. The findings suggest several future directions (see section 7.4 below), however in the context of this thesis and establishing the P-I model, the objective transitions between research phases are the characteristics of the research design that provide balance. The change in objective between the initial and the middle phases meant that more-specific evidence of constructs needed to be found in the data in order to develop the P-I model. This is because the objective changed from a broadly scoped exploration of innovation implementation in PBE to the further development of a proposed model. The analysis work was most time-consuming during the middle phase because broad implementation factors were no longer the focus, as in the initial phase. In contrast the data needed to be interpreted iteratively in terms of the evolving P-I model as well as what developments the data were suggesting. Furthermore, the change in objectives between the middle and the final research phases, P-I model development and evaluation respectively, allowed for some explanatory findings in addition to the exploratory thesis outcomes. It was somewhat refreshing to move from an inductive style of analysis to a more deductive style in which a wider perspective on what had been found could be assumed. At a time when the P-I model and associated NVivo7 coding procedure were relatively stable, the final research phase was able to apply the analysis method from the middle phase as part of an analysis that sought to evaluate how the P-I model could be used.

7.3 Applications of the P-I Model for PBE Practitioners

The two most apparent and logical ways of using the P-I model to help better manage an innovation implementation are: 1) as a tool for evaluating implementation strategies (i.e. those that are complete or stifled); and 2) as a tool for improving innovation implementation strategies (i.e. those already in progress). To introduce the P-I model to relevant engineering professionals, a double-sided A4 fact sheet[73] has been used (Appendix J.3).

7.3.1 A Tool for Evaluating Innovation Implementations

The P-I model can be used to process data from a completed innovation implementation. One of the most important things an individual or group of any size should do in order to improve subsequent performances of the same process is to document lessons learned (Kartam 1996). With this intention the P-I model can be applied as a tool for evaluating an implementation. Because a compiled P-I model is a summary that captures the decisions made at the project and individual levels, it is a reference that can help guide the documentation of lessons learned. The findings suggest a P-I model can be beneficially compiled using two techniques:

[73] The fact-sheet is a concise summary of the P-I model that helps raise awareness about what is important to the project-participants regarding a proposed or active innovation implementation.

1. **NVivo7 textural analysis** (*Detailed*) – the final revision of the NVivo7 analysis template file '*Coding Structure Master – Final Phase.nvp'* (see Appendix F.3) along with the method used to apply it (explained in chapters 5 and 6) is a transferable outcome of this thesis;

2. **Worksheet Technique** (*Rapid*) – This technique allows a technology champion to compile a P-I model from memory using the evidence of each theoretical construct they have personally witnessed rather than by systematic processing of detailed textural data.

The worksheet technique is a small extension of the summary sheet (Figure 6-14), a finding from the final research phase, and thus is a further outcome (see Appendix J.1). It is a succinct summary of the P-I model as well as the theory behind it and provides a technique for an on-the-run compilation. With some consistency, the creation of this simplified and streamlined technique for delivering the P-I model compilation method heeds the second recommendation in section 7.1.5 associated with proposing and implementing an innovation as incrementally as possible. Because a technology champion implementing an innovation is unlikely to have enough time to perform a detailed analysis of all implementation data from every instance, the rapid compilation method should help improve the P-I model's rate diffusion which is an innovation itself.

A P-I model evaluation of the TC_{PO} implementation used in the initial empirical investigation (see chapter 4) provides a useful demonstration of the worksheet compilation technique. Even though this data set is more-broadly scoped in comparison to those from the other six implementations, an adequate representation of what happened and the P-I model constructs that were witnessed can be put together by reading chapter 4, viewing Appendix A and then filling out the worksheet (Appendix J.1). This has been done and included in Appendix J.2.

The worksheet and NVivo7 methods are effectively short-hand and long-hand techniques for carrying out the P-I model compilation method. The choice of which one to use will ultimately depend on how much time is available to capture the events of a particular implementation and how much detail or formality is required.

In scenarios where the implementation is in progress, time would, understandably, be of the essence.

7.3.2 A Tool for Improving Innovation Implementation Strategies

The P-I model can also be applied to an in-progress innovation implementation by a technology champion to help assess and improve their current strategy. In a functional sense this was demonstrated during the final research phase because at times the analysis was carried out in parallel with the implementations themselves. The analysis outcomes that best show this are the CB_{PO} and TU_{PO} P-I models compiled from the data available midway through each implementation (see Figure 6-11). They present illustrative examples of the P-I model being used to interpret two implementations from ‘in-progress data’ therefore the two models could have been compiled at the point in time they represent. Compiling a P-I model for an in-progress implementation provides a structured hindsight as well as something to use for predictive foresight; perhaps involving brainstormed ‘what ifs’. In other words, if a technology champion compiles a P-I model for an innovation implementation they have initiated, they will have identified some critical factors that are influencing the implementation’s effectiveness and can use this knowledge to alter the ongoing implementation.

As with the post-implementation use of the P-I model, an in-progress application can be carried out using either of the two suggested techniques. The establishment of a compilation method with two suggested techniques of delivery is a finding that emerged largely as a result of the research design. This is because the qualitative exploration coupled with the phased conception, development and evaluation of the P-I model can be reproduced by others with the intention of interpreting a particular implementation. This outcome is perhaps a benefit of the ‘ebb and flow’ of exploratory research, however it would not have been achieved without the desire to produce useful findings – an underlying motivation behind the evolution of the research design.

7.4 Future Directions

The P-I model provides a grounded-theory basis of developing new project management techniques that foster the effectiveness of innovation implementation

– the successful uptake of new techniques and technology in engineering projects. These management strategies should be aimed at influencing (in a positive way) the views and opinions of project-participants about the benefits, to them, of a proposed new innovation.

Future work should also consider other implementation contexts in engineering. This scope in this thesis was bounded by project-based engineering (PBE) and the implementation of 4D CAD modelling. This means the implementation style investigated was social interactionism and the innovation type incremental. Presumably, for a synthesis such as the P-I model to have a functional application in another implementation context (say, one that involves managerial rationalism and a systemic innovation), an adjusted relational network of theoretical constructs would exist.

This study paves the way for further use of NVivo7 to qualitatively interrogate other aspects of PBE activity and engineering practice in general. It is a worked example of real-world data being processed in NVivo7 to help explore a particular engineering context. The detailed explanations of how NVivo7 was used to do this should assist the planning or start-up of similar engineering research projects as well as researchers who have little working knowledge of NVivo7.

With the foundation of the P-I model now established, other research methods could provide some interesting and perhaps more quantitative results. Surveys and questionnaires designed to test specific and/or wider aspects of the P-I model and the compilation method might be used as the basis for a subsequent research project. If they were structured toward a statistical analysis, a discussion of quantitative results as a contrast should provide further insights.

Regarding the embedded or industry-immersed research design of this thesis, it is hoped the number of studies assuming this approach will increase in the future. Combining real problems from industry with the investigative resources of an academic institution is rewarding for all involved.

8 Conclusions

> *A successful implementation process is critical to gaining the economic and competitive advantages that innovation offers. Not enough is understood about the implementation process since so many firms' efforts are either complete or partial failures.* (Linton 2002)

Based on the findings from chapters 4, 5, 6 and the ensuing discussion in chapter 7, the conclusions stated in this chapter can be made. The thesis explored the process of innovation implementation as it occurs in project-based engineering (PBE) by using construction as a typical example and an industry-immersed researcher.

The Perception-Influence (P-I) model and the theory behind it are the major findings of this thesis. Together they are an informative paradigm that helps clarify and structure the long list of implementation factors in implementation research literature, particularly those relating to the individual decision-making level. The P-I model shows how the opinions and concerns of participating users and managers can affect an innovation implementation and which are likely to be important for achieving an effective implementation. A further significance of the findings is the accessibility to the subject area that they create for those that are unfamiliar with it. This is largely a result of the inherent simplicity of the synthesis that has been built into the theory behind the P-I model. At the core of the synthesis are the three connecting relationships between existing theoretical constructs from implementation research literature that were identified. They are:

1) Encompassing – The inclusive, multi-faceted, contribution-style relationship between a parent theoretical construct and any number of child constructs;

2) Paralleling – The relationship between two theoretical constructs of similar or synonymous definition that are labelled with different or confusing terms;

3) Dividing – The relationship between a theoretical construct with a broadly scoped definition and one or more other theoretical constructs with narrower scoped definitions that exist as divisions but also as examples of the parent construct.

The hierarchical nature of the three relationships is evident in the functionality of the P-I model. For an innovation implementation in PBE, the P-I model asserts that four project-participant perceptions are influential and these influences result in either a positive or negative action. Furthermore, in considering the four perceptions as a model constructs, they each encompass a set of contributing factors which, in reality, are project-participant opinions and concerns. Each set of contributing factors is made up of theoretical constructs previously theorised by implementation researchers that do not compete with or contradict one another. Those that are disparate or present ambiguously are listed as being either a division of, or paralleled or encompassed by, another construct in the set of contributing factors.

A method for compiling a P-I model was also developed as part of the exploration carried out in this thesis. It can be applied to both in-progress and completed innovation implementations to either help improve the current strategy or document lessons learned. Furthermore, by considering the possible applications of the P-I model, a new concept was identified in ‘implementation states’. This concept helps explain the current status of an in-progress implementation and each state is able to be represented clearly using the P-I model.

An important message that this thesis imparts is that the effectiveness of innovation implementations, particularly in PBE, is largely subject to the perceptions of individuals, both users and management. Technology champions need to know as much as possible about what targeted adopters are thinking and how their perceptions, opinions and concerns may affect the implementation. Only then will those in control of the implementation be able to make informed decisions to adjust and better plan implementation strategies.

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Appendix A – Samples of TC_{PO} Data

A.1 Participant notes made at start-up of TC_{PO} 4D modelling

26.05.05 Meeting with [redacted]

[redacted] (introductions) [redacted]

Scope of Work: [redacted] → [redacted]

[redacted]

[redacted], [redacted]

- 4d modelling commence 6th June
- Full extent of Interchange? YES
  Jackson Ave work important.
- [redacted] cost & construction of Interchange.
- Microstation V8 & DTM's

CAD DATA: - Bridge abutments have been modelled
- Existing survey → Terrain Model.
- Staging Dwg's [redacted] (Traffic management)
- Earthworks dwgs [redacted]
- D01 → D04 extent of work
- D06/7 on [redacted] fwy. & D02

- 29 month program
- 2 side tracks in place for ≈ 1 Year. 3 lanes E/W.

30.05.05 [redacted] set-up delays

[redacted] ⇒ - 3 weeks in Quotation
- [redacted]
- 3 weeks + IT
- Missorders

06.06.05 [redacted] 4D MODEL (IN [redacted])

Slope of work:
- 4D model of [redacted] interchange
  - Earthworks (Existing → Design)
  - Construction
  - Traffic phasing

Data:
- Need latest program of works
  ⇒ Effects no. of objects in CAD model
- Need staging & phasing DWG'S
- Need structure's (IN file format if pos.)

