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An approach for the development and implementation of systems in complex business contexts through methodology tailoring

By

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Declaration of Authenticity and Author's Rights

This thesis is the result of the author's original research. It has been composed by the author and has not been previously submitted for examination, which has led to the award of a degree.

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Date: 5/5/2017

Abstract

Systems utilised in complex business contexts commonly need to be well integrated within the business in which they operate. There is a risk of poor acceptance, adoption, and sustainment in the business if the system does not take into account key business related considerations. Utilising DePuy Orthopaedics resource management business context as a case study, an assessment of potential System Development Methodologies (SDM) that could be utilised in the development of an IT system was carried out. It was established that no single SDM could provide the level of support that was identified as required. Further investigation of system development within complex businesses ascertained that methodology tailoring is an approach utilised to ensure that methodologies incorporate business specific complexities with a subsequent aim to ensure that developed systems are fit for purpose. However, there is little proven procedural guidance that illustrates an approach towards SDM tailoring in the complex business environment of resource management for New Product Development at DePuy. There was, therefore a gap in research and an identified need for an approach that provides the appropriate level of support for SDM tailoring for the development of systems in this complex business context.

Utilising the knowledge gathered within DePuy Orthopaedics, as well as from literature in the field, methods for managing business related complexities in system development were established, developed, and formalised into an approach that addressed the tailoring of SDMs. The approach was influenced by the critical evaluation of DePuy's complex business context which aided in the creating and application of the approach.

The approach was validated through its application in a business context, where it was used to develop a tailored methodology for use in developing and implementing a resource management IT system at a portfolio level. The validation proved the approach was legitimate and produced a methodology and subsequent system which were readily adopted and accepted by the company. Furthermore, the tailored methodology was evaluated by industrially based engineers with experience of systems development in a complex business context, resource management and systems engineering. From this evaluation, it was established that the tailored methodology was sound and can be said to be valid in the context that it was developed.

Acknowledgments

This thesis is the culmination of nearly 7 years of hard, and often frustrating work, on behalf of both myself and number of very lucky individuals who were involved with my research. At the start of my research "journey", I was very much the expectant and joyful new recruit, eager to make an impression and to do well. I can now say I am a battle weary, well-formed and thoroughly grown up individual who can barely believe the change that has occurred over this period of time. A change I am very proud and happy to say has occurred.

Although I would very much like to take full pleasure in presenting this work as my own, I cannot deny that I have had a lot of help along the way. My single name may be on the cover page but it has been through the guidance and cooperation of a number of other individuals. In particular, I would like to thank my DMEM supervisor Ian Whitfield, who was been my mentor, friend, colleague and slave driver. Without whom I very much doubt I would have got this far, to you I am eternally thankful. I would also like to thank my other DMEM supervisors/advisors Kepa Mendibil and Alex Duffy who guided me and offered much needed advice throughout my research journey. I especially would like to thank DePuy Orthopaedics for their continued support and cooperation. In particular Dexter Corbin, John McCabe and Neville Turner, who gave up their time and resources to aid me in my research and without whom this research would never have come to light.

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1 Introduction

An important factor when considering the success of a system development project is the approach which is taken towards its development (Royce 1970). Therefore, a requirement of system development projects, to facilitate success, is the utilisation of an appropriate methodology. When considering the use of a system development methodology, it is necessary to understand the steps to be carried out through the course of the project and the considerations that need to be made. Without this systematic method for the development there is potential for the system provided to become miss-directed and ill-defined (Royce 1970, Ulgen 1991, Nordgren 1995).

Currently, existing un-tailored system development methodologies illustrate a lack of awareness of the considerations required when developing and/or implementing systems in complex business contexts, as well as their potential impact on the success of the system. This has been shown in particular with the research presented in this thesis regarding resource management system development in NPD business contexts. This lack of awareness shown in un-tailored system development methodologies is experienced through the omission, underutilisation, or the use of highly implicit language; relating to a number of key considerations important in the development and implementation of systems within a business context.

As a result, the tailoring of methodologies is commonplace in the vast majority of software development projects and organisations (Fitzgerald, Hartnett et al. 2006). Tailoring is a widely accepted approach to ensure the methodology utilised in system development is applicable within the context it is being utilised (Russo, Wynekoop et al. 1995). However, there is little guidance in literature and standards that suggest a process by which a business would achieve an appropriate tailored methodology. This is especially hard to achieve when dealing with a complex business context where uncertainty is commonplace, such as resource management in NPD businesses.

To address this knowledge gap, it is proposed in this thesis that an approach to system development and implementation utilising methodology tailoring is created. This approach will take into account the complexities within the business context that may affect the acceptance, adoption, and sustainment of the desired system. The research will utilise the area of resource management in NPD businesses as an example of a complex business context due to the complexity and uncertainty experienced in this domain. This will be illustrated through the use of a case study within DePuy Orthopaedics.