The model:
- Traffic phasing as Overlay of 2D strings!
- Design surface from DGN'S
- Intermediate earthworks to be modelled.
- Structures to be modelled

Questions:
- Can we get DGN's with layered surfaces as previously?
- Incite access?
- Mapping to network drives?

08.06.05 Current Situation/Plan

- [redacted] has latest P3 program
  waiting on P3 for [redacted] machine

- [redacted] staging DVC's for [redacted]

- [redacted] to be the man to run it?
  Train on existing models

- New model/S
  [redacted] 20/30

- [redacted] wants a written proposal.

[redacted]

Outcomes ⇒
- 2-3 people who can drive it.
- Machine out there.
- Graphics card installed.
- P3 installed.

[redacted]

Training Times

8:30 am Friday Morning - [redacted]
1pm Thursday [redacted] / [redacted]
2pm " " [redacted]

A.2 On-site ACL technology team member email reporting on TC_{PO} implementation status

From: [redacted] Sent: 8/06/2005 03:57 PM

To: [redacted]; [redacted]; [redacted]

CC: [redacted]

Subject: Latest update

Afternoon all

I've just booked one on one Navisworks training sessions with [redacted], [redacted] and [redacted] (programmer) with [redacted] to sit in. It should only take an hour at the most to get them to the stage where they can interogate a model. They were hesitant at first but after explaining all they were going learn was how to navigate and play through a model they were fine with the idea. Similarly, once the designers realised we weren't going to build anything from they're CAD they became far more relaxed about handing over files.

FYI [redacted], [redacted] (who is nearing the end of his take-over phase from [redacted] has requested that all program exchanges go through him.

I asked [redacted] again about a spot to put the machine, he's worried about it destracting people from their work. I can understand that it may be a destraction untill we produce the next model but after that it should be a productive tool for them. Depending on how well it is received in the training sessions tomorrow and friday, particularly by [redacted], will determine if it makes it out there before or after weproduce the first new model.

I've collected the latest design/staging CAD and processed it into a Navisworks model. It's quite good and should be relatively easy to format into 'linkable' CAD objects. I'll use this model for navigation training as the boys seem keen to see the job they're working on.

I still need to chase up any info on the internediate earthworks that I can get. [redacted] is the man for this.

The program we have to work from is a little hard to digest according to [redacted] and confirmed by [redacted]. It's constantly changing as well. To my way of thinking one of the most critical thing to build into the first model is updateability. If this is going to be of maximum use to these guys, a new program revision needs to be able to be slotted in more or less straight away (and perhaps remotely) and then thrown up on screen as a 4D model to play through. Otherwise I don't think they'll get maximum use of it for development of the program. With this in mind it may be better for [redacted] and I to have three solid days in [redacted] next week putting the model together. This would give the Navisworks trainees time to digest it themselves as well. Naturally, we can decide if this is best at the end of the week.

The third monitor has arrived and is remarkably similar to the other two! Still waiting on the re-ordered-re-ordered graphics card and P3 installation which should be any time soon.

Regards

[redacted]

A.3 Three TC_{PO} emails showing slow response time

From: [redacted]
Sent: Wednesday, 20 July 2005 7:38 PM
To: [redacted]
Cc: [redacted]; [redacted]
Subject: RE: [redacted] - 4D Modelling?

Hi [redacted],

I apologise in not getting back to you earlier.

With respect to the [redacted] area it has recently been the subject of negotiations to contract his work out as a completely separate package that we will not directly manage and so has been on hold for the last month. The detailed program is being put together by the Regional [redacted] Team under the direction of the Regional Manager. I am yet to receive any further detailed programme from the [redacted] Region Team on the programming than what we have provided to you mid to late June.

Irrespective of the above could we please progress with the modelling and target the next time that you have available to come to [redacted] and work with the program as we have it (or more current should it be completed by the time you arrive). After Monday next week (25/7) [redacted] & I will be available to work with you here at [redacted] Road on the Model.

I am out on site again tomorrow morning and will call you upon my return (approx. midday) to coordinate a time that we can move on with the 4-D model.

Regards, [redacted]

From: [redacted]
Sent: Wednesday, 20 July 2005 1:47 PM
To: [redacted]
Cc: [redacted]; [redacted]
Subject: RE: [redacted] - 4D Modelling?

Dear [redacted],

Three weeks have past since I wrote to you informing you that we were ready to come to site with the model we have been working on. [redacted] and I have since sent 2 follow-up e-mails and left a couple phone messages with you. I 'm not sure if you have received these messages/e-mails. We do not wish to hassle you but would appreciate a quick cal or e-mail from you to confirm that you have received our messages/requests.

Please let me know if I need to resend the e-mails.

Regards,

[redacted]

From: [redacted]
Sent: Thursday, 14 July 2005 12:09 PM
To: [redacted]; [redacted]; [redacted]
Cc: [redacted]
Subject: [redacted] - 4D Modelling?

Gentlemen

I appreciate your limited availability of time and the complexity of work you are confronted with, but I need to clarify your requirements pertaining to the 4D modelling for [redacted]. To date the project has made a reasonable financial commitment to this application but it no longer seems to be as active as perhaps it should.

[redacted] has previously indicated to me his preferences for us to support your related planning and to drive this work on-site. Is there a framework for us to do this? I can offer [redacted] at a reduced day rate to champion the application. Ideally he would need to become more involved with your planning process etc. Through this he would be able to model and present your progressive work sequence strategies for any part of the job.

Can you please call or indicate your preferences to proceed with this?

Thanks and regards

[redacted]

[redacted]
Manager [redacted]
[redacted]

[redacted]

Ph: [redacted]
Fax [redacted]

A.4 Exploratory notes made after critical TC_{PO} phone call

22-11-05 [redacted] - Update
* Phonecall with [redacted]
- "The vibe is that it's not worth it"

* What has lead to this vibe?
=> No clear application for the model?
=> Volatile staff base / Management Changeover?
[redacted] -> [redacted]
[redacted] -> [redacted]
=> Mix of opinions on VCT in volatile staff base?
=> Outsourced program to [redacted]?
- Slow generation of data.
- Shift of location of maximum model benefit. ([redacted] ltd -> [redacted])??

* What possible uses are / were there for the model?
  - An aid in presentation of logic to management & client. (Organisation level)
  - A developement tool for planners (Project level)
    - Temporal & spacial issue resolution.
    - Comparison of planned vs as-built.
    - Highlighting of program changes.

* What were the percieved benefits?
  - Competative advantage (somewhere?)
    - (Proj level) Less to no emphasis on competative advantage at project level. (Joint venture)
  - Program visualisation (Org & project level)

* What else has lead to the vibe?
  - Key decision makers not working with model developement in mind. Not following up decisions that effect model developement with measures to ensure model completion / updating.
  - Large no. of stakeholders → communication breakdown.

A.5 Research notes emphasising connection with literature

23.11.05 Reading

- Refs to chase: Hartholo (1995) "Diffusion of Const. Tech. in a Japanese firm"
- Stephen Emmitt "Diffusion of innovations in the building industry" 1997 (PhD Th.)

- Possible key factors contributing / influences to successful diffusion:
  - Percieved value (by adopters, stakeholders etc.)
  - Company & project level decisions
  - The relationship between the innovation & the social system it is diffused into (Larsen 2004, Rogers 1995)
  - Informal communication networks
  - Awareness thresholds. Personal & System
    Project & Organizational
    Interfirm & Intrafirm

- Larsen
  - Call for methodological techniques beyond traditional recall methods
  - Call for understanding the influence ratio between personal & system awareness thresholds & the influences upon them.
  - Must understand how diffusion concepts relate to the stages of the diffusion process.

Appendix B – Samples of PP_{PO} Data

B.1 PP_{PO} emails coded to project value contributing factors

Coding Summary Report

Project: Process Plant Construction Project
Generated: 24/06/2008 1:21 PM

4D for PP	**Document**

Email

Total References **2**

Node Coding **Tree Nodes\1. Project Value\Availability of financial resources** **References** **1** **Coverage** **93.67 %**

Reference 1 *Character Range 16 - 371*

From: [redacted] Sent: Friday, 19 August 2005 9:47 AM To: [redacted] Subject: 4D for [redacted]

Thanks for your help with the terrain models yesterday.

With the 4D, [redacted] is harassing me daily to get it under way, but I've been a bit busy. Hopefully I can get [redacted] onto it next week, so we should be in touch then.

Regards
[redacted]

Node Coding **Tree Nodes\1. Project Value\Management Support** **References** **1** **Coverage** **93.67 %**

Reference 1 *Character Range 16 - 371*

AS ABOVE

SD44 programme	**Document**

Email

Total References **2**

Node Coding **Tree Nodes\1. Project Value\Management Support** **References** **1** **Coverage** **18.42 %**

Reference 1 *Character Range 165 - 614*

Hi [redacted],
Good to hear we got at least some selection sets back, I guess we can spend a bit of time to fix the other ones up manually.
I did a presentation of the model this morning and it went really well, [redacted], [redacted] and [redacted] were really happy with it and the

supervisors found it very helpful and want to have a 4D model meeting at the beginning of every roster, so it seems to be finding
its place in our construction plan and program.

Node Coding **Tree Nodes\1. Project Value\Results Demonstrability** **References** **1** **Coverage** **18.42 %**

Reference 1 *Character Range 165 - 614*

AS ABOVE

Coding Summary Report Page 1 of 7

PP 4D	**Document**

Email

Total References **1**

Node Coding **Tree Nodes\1. Project Value\Management Support** **References** **1** **Coverage** **9.77%**

Reference 1 *Character Range 931 - 1,270*

-----Original Message-----From: [redacted] Sent: Tuesday, May 09, 2006 2:16 PMTo: [redacted] Cc: [redacted] Subject: RE: Emailing: [redacted] 4D
[redacted] Get a quote and the supplier etc, probably [redacted] has it, and we'll get it organisedasap. We can't afford any more holdups with the 4D. I'll figure out who has to signoff.
Regards [redacted]

Serial numbers for thiess	**Document**

Email

Total References **1**

Node Coding **Tree Nodes\1. Project Value\Management Support** **References** **1** **Coverage** **4.81%**

Reference 1 *Character Range 4,238 - 4,552*

From: [redacted] Sent: Wednesday, 4 January 2006 7:08 AM To: [redacted] Cc: [redacted] Subject: RE: Serial Numbers for [redacted]
[redacted],
I have arrived back from annual leave and would like to get an update today if possible on the 4D model development.
Regards [redacted]

4D model	**Document**

Email

Total References **5**

Node Coding **Tree Nodes\1. Project Value\Availability of financial resources** **References** **2** **Coverage** **27.95%**

Reference 1 *Character Range 2,088 - 2,332*

Email: [redacted]
From: [redacted] Sent: Wednesday, 23 November 2005 4:38 PM To: [redacted] Subject: RE: 4D Model
From what I have seen, I think this would be a beneficial investment.
Please proceed.
[redacted]

Reference 2 *Character Range 2,505 - 3,191*

From: [redacted] Sent: Tuesday, 22 November 2005 10:51 AM To: [redacted]
http://mailarchive.[redacted]/ViewMessage.aspx?CheckSum=3d854dd3-f96d-d32e-2237-efdc7a604976
18/01/2007 Page 3 of 3
Cc: [redacted]; [redacted] Subject: 4D Model
[redacted],
Would you please authorise the purchase of the Navisworks software (Full version) to allow the CPP team to build and maintain the 4D model throughout the project.
The cost of this will be approximately $3,000. [redacted] has advised he can raise this order once we receive your approval.
Regards [redacted]
Senior Project Engineer [redacted] Phone: [redacted] Direct Mobile: [redacted]

Node Coding **Tree Nodes\1. Project Value\Management Support** **References** **2** **Coverage** **27.95%**

Coding Summary Report Page 2 of 7

Reference 1	*Character Range 2,088 - 2,332*

AS ABOVE

Reference 2	*Character Range 2,505 - 3,191*

AS ABOVE

Node Coding **Tree Nodes\1. Project Value\Results Demonstrability** **References** **1** **Coverage** **7.33 %**

Reference 1	*Character Range 2,088 - 2,332*

AS ABOVE

Site visit **Document**

Email

Total References 1

Node Coding **Tree Nodes\1. Project Value\Management Support** **References** **1** **Coverage** **98.75 %**

Reference 1	*Character Range 16 - 1,435*

From: [redacted]
Sent: Tuesday, 23 May 2006 4:38 PM
To: [redacted]
Cc:
Subject: RE: Site Visit

[redacted]
Excellent result, look forward to having you here.

Cheers
[redacted]

From: [redacted] Sent: Tuesday, 23 May 2006 3:55 PM To: [redacted] Cc: [redacted] Subject: RE: Site Visit
Hi [redacted],
I am available to come to site next week.
If possible, I would like to fly to [redacted] on Tuesday (30/5/06) afternoon and return to [redacted] on Friday (2/6/06) night.
Please let me know what other arrangements are necessary, e.g. site inductions, hire car (directions?), etc.
Thanks for your help.
Regards,
[redacted]
From: [redacted] Sent: Tuesday, 23 May 2006 3:29 PM To: [redacted] Cc: [redacted] Subject: Site Visit
[redacted],
In order to assist with fine tuning the 4D model for the CPP, [redacted] has advised that [redacted] might be available to visit the [redacted] site next week.

Coding Summary Report Page 3 of 7

[redacted] would be travelling on Tuesday 30 May 2006 and staying on site through to (possibly) Monday 5 June 2006.
Could you please advise as soon as possible the exact dates of this visit so that [redacted] travel and accommodation can be arranged.
Regards,
[redacted] Project Secretary CPP Construction [redacted] Tel: [redacted] E-M: [redacted]
1

PP 4D modelling - pls provide estimate **Document**

Email

Total References **1**

Node Coding **Tree Nodes\1. Project Value\Management Support** **References** **1** **Coverage** **22.01%**

Reference 1 *Character Range 2,797 - 3,849*

From: [redacted] Sent: Monday, 26 September 2005 11:48 AM To: [redacted] Cc: [redacted] ; [redacted] Subject: [redacted] 4D modelling - pls provide estimate
[redacted],
I am trying to get the relevant list from [redacted], and will send through as soon as I get it.
Can you please put an estimate together for the 4D modelling works for the [redacted] CPP. I understand you will do it as a schedule of rates, but please provide an indication of the time required to carry out the works, and allowing for a bit of maintenance/assistance throughout the project. I believe we will train someone to do the updating along the way.
Also, we are looking at extending the scope of the 4D to include the Coal Handling Plant (CHP), including conveyors, bins, transfer stations etc. I will give you more information when I can get it. Please don 't consider this for your estimate at this stage.
Thanks [redacted]
[redacted] Senior Project Engineer [redacted] Ph: [redacted] Fx: [redacted] Mb: [redacted]

Assistance on PP **Document**

Email

Total References **4**

Node Coding **Tree Nodes\1. Project Value\Management Support** **References** **3** **Coverage** **57.84%**

Reference 1 *Character Range 14 - 1,263*

From: [redacted] Sent:7/12/2005 8:28:02 PM

To: [redacted]
CC: [redacted]; [redacted]; [redacted]; [redacted] Subject: RE: Assistance on [redacted]
[redacted] - further to our telecon this morning, I welcome and encourage the type of planning tools you've offered and would be very surprised if 4D modelling didn't generate some innovative ideas in the design and construction teams.
I appreciate the offer to have [redacted] give the Alliance team a presentation with examples of other projects where this has been used.
I'll make sure we get it set up shortly.
Thanks
[redacted]
From: [redacted] Sent: Tuesday, 12 July 2005 11:25 AM To: [redacted] Cc: [redacted] Subject: RE: Assistance on [redacted]
[redacted],
I have this morning spoken to [redacted] who says he would be happy to present the work [redacted] have and are doing on 4D planning to the project team this week if there was some interest.
His contact details are as follows: [redacted]
Regards
[redacted] Manager Engineering - Process Group
Ph: [redacted] Fax: [redacted] Mb: [redacted]

Reference 2 *Character Range 1,265 - 1,402*

From: [redacted] Sent: Monday, 11 July 2005 3:59 PM To: [redacted] Subject: RE: Assistance on [redacted]
[redacted]

Coding Summary Report Page 4 of 7

Reference 3 *Character Range 2,210 - 2,705*

The [redacted] work on 4D has been championed by [redacted] and [redacted]. [redacted] is due back in the office tomorrow and could present some information to the [redacted] team if you wish. [redacted] is aware of this work having used it at [redacted] on the tank job.

http://mailarchive.[redacted]/ViewMessage.aspx?CheckSum=04e17acc-75ca-3db0-9f85-e33fac3e49b3
19/01/2007 Page 2 of 2
Regards
[redacted] Engineering - Process Group
Ph: [redacted] Fax: [redacted] Mb: [redacted]

Node Coding **Tree Nodes\1. Project Value\Results Demonstrability** **References 1** **Coverage 38.41%**

Reference 1 *Character Range 14 - 1,263*

AS ABOVE

PP 4D.GI-9 trans	**Document**

Email

Total References 1

Node Coding **Tree Nodes\1. Project Value\Management Support** **References 1** **Coverage 12.47%**

Reference 1 *Character Range 3,808 - 4,408*

-----Original Message-----From: [redacted] Sent: Friday, 10 March 2006 9:26 AMTo: [redacted] Subject: RE: Emailing: [redacted] 4D G1-9 transparent 2.wmv
Hi [redacted],
Thanks for the file, the guys are happy to see it coming along. [redacted] got back todayfrom his break and he has the program on his (slow)computer (- the new laptop hasn'tarrived yet), so I hope to have a look at it over the next couple of days. If you havedone any work on it since the copy you gave me can you please let me know. I willconcentrate more on Grids 9-14 since the rest is pretty much finished now.
Kind Regards,[redacted]

PP Crk	**Document**

Total References 2

Node Coding **Tree Nodes\1. Project Value\Management Support** **References 2** **Coverage 32.56%**

Reference 1 *Character Range 1,694 - 2,359*

From: [redacted] Sent: Wednesday, 27 July 2005 8:51 PM To: [redacted] Cc: [redacted] Subject: RE: [redacted]
[redacted] - as discussed this afternoon, I am very keen that we arrange a demo of the 4D modelling to the entire

Coding Summary Report Page 5 of 7

Project Team
next week since it could well influence thinking on construction sequencing.
We discussed applying this to construction of the CPP, as well as to ancilliary structures crowded around the CPP.
Instinctively I feel there are other potential applications.
In your Meeting Invitation can you include [redacted] design engineers and all construction engineers in the Project Office.
Thanks
[redacted]

Reference 2 *Character Range 3,105 - 3,670*

To: [redacted] Subject: [redacted]

Can you please contact [redacted] at [redacted] to establish a time to do a 4D demo for the [redacted] team? He will refer you to [redacted] who will be supporting you on this front. He said it would be best to do it next week and that they would like to get a few of their guys together to look at it. Also said they have a budget for it and a graduate or some one who could ultimately champion the work.
You will need to go to [redacted]
[redacted] is on [redacted] Reception [redacted]
Cheers [redacted]

3D site model **Document**

Email

Total References 2

Node Coding **Tree Nodes\1. Project Value\Availability of financial resources** **References 1** **Coverage 19.06%**

Reference 1 *Character Range 1,049 - 1,635*

From: [redacted] Sent: Tuesday, 7 February 2006 8:31 AM To: [redacted] Cc: [redacted] Subject: RE: 3D Site Model
[redacted],

I would like 3D site drawings in both pdf and AutoCAD (preferably CAD14) file types please.
[redacted] is on site this week. Please ring her [redacted] and discuss your requirements of the P3 schedule (any additional columns).
I would also like for you to get the latest prx file from her for CD02 (Contract [redacted] Schedule).
We must make this 4D model work, and I need us to get the support of our Planners.

Regards
[redacted]

Node Coding **Tree Nodes\1. Project Value\Management Support** **References 1** **Coverage 19.06%**

Reference 1 *Character Range 1,049 - 1,635*

AS ABOVE

Navisworks 3D model - structure **Document**

Email

Total References 1

Node Coding **Tree Nodes\1. Project Value\Management Support** **References 1** **Coverage 5.56%**

Coding Summary Report Page 6 of 7

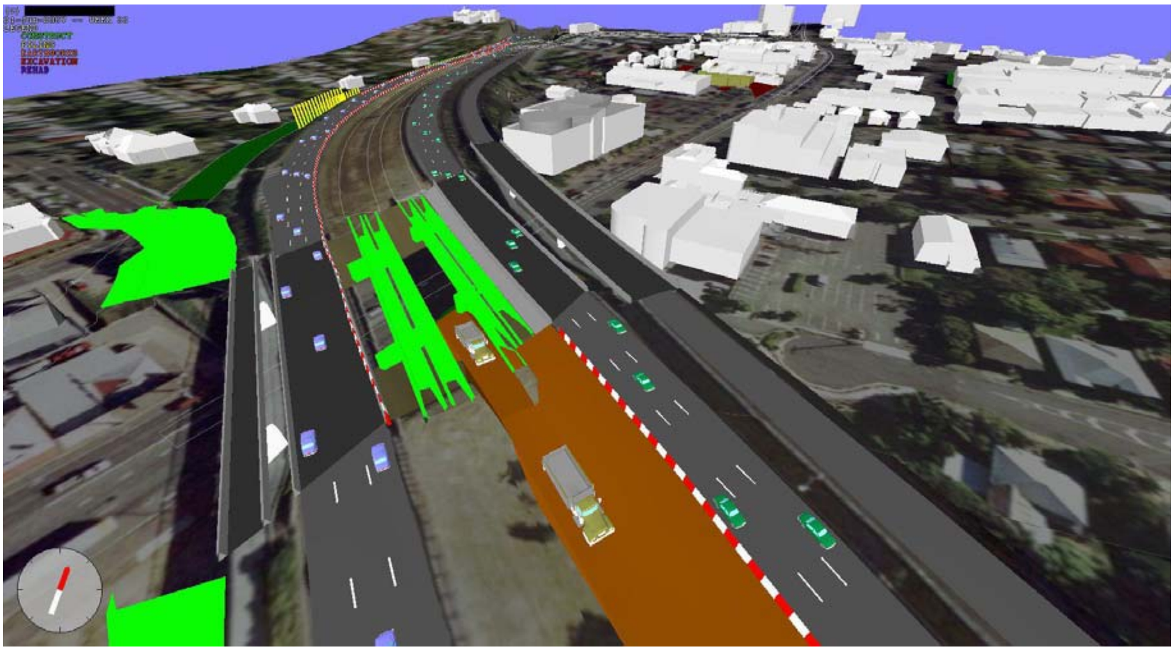
Reference 1 *Character Range 4,677 - 5,036*

From: [redacted] Sent: Friday, 10 February 2006 9:44 AM To: [redacted] Subject: RE: NavisWorks 3D Model- Structure
Sounds good [redacted]
No real need to come earlier - just wanted to say g'day and see how it is all going.