The intention of such an approach would be to provide a systematic and repeatable process for the tailoring of methodologies. The approach will enable businesses and developers to take into account a wider range of influencing considerations than have not been incorporated in system development methodologies commonly utilised in the development of systems. The approach will improve the level of acceptance, adoption, and sustainment of systems developed for use in a business context. This will be achieved by providing explicit guidance to developers when managing the complex interaction between the business context and the system development process.

1.1 Scope and contribution to knowledge

The research reported in this thesis, and therefore the significant contribution to knowledge achieved, is the creation of an approach to system development and implementation utilising methodology tailoring. The approach aims to improve the acceptability, adoption and sustainability of the systems that it produces by taking into account contextual development/implementation considerations evident within the complex business context that will influence system development.

This research was undertaken within DePuy Orthopaedics, a Johnson & Johnson company, who are a NPD company that specialise in the design and manufacture of hip, knee, and extremity implants. The boundary of the research is as follows:

Domain – Complexity and Uncertainty

The work presented in this thesis is directly focused on the tailoring of system development methodologies for use in complex business contexts. High levels of uncertainty and complexity are commonplace within many businesses. This can be attributed to a number of reasons; such as the highly innovative nature of the project work carried out or the size and structure of the business unit. The complex and uncertain business context impacts on system development as it is unclear how systems should be developed and implemented to ensure adoption, acceptance and sustainment. The tailoring approach demonstrated in this thesis will guide developers within these contexts to tailor system development methodologies that will aid in the management of complexity and uncertainty.

Context – Business based systems and their development

The research work focuses on the process of system development and implementation within businesses, which is primarily governed by developers and managers and the decisions they make. Systems that support decision-making are key in supporting managers' efforts and are therefore highlighted throughout the work. The tailoring approach developed in this research will be utilised in a complex business context, however, the tailoring approach can be generalised to be applicable to the development of systems in any business setting.

Approach – Systems Engineering

Systems theory and engineering is utilised in the management of complex problems as it promotes a holistic and top-down understanding of a system and its interactions. It is clear that this approach/philosophy would benefit the method of the research due to the complex nature of the context and knowledge to be developed. Therefore, the research will utilise systems theory and systems tools throughout to aid in all aspects of the research. The application of systems theory and its associated tools set in this field of research is seen to be novel and will add to the originality of the research.

1.2 Aim and Objectives

The aim of this research is to create an approach for the development and implementation of systems in a complex business context through the use of methodology tailoring. This approach will enable system developers to tailor a system development methodology to the complex context within which it is expected to be utilised.

1.2.1 Objectives

In order to realise the aim of the research, a number of objectives were identified.

The objectives identified are as follows:

- (O1) Choose and apply an appropriate research methodology and design the research with respect to this. Utilise systems engineering principles to ensure the research is carried out in a systematic and repeatable manner fitting of systems engineering research. (**Achieved in Section 2**)

- (O2) Identify research focus through a critical review of literature:

    - (O2.1) Detail questions to be answered through the review of literature and structure the review accordingly (**Achieved in Section 3.1**)
    - (O2.2) Review literature in the field of system development in relation to the research questions set (**Achieved in Section 3.2**)
    - (O2.3) Frame research problem and prove its novelty and place within the state of the art (**Achieved in Section 3.3**)

- (O3) Create and document an approach to the development and implementation of systems in complex business contexts utilising methodology tailoring:

    - (O3.1) Develop and formalise an approach that addresses complexity and takes into consideration system development influences that may affect the acceptance, adoption, and sustainment of the resultant system. (**Achieved in Section 4.1 and 4.2**)
    - (O3.2) Apply the tailoring approach in a business context i.e. DePuy Orthopaedics, where it will be utilised to develop a tailored methodology for use in developing an IT system for use in NPD resource management at a portfolio level. (**Achieved in Section 4.2**)

- (O4) Validate the tailoring approach through the application of the tailored methodology produced within a complex business:

    - (O4.1) Apply tailored methodology within business context to deliver a resource management system for use in DePuy Orthopaedics. (**Achieved in Section 5**)
    - (O4.2) Assess success of the system delivered in its ability to fulfil the requirements of the business (**Achieved in Section 5.5.6**)
    - (O4.3) Discuss the limitations present in the business contexts when applying the tailored methodology (**Achieved in Section 5.6.1**)

- (O5) Evaluate tailoring approach through external assessment of the tailored methodology:

- O5.1) Evaluate tailored methodology with respect to its ability to produce desired results with external experts. (**Achieved in Section 6.1**)
- (O5.2) Identify strengths and weaknesses of the tailored methodology based on its evaluation. (**Achieved in Section 6.1.2**)
- Ascertain the tailored methodology's ability to produce valid results that will either substantiate or disprove the findings from O4 (**Achieved in Section 6.1.2**)

1.3 Thesis structure

The research discussed in this thesis is organised in three parts, which are listed below:

Part 1: Research problem formalisation (Sections 2 & 3)

Section 2 will provide a consideration of the different research methodologies available; discussing their strengths and weaknesses. The context of the work being undertaken will be discussed, with particular reference to the use of systems engineering, as well as the type of knowledge being created. This will be utilised in the selection of the most appropriate methodology, illustrating the rationale behind the choice.