[redacted] Senior Project Engineer [redacted]

Appendix C – Samples of TT_{PO} Data

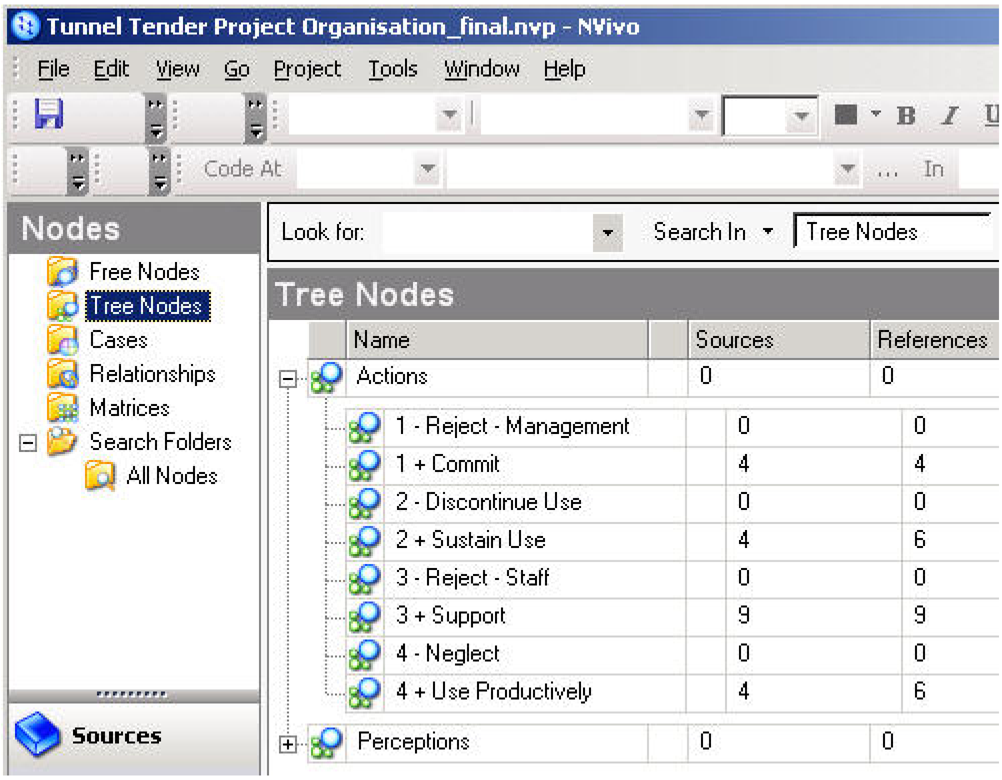
C.1 Image from the TT_{PO} 4D model presented to the client



Post-event field notes linked to image and added to NVivo7 analysis

The image shows a frame from the live/animated/navigated presentation of the ***[TT_{PO}]*** 4D model at the client presentation (model controlled by ***[ACL TECHNOLOGY CHAMPION]***). The client presentation lasted for a whole day and involved all the different factions from within ***[THE TT_{PO}]*** presenting what they had planned/designed (see the client presentations agenda for more info). The model was used to show the planned construction of the *[…..]* portal for the tunnel and focused also on the associated temporary traffic plans/measures. Displaying to the client that there were feasible plans in place to meet the required minimum traffic flows was of high importance. ***[……]*** (Construction manager) read from a prepared script in narrating the model for a period of about 3 minutes. This and other images and animations were included in the tender submission documentation and DVD.

C.2 Summary of TT_{PO} coded actions



Note that the Actions and Perceptions NVivo7 tree nodes were only used to group the other tree nodes therefore were not relevant for coding data to them.

Appendix D – Samples of PT_{PO} Data

D.1 Photo from a toolbox meeting[74] presenting PT_{PO} 4D model

Post-event field notes linked to photo and added to NVivo7 analysis

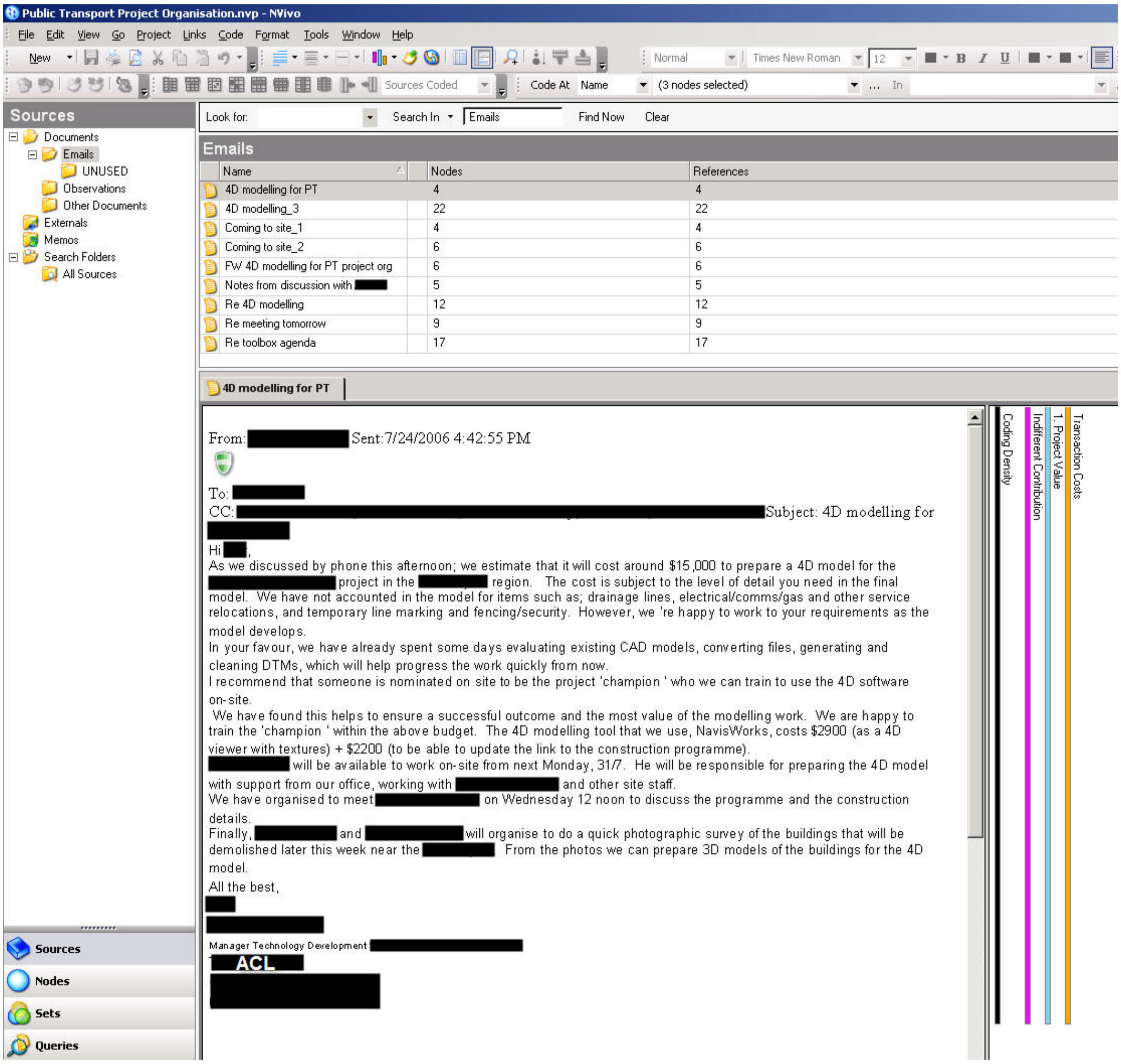
The photo shows the 4D model for the ***[PT_{PO}]*** being presented by ***[….]*** (site engineer) to all the on-site office staff (i.e. project managers, engineers, designers. admin and support staff). The model was not complete so it was more of a progress report and introduction to 4D modelling technology for the audience. At this time the model showed the work areas for the first two construction stages of the project as well as the temporary public parking area locations that were allocated to balance the permanent public parking areas that had to be occupied during each of the construction stages. Communicating these two messages was the main drive and intended benefit of the 4D modelling on the ***[PT_{PO}]***.

<u>Later Entry</u>

This was the only presentation of the model to a group of people that occurred. Project management failed to approve the purchase of a dedicated laptop computer for ***[THE SITE ENGINEER]*** to use for presenting the model to community stakeholders as per the initial intention of the model. Largely as a result of the lack of support from management but also because the project-participants neglected to use the 4D model - the implementation was discontinued.

[74] A 'Toolbox Meeting' is a the term given to a regular staff meeting (e.g. office staff Friday toolbox).

D.2 Screenshot from PT_{PO} NVivo7 analysis



This screenshot shows the emails that were collected from the PT_{PO} 4D CAD implementation and coded. The first one, an email sent by a member of the ACL Technology Group to one of the PT_{PO} project managers, is open and coded as having an indifferent contribution to the formulation of the project value perception in the P-I model via the transaction costs contributing factor.