Section 3 will review literature in relation to system development in an effort to answer the research questions set by the researcher. The review will attempt to highlight a gap in current knowledge that will focus the direction of the research. This gap will be assessed for its novelty and will place the research within the state of the art.

Part 2: Approach and findings (Sections 4 & 5)

Section 4 will discuss the development and application of the tailoring approach proposed as the primary contribution to knowledge within this research. A summary will firstly be given, then the Section will go into detail as to how the approach was developed and applied to achieve the outcomes that were delivered.

Section 5 will discuss the work that was carried out by the research through the application of the tailored methodology developed in Section 4. The outcomes from the application of the tailored methodology will be discussed in detail, providing insight into the validity of the approach taken towards its development. This will aid in ascertaining the validity of the tailoring approach and its ability to produce fit for purpose tailored methodologies.

Part 3: Evaluation and discussion (Sections 6 & 7)

Section 6 will further validate and evaluate the tailoring approach through an external review of the tailored methodology produced for use in DePuy. This assessment will provide further understanding of the validity of the tailoring approach external to the context within which it was developed. The section will then go on to discuss the quality of the research and the application of the research design, highlighting any deviations and limitations that were experienced in the practical application of the research.

Section 7 will conclude the thesis with an overview of the contribution to knowledge that the research has delivered, from both a declarative and procedural standpoint, as well as from a contribution to practice and theory standpoint. This section will also discuss any limitations of the research conducted, further development requirements, and personal reflections of the researcher.

1.4 Definition of Key Terms

To ensure clarity in the discussion that follows, a number of key terms utilised throughout the research will be defined. The terms that have been chosen for definition are those that are utilised in key areas of the research or define the contribution that will be made.

Complexity

Complexity is generally used to describe something with many parts where those parts interact with each other in multiple ways, culminating in a higher order of emergence greater than the sum of its parts (Antunes and Gonzalez 2015). In the context of this research, complexity relates to the manifestation of complications experienced within the business context that make it difficult for systems to be developed that fulfil their requirements and achieve acceptance, adoption, and sustainment.

Uncertainty

Uncertainty is a situation of inadequate information, which can be of three sorts: inexactness, unreliability, and border with ignorance (Funtowicz and Ravetz 1990). Uncertainty can be present due to lack of knowledge and also due to variability inherent to the system under consideration (Walker, Harremoës et al. 2003). Uncertainty in this context relates to the uncertain nature of complex businesses and the prevalence of uncertainties that constrain system development. It is necessary for these uncertainties to be understood and managed in order to provide a satisfactory system for use within the business context.

Methodology

In this context, the term methodology will relate to system development methodologies which are utilised to manage the creation and application of systems in business contexts. This can often be referenced as a lifecycle model, which is defined in ISO 15288 as "a framework of processes and activities concerned with the life cycle, which also acts as a common reference for communication and understanding" (Standards 2015). Primarily the term "methodology" will be utilised in this thesis when considering the processes and methods utilised when developing and implementing systems.

Approach

The word approach is defined in the Merriam-Webster dictionary as "a way of dealing with something : a way of doing or thinking about something" (Merriam-Webster 2015). In the context of this research, the term "approach" will be utilised when describing the procedural knowledge developed in relation to the tailoring of methodologies for use in complex business contexts.

Tailoring

Within the context of this research, "tailoring" will refer to the process of adapting existing system development methodologies and principles to fit the complex business context (Fitzgerald 1998). Tailoring will involve utilising influences within the business context to adapt and change existing processes, methodologies, and methods so as to produce a business context specific solution.

Part one: Research problem formalisation

2 Research methodology

It is well known that the research problem will dictate the approach and methods utilised in the research (Olkkonen 1993). For this reason, it is essential that the correct methodology is applied to the specific problem under examination. In this instance, the problem being researched is the creation of an approach to system development and implementation within complex business contexts utilising methodology tailoring. As discussed in Section 1, this is a complex problem that requires an accumulation of various types of knowledge to develop a relevant solution for use within a business environment. The production of a tailored methodology needs to ensure that a number of influencing factors and requirements are incorporated to ensure that it is successful in its application. For example, the tailored methodology will need to provide developers with a systematic approach to system development; it will also need to include system development and implementation influences critical to successful system development. Overall, the tailoring approach needs to provide the means by which a business would tailor methodologies to deliver a system that is aligned with their business context. This will in turn provide a system that the business want, need, and can realistically sustain, minimising the likelihood that the system suffers from poor adoption. Therefore, the research methodology utilised has to address these needs to ensure that it is well matched for the research problem under examination.