Appendix E – Samples of PB_{PO} Data

E.1 Series of critical PB_{PO} emails (coded) – NVivo7 screenshots

From: [redacted] Sent: Sunday, 18 March 2007 1:03 AM To [redacted] Subject: RE: 3D Model
Hi [redacted],
Sorry I couldn't get back to you earlier. Thanks for your comments, I think I'm getting a much better appreciation of what's involved in this whole gig.
At the moment, people are concentrating on putting out fires in the immediate vicinity, as it were, and have no time to prepare for the big one building up in the relatively far distance (what else is new, do I hear you ask?!). I shall persist, however, and continue chasing any other 3D files I can lay my hands on, to see if they have better detail, and to continue selling the virtues of modeling. Will keep you posted.
Regards,
[redacted]

From: [redacted] Sent: Tuesday, 27 February 2007 12:16 AM To: [redacted] Subject: 3D Model
Hi Erik,
Greetings from [redacted]. I'm not sure if you heard but I decided to move across to [redacted] for a couple of years, mainly to be closer to my family [redacted]. I've been in [redacted] since mid-November 06 on this US$400 million project.
We have quite a challenging Arena to construct and there are a host of buildability issues to be overcome and I have been thinking about 3D/4D modelling. Would you guys be interested in giving us a quote? Of course, I expect you would need to check if you can do work for another group company, but I'm hoping that would not be a problem.
Assuming you are interested, perhaps in the first instance you could have a look at the link below, for an overview of the project.
[redacted]
The project is fully documented and we have all the Autocad files available, as well as a reasonably detailed programme. I expect you'll have a lot of questions before you can put together a cost estimate, so please feel free to get in touch by email or you can ring my mobile number below.
Looking forward to hearing from you,
Regards
[redacted]

[redacted]
Planning Manager

From: [redacted] Sent: Fri 02-Mar-07 10:41 AM
To: [redacted] Cc: [redacted]; [redacted] Subject: RE: 3D Model
22/05/2007
Thanks very much for the response and files. We've had a good look at them – and certainly impressed with the project.
If all the available designs are in 2D, we estimate it will take approximately 6 weeks to convert the drawings to 3D models and add textures, lighting, and viewpoints. The models will be geometrically correct but, of course, only suitable for visualisation and assessing aspects of constructability (including eventual 4D application). If you can source some of the design as 3D models then we can save a lot of time. The rate for this work is A$1280/day (so about $40k-50k) + travel/ accommodation/ other expenses (allow for 2x return airfares).
Do you expect any design changes or additions that will impact on this work?
Once the 3D model is complete, anyone can view the model using a free viewer, such as Navisworks Freedom, but we also recommend the project purchasing a full license of Navisworks Jetstream with the Presenter and Timeliner modules (about A$6000). This version also includes a measurement tool and 4D modelling (linking to the programme). We can provide training on-site.

07.02.27 From Project Manager (P | 07.03.02 From Technology Cham | **07.03.03 From PM** | 07.03.12 From PM | 07.03.13 From TC | 07.03.18 From PM

From: [redacted] Sent: Sat 03-Mar-07 11:52 AM To: [redacted] Subject: RE: 3D Model
Hi [redacted],
Thanks a lot for having a good look at the project and coming back with a preliminary cost estimate (at such short notice), which is exactly what we needed at this stage.
I have already started chasing various people to see what may be available in 3D. I know for a fact that the Structural Steel subcontractor has done detailed 3D modelling for all the main steel and we should be able to obtain their files. The architect did some early client presentation-style perspectives and I'm trying to get more detail on those. I'll let you know as soon as I can lay my hands on any of the stuff.
I will be discussing your proposal in detail with my colleagues as well as the Project Director over the next week or so and will get back to you shortly thereafter.
Best regards,

Coding Density | Indifferent Contribution | 1. Project Value | Management Support

07.02.27 From Project Manager (P | 07.03.02 From Technology Cham | 07.03.03 From PM | **07.03.12 From PM** | 07.03.13 From TC | 07.03.18 From PM

From: [redacted] Sent: Monday, 12 March 2007 9:24 PM To: [redacted] Subject: FW: 3D Model
Hi [redacted],
As a start, I've got hold of the first 3D model file, from the Steel subcontractor, which is attached. Would it be possible for you to have a look at it and advise if it is usable? In the meantime I'll continue to chase other sources. I am also investigating the possibility of getting 2D to 3D
"conversions" done in India. What do you think? Regards,

[redacted]
Planning Manager

Coding Density | Negative Contribution | 1. Project Value | Transaction Costs

07.02.27 From Project Manager (P | 07.03.02 From Technology Cham | 07.03.03 From PM | 07.03.12 From PM | **07.03.13 From TC** | 07.03.18 From PM

From: [redacted] Sent: Tue 13/03/2007 2:07 AM
To: [redacted] Cc: [redacted] Subject: RE: 3D Model
Hi [redacted],
It's good to hear back from you. Thanks for the file.
The 3D model is a good start but there's some work required to make it useable as either a 3D or 4D model, for example; The model shows the steel structure as a wire-frame model. I think this should be converted to a solid model otherwise you won't see much against all the other components. Currently the CAD objects are large single objects. They will need to be cut into sections that reflect the detail in the construction programme
Regarding 2D to 3D modelling, I would also recommend using CAD drafting houses in India or China if this is all you want to do. [redacted] help with contacts in India.
However, we recommend a company in China, [redacted]
The danger is that they produce a lovely textured 3D model but without regard for other end-uses such as 4D (the second dot-point above is always a concern). With some direction this problem can be avoided, but you have to weigh-up the extra time to manage these people. [redacted] has done quite a lot of this type of work, generating 3D models from 2D drawings, but it's a question of the number of drawings, detail required, and what you expect to do with it in the end.
Hope this helps.

Regards, [redacted]

Coding Density | Indifferent Contribution

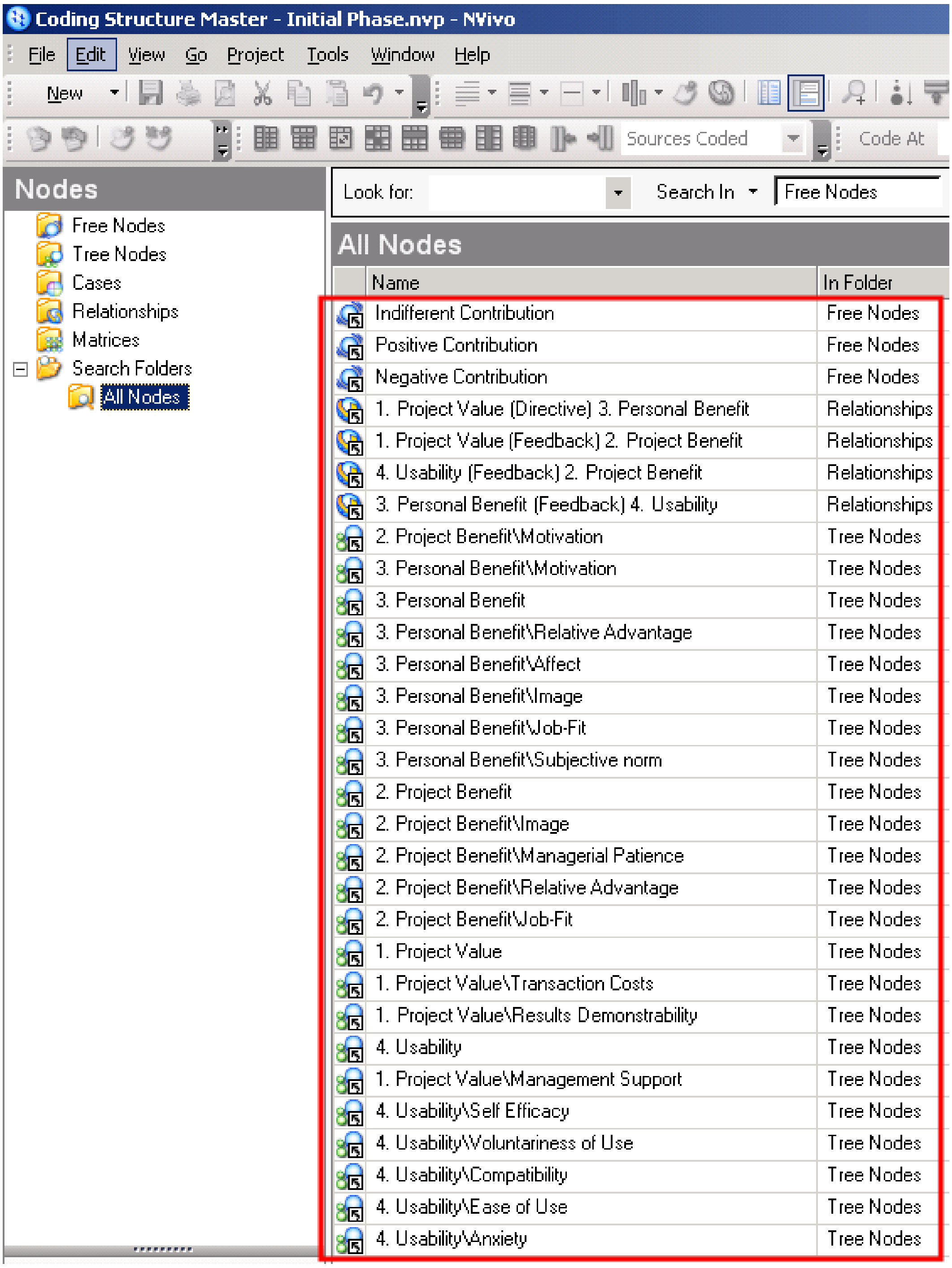
Appendix F – NVivo7 Coding Structure Evolution

Key for Appendix F Screenshots

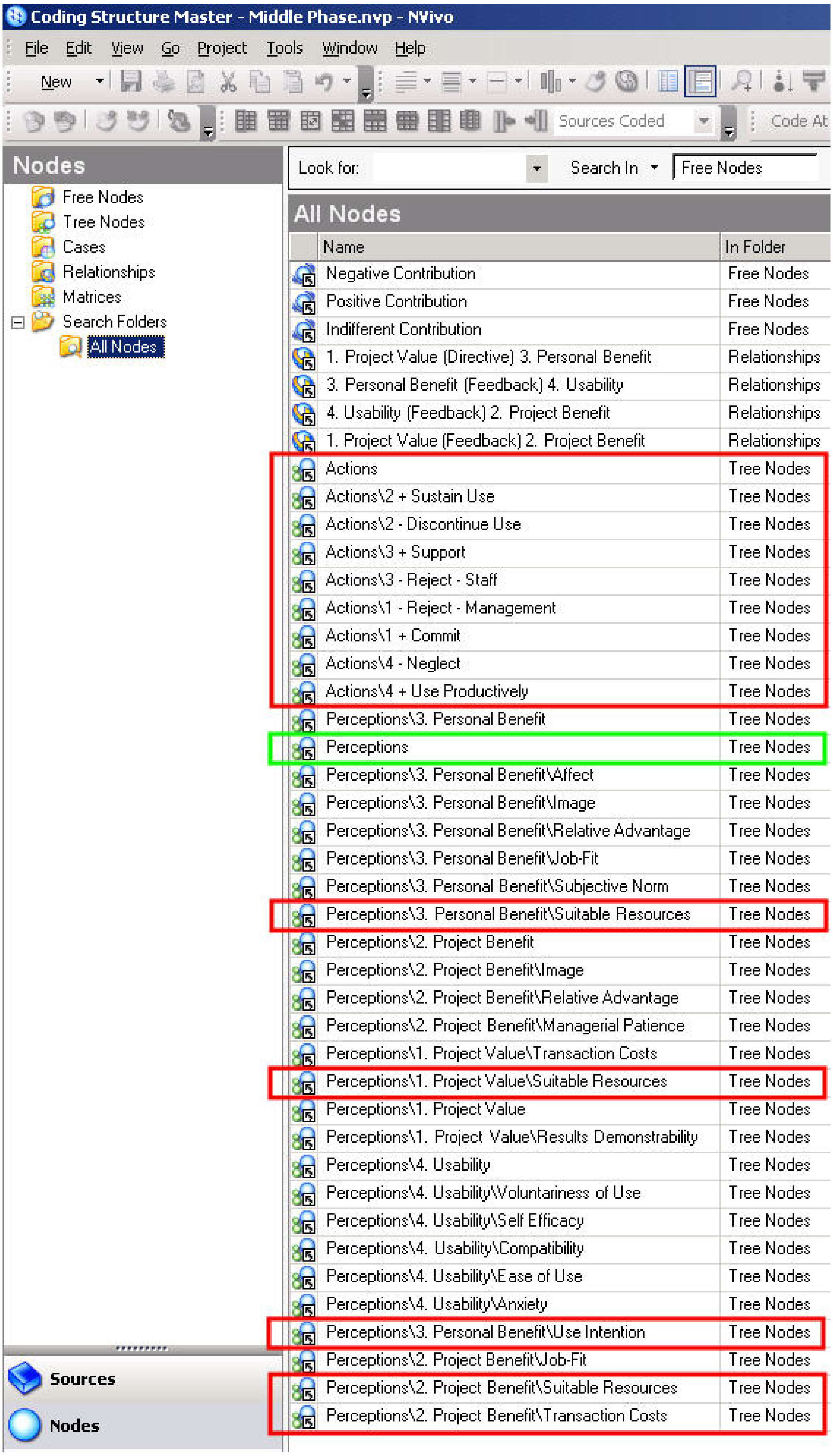
NEW CONSTRUCT ADDED

EXISTING CONSTRUCT ADJUSTED

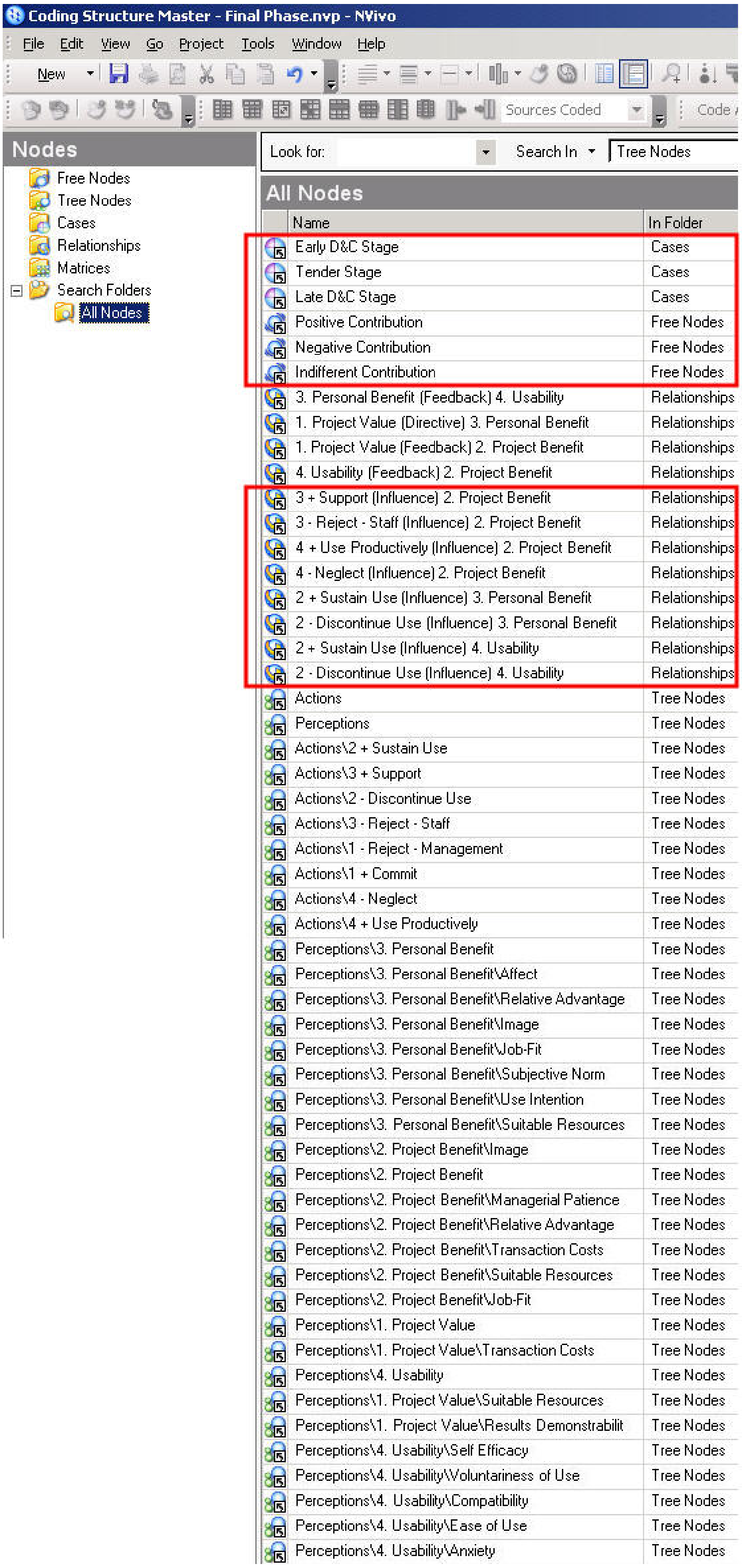
F.1 P-I_1 model coding structure – Initial research phase



F.2 P-I$_2$ model coding structure – Middle research phase



F.3 P-I_3 model coding structure – Final research phase



Name	In Folder
Early D&C Stage	Cases
Tender Stage	Cases
Late D&C Stage	Cases
Positive Contribution	Free Nodes
Negative Contribution	Free Nodes
Indifferent Contribution	Free Nodes
3. Personal Benefit (Feedback) 4. Usability	Relationships
1. Project Value (Directive) 3. Personal Benefit	Relationships
1. Project Value (Feedback) 2. Project Benefit	Relationships
4. Usability (Feedback) 2. Project Benefit	Relationships
3 + Support (Influence) 2. Project Benefit	Relationships
3 - Reject - Staff (Influence) 2. Project Benefit	Relationships
4 + Use Productively (Influence) 2. Project Benefit	Relationships
4 - Neglect (Influence) 2. Project Benefit	Relationships
2 + Sustain Use (Influence) 3. Personal Benefit	Relationships
2 - Discontinue Use (Influence) 3. Personal Benefit	Relationships
2 + Sustain Use (Influence) 4. Usability	Relationships
2 - Discontinue Use (Influence) 4. Usability	Relationships
Actions	Tree Nodes
Perceptions	Tree Nodes
Actions\2 + Sustain Use	Tree Nodes
Actions\3 + Support	Tree Nodes
Actions\2 - Discontinue Use	Tree Nodes
Actions\3 - Reject - Staff	Tree Nodes
Actions\1 - Reject - Management	Tree Nodes
Actions\1 + Commit	Tree Nodes
Actions\4 - Neglect	Tree Nodes
Actions\4 + Use Productively	Tree Nodes
Perceptions\3. Personal Benefit	Tree Nodes
Perceptions\3. Personal Benefit\Affect	Tree Nodes
Perceptions\3. Personal Benefit\Relative Advantage	Tree Nodes
Perceptions\3. Personal Benefit\Image	Tree Nodes
Perceptions\3. Personal Benefit\Job-Fit	Tree Nodes
Perceptions\3. Personal Benefit\Subjective Norm	Tree Nodes
Perceptions\3. Personal Benefit\Use Intention	Tree Nodes
Perceptions\3. Personal Benefit\Suitable Resources	Tree Nodes
Perceptions\2. Project Benefit\Image	Tree Nodes
Perceptions\2. Project Benefit	Tree Nodes
Perceptions\2. Project Benefit\Managerial Patience	Tree Nodes
Perceptions\2. Project Benefit\Relative Advantage	Tree Nodes
Perceptions\2. Project Benefit\Transaction Costs	Tree Nodes
Perceptions\2. Project Benefit\Suitable Resources	Tree Nodes
Perceptions\2. Project Benefit\Job-Fit	Tree Nodes
Perceptions\1. Project Value	Tree Nodes
Perceptions\1. Project Value\Transaction Costs	Tree Nodes
Perceptions\4. Usability	Tree Nodes
Perceptions\1. Project Value\Suitable Resources	Tree Nodes
Perceptions\1. Project Value\Results Demonstrabilit	Tree Nodes
Perceptions\4. Usability\Self Efficacy	Tree Nodes
Perceptions\4. Usability\Voluntariness of Use	Tree Nodes
Perceptions\4. Usability\Compatibility	Tree Nodes
Perceptions\4. Usability\Ease of Use	Tree Nodes
Perceptions\4. Usability\Anxiety	Tree Nodes

Appendix G – Samples of CB_{PO} Data

G.1 Minutes from first ACL - CB_{PO} meeting and NVivo7 memo

ACL Technology Group

MINUTES OF MEETING

Subject of Meeting:	PBPO Tender 4D Modelling				
Location:	ACL Meeting Room	Date:	24/04/2006	Time:	4:00pm

Chaired By: [redacted]	Minuted by: [redacted]	Distribution Date: 26/04/2006

Attendees: [redacted]
Apologies: [redacted]
Not Present::

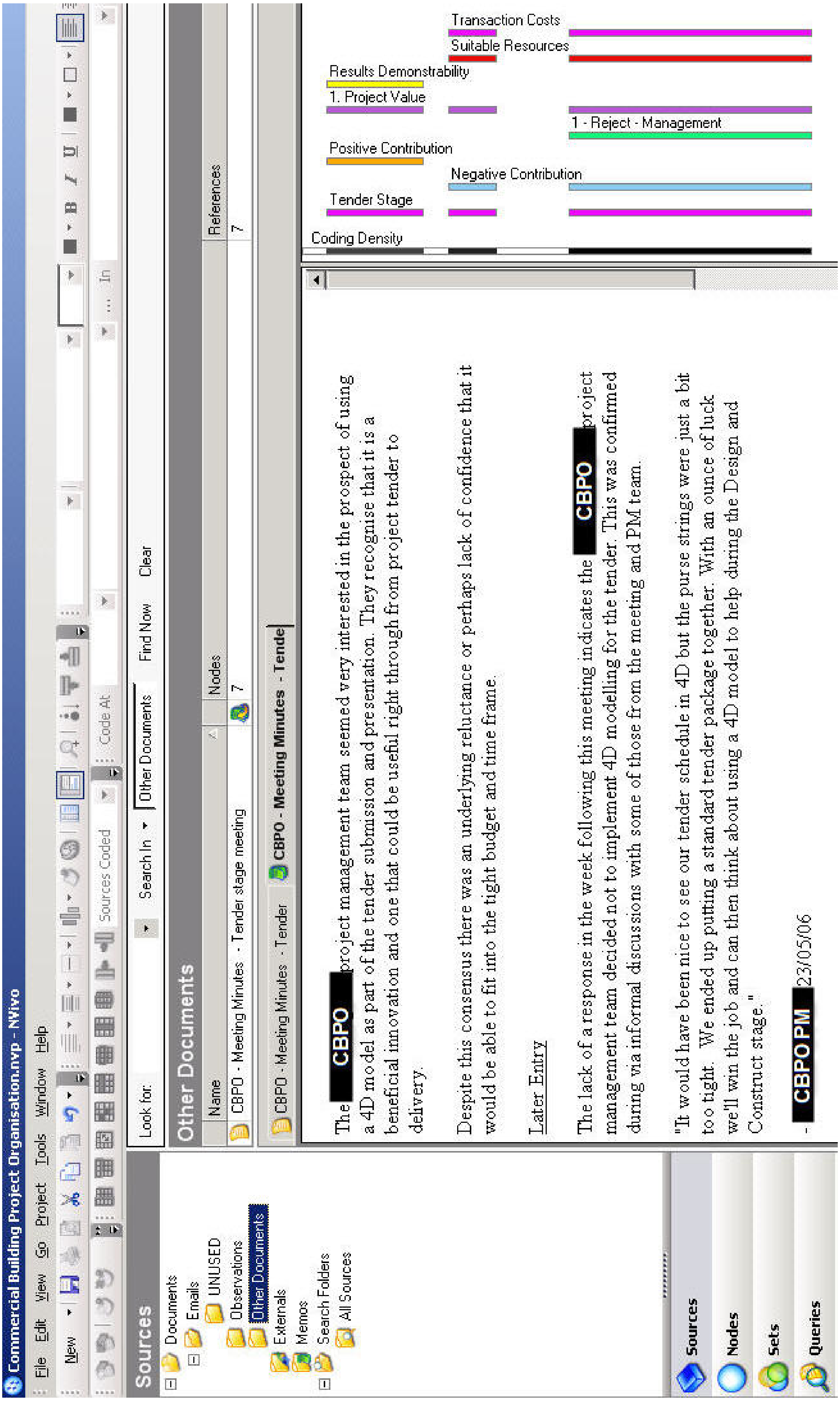
Distribution (Method e.g. email): Email
Attendees and apologies plus: [redacted]

Item	Action	By Whom	By When
1.	Introduction to 4D modelling (context) • Work flows • Potential Benefits • Example 4D models ([redacted])	[redacted]	
2.	<u>Discuss the use of 4D modelling during PBPO tender</u> Possible applications: • Visualisation of construction schedule (particularly milestones) for presentation to client Required Personnel • ACL Technology group and PBPO planners ([redacted]) Cost • $15-20k Timeframe • Tender submission due in 4 weeks (22/05/06) • Client Presentation the week after	ALL	
3.	PBPO Management to review proposal to use 4D modelling	[redacted]	30/04/06

<u>Next Meeting:</u>

Location: TBC Date: TBC Time: TBC

[redacted] Page 1 of 1


Commercial Building Project Organisation.nvp - NVivo
File Edit View Go Project Tools Window Help
New
Sources Coded
Code At
In
Sources
Documents
Emails
UNUSED
Observations
Other Documents
Externals
Memos
Search Folders
All Sources
Look for:
Search In
Other Documents
Find Now
Clear
Other Documents
Name
Nodes
References
CBPO - Meeting Minutes - Tender stage meeting
7
7
CBPO - Meeting Minutes - Tender
CBPO - Meeting Minutes - Tende
The CBPO project management team seemed very interested in the prospect of using a 4D model as part of the tender submission and presentation. They recognise that it is a beneficial innovation and one that could be useful right through from project tender to delivery.
Despite this consensus there was an underlying reluctance or perhaps lack of confidence that it would be able to fit into the tight budget and time frame.
Later Entry
The lack of a response in the week following this meeting indicates the CBPO project management team decided not to implement 4D modelling for the tender. This was confirmed during via informal discussions with some of the those from the meeting and PM team.
"It would have been nice to see our tender schedule in 4D but the purse strings were just a bit too tight. We ended up putting a standard tender package together. With an ounce of luck we'll win the job and can then think about using a 4D model to help during the Design and Construct stage."
- CBPO PM 23/05/06
Coding Density
Tender Stage
Negative Contribution
Positive Contribution
1 - Reject - Management
1. Project Value
Results Demonstrability
Suitable Resources
Transaction Costs
Sources
Nodes
Sets
Queries

Appendix H – Samples of FU_{PO} Data

H.1 FU_{PO} 4D model management guideline TOC and NVivo7 memo

[redacted] [redacted]

FUPO 4D Model Management Guideline

1.0 4D Model Support 2

2.0 Data Management 2

2.1 Job Folder Access Privileges 2
2.2 Job Folder Backup 2
2.3 4D Model Workstation 2
2.4 P3/Suretrak Programme 2
2.5 Navisworks Licenses 3

3.0 Model Update and Issue 3

3.1 Updating the Model/s with a new P3 Programme 3
3.2 CAD Updates 3
3.3 Issuing Updated Models 3

4.0 Model Use 4

4.1 Floating and Fixed Licenses 4
4.2 Loading Published Models 5
4.3 Navigating Models 6

Appendices 8

Appendix A 8

Rev A 1 of 13 03/10/2007

H.2 Ministerial review of FU_{PO} traffic management

[redacted]

Ministerial Briefing

TO: [redacted]
Minister for Roads and Ports

Ref: [redacted]

CC: [redacted]
Deputy Secretary – Capital
Department of Infrastructure

[redacted]
Chief Executive Officer
[redacted]

[redacted]
Executive Director, Major Projects
[redacted]

FROM: [redacted]
Chief Executive Officer
[redacted]

SUBJECT: [redacted] **Traffic Management Review**

DATE: 27 September 2007

PURPOSE

1. To advise the Minister about the suitability of the traffic management arrangements proposed by [redacted] and its contractors for the [redacted] Project. (This briefing note addresses only the [redacted] Freeway section.)

BACKGROUND

2. The works which are to be undertaken on the [redacted] Freeway to provide additional capacity are far reaching and complex. Widening of structures, introduction of long term traffic management hardware and [redacted] will all impact on the very high volumes of traffic which use this road. Traffic management during construction will therefore be a critical activity.

3. The Minister and the [redacted] requested that [redacted] review the traffic management requirements and proposed strategies for the [redacted] Project, to ensure that disruption during construction is minimised.

4. This request was confirmed by [redacted] Executive Director, Major Projects, Mr [redacted], who arranged a briefing by the [redacted] Alliance Team. [redacted], of [redacted] Needs Assessment team and I attended a meeting with members of the Alliance on Thursday, 20 September 2007, and were given a detailed presentation about the traffic management techniques that were being developed for this section of the [redacted] Project.

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[redacted]

FINDINGS OF THE REVIEW

5. It will not be possible to undertake the works on the [redacted] Freeway without lane closures at certain times. It will also be necessary at some times to implement full closure of a carriageway to allow positioning of cranes for beam placement. Realignment of operating traffic access will also be required at times.

6. The Alliance team has given a very high priority to planning for traffic management, and from the outset has ensured that traffic engineering considerations have been fully integrated with the design development. This has been done to ensure that construction will be undertaken with the traffic implications being fully assessed.

7. There is a high level of confidence that the team is aware of the critical issues and importance of ensuring effective co-ordination between those involved in the planning of the work with those responsible for the implementation of construction activities. This confidence is supported by extensive computer based systems which will be used by the Alliance team to co-ordinate traffic management along the length of the works, as well as to test the effect (using computer modelling) of the traffic changes that will be required to undertake certain works.

8. It was considered that traffic management planning is thorough and well considered.

9. Some areas that were discussed with the team that could be looked at in further detail include:

i. [redacted]

ii.

iii.

iv.

v.

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10. Overall, it was considered that the planning work for the [redacted] section of the [redacted] Project establishes a new benchmark for traffic management during construction on [redacted]'s inner freeway network.

NEXT STEPS

11. Further reviews will be taken for the other sections of the [redacted] Project when [redacted] advises that the team is ready for such review.

RECOMMENDATION

12. That the Minister notes the information contained in this briefing.

Prepared by:

[redacted]

[redacted]
Chief Executive Officer
[redacted]
Phone: [redacted]

[redacted]

26 / 9 / 2007

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Appendix J – Miscellaneous Appendices

J.1 P-I Model Summary/Work Sheet

RESEARCH FINDINGS in Innovation Implementation

[redacted]

Perception-Influence Model Compilation – Summary/Work Sheet

	Contributing Factors (Secondary Constructs)	Tick OR Weight of Evidence +VE	Tick OR Weight of Evidence -VE	Perceptions (Primary Const.)	Tick OR Weight of Evidence +VE	Tick OR Weight of Evidence -VE	Actions (Primary Constructs)	Tick OR Weight of Evidence
Project Management	Transaction Costs			VALUE			COMMIT	
	Results Demonstrability						REJECT	
	Suitable Resources							
	Job-Fit			PROJECT BENEFIT			SUSTAIN USE	
	Relative Advantage							
	Image							
	Managerial Patience						DISCONTINUE USE	
	Suitable Resources							
	Transaction Costs							
Individual User	Job-Fit			PERSONAL BENEFIT			SUPPORT	
	Affect							
	Relative Advantage							
	Image							
	Subjective Norm						REJECT	
	Suitable Resources							
	Use Intention							
	Compatibility			USABILITY			USE PRODUCTIVELY	
	Ease of Use							
	Voluntariness of Use						NEGLECT	
	Self-Efficacy							
	Anxiety							

See overleaf for descriptions of theoretical constructs.

Further Information

[redacted]

The [redacted] key subject, [redacted], is sponsored by [redacted] Corporate, Research and Development. For further information please visit [redacted] or contact [redacted]

RESEARCH FINDINGS in Innovation Implementation

[redacted]

Perception		Contributing Factors	Description
Project Management	VALUE	**Transaction Costs**	A positive or negative opinion about the costs associated with implementing an innovation.
Project Management	VALUE	**Results Demonstrability**	An opinion about how amenable to demonstration an innovation is and how visible its advantages are.
Project Management	VALUE	**Suitable Resources**	An opinion or concern about the ability of the project to implement the innovation or about the facilitating conditions at the project organisation.
Project Management	PROJECT BENEFIT	**Job-Fit**	An opinion or concern about how the capabilities of a new innovation will enhance (or otherwise) the project organisation's performance.
Project Management	PROJECT BENEFIT	**Relative Advantage**	An opinion or concern about how an innovation might improve (or otherwise) existing systems and workflows at the project organisation.
Project Management	PROJECT BENEFIT	**Image**	An opinion about how the use of an innovation might enhance (or otherwise) the managers' status or image.
Project Management	PROJECT BENEFIT	**Managerial Patience**	An opinion that shows patience (or lack thereof) in project management.
Project Management	PROJECT BENEFIT	**Suitable Resources**	*As for the perception of value above* – BUT in the ongoing sense of an implementation.
Project Management	PROJECT BENEFIT	**Transaction Costs**	*As for the perception of value above* – BUT in the ongoing sense of an implementation.

Perception		Contributing Factors	Description
Individual User	PERSONAL BENEFIT	**Job-Fit**	An opinion or concern about how the capabilities of a new innovation might enhance (or otherwise) an individual's job performance.
Individual User	PERSONAL BENEFIT	**Affect**	An opinion or concern about a liking (or otherwise) for the behaviours associated with using an innovation.
Individual User	PERSONAL BENEFIT	**Relative Advantage**	An opinion or concern about how an innovation might improve (or otherwise) relevant workflows and existing systems.
Individual User	PERSONAL BENEFIT	**Image**	An opinion or concern about how the use of an innovation might enhance (or otherwise) the individual user's status or image.
Individual User	PERSONAL BENEFIT	**Subjective Norm**	An opinion or concern in an individual user about people important to them and whether they believe they should or should not use the innovation.
Individual User	PERSONAL BENEFIT	**Suitable Resources**	An opinion or concern about the facilitating conditions at the project organisation.
Individual User	PERSONAL BENEFIT	**Use Intention**	An opinion that shows an intention to use a new innovation (or otherwise) in an individual user.

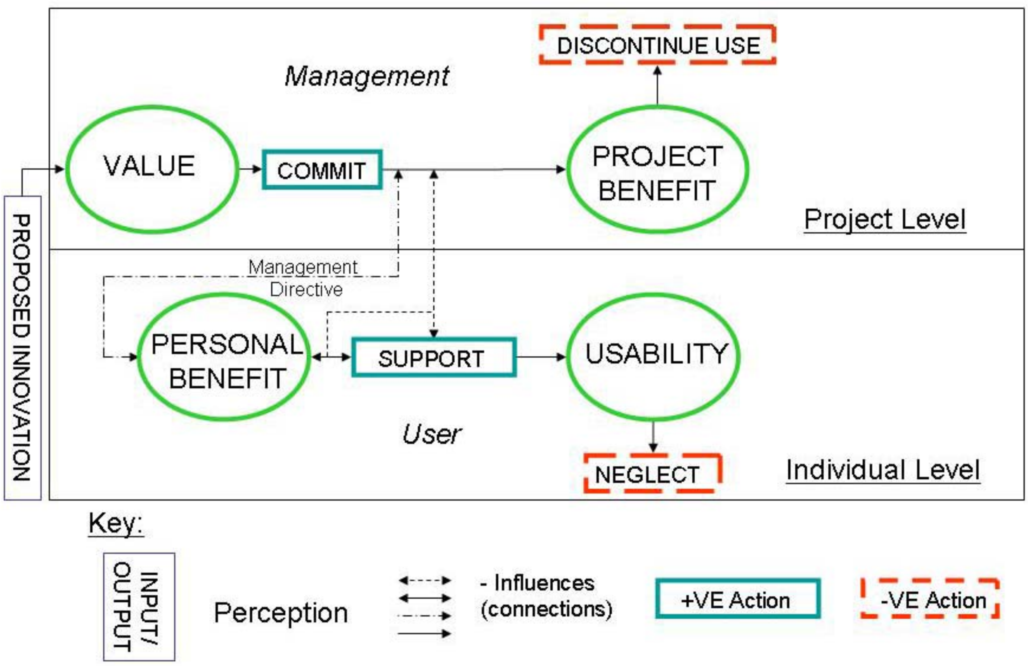
Perception		Contributing Factors	Description
Individual User	USABILITY	**Compatibility**	An opinion or concern about whether or not an innovation is consistent with the individual user's existing values, needs and past experiences.
Individual User	USABILITY	**Ease of Use**	An opinion or concern about whether or not actually using an innovation would be free from physical and/or mental effort.
Individual User	USABILITY	**Voluntariness of Use**	An opinion or concern about the use of an innovation and whether or not it is voluntary.
Individual User	USABILITY	**Self-Efficacy**	An opinion or concern that represents one's judgment of their ability to use an innovation to accomplish a particular job or task.
Individual User	USABILITY	**Anxiety**	An opinion or concern that shows anxious or emotional reactions (or otherwise) when it comes to performing the behaviours associated with using an innovation. A suitable positive connotation is *Confidence*.

The [redacted] key subject, [redacted], is sponsored by [redacted] Corporate, Research and Development. For further information please visit [redacted] or contact [redacted]

J.2 Sketched TC_{PO} P-I Model

Perception-Influence Model Compilation – Summary/Work Sheet

	Contributing Factors (Secondary Constructs)	Tick OR Weight of Evidence +VE	Tick OR Weight of Evidence -VE	Perceptions (Primary Const.)	Tick OR Weight of Evidence +VE	Tick OR Weight of Evidence -VE	Actions (Primary Constructs)	Tick OR Weight of Evidence
Project Management	Transaction Costs	✓✓		VALUE	✓		COMMIT	✓✓
	Results Demonstrability	✓						
	Suitable Resources	✓					REJECT	
	Job-Fit	✓	✓✓	PROJECT BENEFIT	✓	✓✓		
	Relative Advantage		✓✓				SUSTAIN USE	
	Image		✓					
	Managerial Patience	✓						
	Suitable Resources	✓					DISCONTINUE USE	✓✓
	Transaction Costs	✓						
Individual User	Job-Fit	✓	✓	PERSONAL BENEFIT	✓✓	✓	SUPPORT	✓
	Affect							
	Relative Advantage	✓						
	Image	✓						
	Subjective Norm	✓✓					REJECT	
	Suitable Resources	✓	✓					
	Use Intention		✓✓					
	Compatibility		✓	USABILITY	✓	✓✓	USE PRODUCTIVELY	
	Ease of Use	✓						
	Voluntariness of Use		✓✓				NEGLECT	✓✓✓
	Self-Efficacy		✓					
	Anxiety							



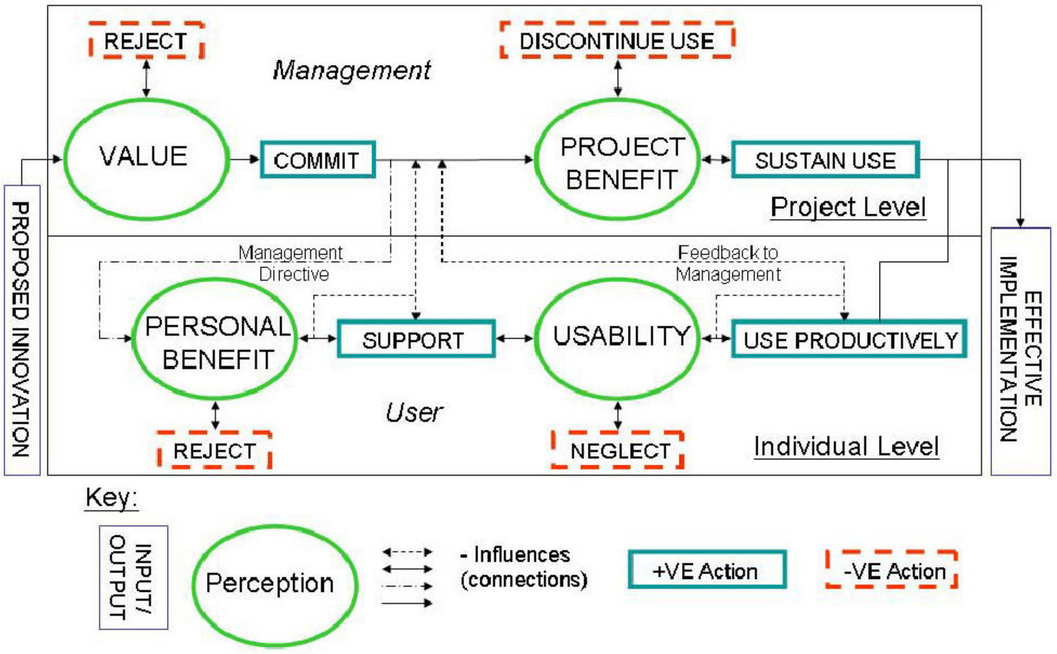
J.3 P-I Model Fact Sheet

RESEARCH FINDINGS in Innovation Implementation

[redacted]

A Perception-Influence Model

of Innovation Implementation in Project-Based Engineering



The Perception-Influence (P-I) model above maps an innovation implementation through the *Actions* and *Perceptions* of the project-participants. It is useful for technology champions because it helps strategise potential and in-progress innovation implementations. It can also be applied to give a concise summary of a completed implementation.

The primary theoretical constructs in the P-I model are the project-participant *Perceptions* and *Actions*. Positive or negative actions are the two types of outcomes from the four (4) project-participant perceptions. Human actions are observable which makes them the simpler of the two primary constructs. The four perceptions form in the minds of each relevant project-participant by a number of secondary theoretical constructs, the so-called contributing factors that are opinions and concerns about the innovation and its implementation. These constructs have been synthesised from previous implementation and user acceptance research. A particular opinion or concern a project-participant has will contribute accordingly to the relevant parent perception – see overleaf for a tabular breakdown of all theoretical constructs.

When used to evaluate a completed innovation implementation or events to date for one in progress, the model is adaptable and can be applied to a wide range of circumstances. An implementation can involve many project-participants or as few as one person to whom a technology must be transferred in order for the implementation to be successful. For the case of a group of people, an application of the P-I model will surmise the opinions and concerns of the group and present inferences in a concise format. Observed actions are, of course, a cross-check for perceptions inferred from evidential project-participant opinions and concerns.

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RESEARCH FINDINGS in Innovation Implementation

[redacted]

	Actions (Primary)	Perceptions (Primary Const.)	Contributing Factors[1] (Secondary Constructs)	'Encompassed'[2], [Paralleled][3] and Divided[4] Theoretical Constructs
Project Management	COMMIT / REJECT	VALUE	**Transaction Costs**	'Availability of financial resources'
			Results Demonstrability	*None found*
			Suitable Resources	'Management support', 'Tight timeframes', 'Climate for implementation' [Behavioural control]
	SUSTAIN USE / DISCONTINUE USE	PROJECT BENEFIT	**Job-Fit**	[Innovation-Values Fit, Usefulness]
			Relative Advantage	Motivation - Intrinsic
			Image	Motivation - Extrinsic
			Managerial Patience	*None found*
			Suitable Resources	*As above plus* 'Technical support'
			Transaction Costs	*As above*
Individual User	SUPPORT / REJECT	PERSONAL BENEFIT	**Job-Fit**	*As above*
			Affect	*None found*
			Relative Advantage	*As Above*
			Image	*As Above*
			Subjective Norm	Motivation - Extrinsic
			Suitable Resources	*As above plus* 'Technical support'
			Use Intention	[Attitude towards use, Behavioural Intention]
	USE PRODUCTIVELY / NEGLECT	USABILITY	**Compatibility**	*None found*
			Ease of Use	'Complexity'
			Voluntariness of Use	*None found*
			Self-Efficacy	*None found*
			Anxiety	*None found*

[1] See 'P-I Model Compilation – Summary/Work Sheet' for construct definitions.
[2] The term 'encompassed' is the descriptor for the inclusive, multi-facet contribution-style relationship that exists between certain secondary constructs or contributing factors and certain primary constructs or perceptions.
[3] The term 'paralleled' is the descriptor for the relationship between two theoretical constructs of similar or synonymous definition but labelled with distinctly different terms.
[4] The term 'divided' is the descriptor for a theoretical construct defined with a wide enough scope such that one or more other theoretical constructs, with narrower scoped definitions, exist as divisions but also examples of the construct.

Further Information

[redacted]

The [redacted] key subject, [redacted], is sponsored by [redacted] Corporate, Research and Development. For further information please visit [redacted] or contact [redacted]