This Section will firstly discuss research philosophies that will highlight how the research fits in with these philosophies. The Section will then go on to examine a selection of research approaches with a view to identifying their strengths and weaknesses and overall their appropriateness for use in the research. This will be utilised to aid in the selection of the most appropriate approach and highlight the rationale for this choice. The Section will conclude with an overview of the research design where the structure of the research will be discussed, giving the main stages of the research.

2.1 Knowledge development

The type of knowledge that will be produced in this research will be predominantly procedural knowledge i.e. knowledge utilised in the performance of a task or how to best perform a task. In this case, the task under consideration will be the tailoring of system development methodologies to take into consideration complex contextual factors. The knowledge will refer to how to carry out this task to ensure a tailored methodology is produced that will create alignment between the business context and the system developed, reducing the likelihood for poor adoption.

Procedural knowledge is dependent on the task being undertaken and is not as general as other types of knowledge, such as declarative knowledge, which is factual knowledge i.e. knowing that something is the case (Berge and Hezewijk 1999, Ullman 2004). This will mean that the knowledge created in this research will be limited in its application. For example, it may only apply to the tailoring of system development methodologies for use in complex business contexts, and not for the tailoring of methodologies for the development of systems for use on a personal/individual basis. Another associated issue with the development of procedural knowledge is that it can be harder to describe than declarative knowledge due to the fact that it often involves implicit learning which can be difficult to verbalise (Berge and Hezewijk 1999, Ullman 2004). Therefore, great care must be taken in the description of procedural knowledge, particularly in the discussion of its development, to ensure a logical and rigorous explanation is provided.

The research will also develop declarative knowledge through the identification of a number of considerations required in the development of complex systems in a business context. This knowledge will be utilised in the development of the procedural knowledge. The knowledge will be derived through research within DePuy as well as literature, and will be utilised as an input to the tailoring process. Although the consideration will be specific to DePuy, they will provide insight into system development and implementation within complex business contexts when considering resource management systems. Therefore, in this context the considerations identified can also be considered as a contribution to knowledge.

2.2 Systems engineering/thinking

The research is dependent on the use of systems engineering, both in the viewpoint taken towards the problem, and in the selection of methods towards the activities within the research. Although systems engineering and systems thinking are related, they are not the same thing, where systems engineering deals with the creation of new systems and the modification of old ones, systems thinking deals more with the application of systems concepts to a situation to understand a certain circumstance (Pahl, Beitz et al. 1996, Checkland 2000, Senge 2006). This research utilises systems thinking to tackle a complex problem and is not seen to be a “traditional” systems engineer research project.

The application of systems thinking in a systematic and repeatable manner can be seen as a systems approach (Pahl, Beitz et al. 1996, Checkland 2000). As systems thinking can be described as being more problem specific and a situational based manner of tackling a problem, it can be said that systems thinking is more applicable to the particular problem specified within the research, rather than traditional systems engineering. This is due to the context that the research is based in i.e. system development in complex business contexts, which is a situational and complex problem with a number of interacting elements that need consideration. Also, since traditional systems engineering lies in the technical domain and is commonly applied to the production of highly complex technical systems, such as aeroplane parts or electronics, it is not as commonly applied to the softer domains, such as management science (Pahl, Beitz et al. 1996). In this research, the system under investigation can be described as a softer system, in comparison to that of electronics or avionics, with very different types of complexity evident within it. For example, human factors, cultural issues and strategic vision replace complexities such as the movement of fluids, computer programmes, and failure modes. Therefore, a softer and more flexible manner at looking at the research is required, where systems thinking, as well as tools and techniques can be applied.

The use of a systems approach is highlighted by Kim (1995), Waring (1996) and Senge (2006), as being appropriate as the problem cannot be solved by breaking it down into its individual elements and finding a separate solution for each single element, the most effective way of solving a problem is by being able to see the whole picture (Kim 1995, Waring 1996, Senge 2006). This rationale is relevant as some problems within complex systems, such as system development, can stem from the structure of the system itself and not actual problems within them (Senge 2006). Utilising a systems approach towards the problem addressed in the research will ensure that the problem is seen as a whole and managed in such a fashion.

2.3 Research Philosophies

Research philosophy can be defined as the development of research knowledge and its nature (Saunders and Thornhill 2007). Research philosophy is also commonly referred to as research paradigm (Krauss 2005), which is defined by Cohen, Manion and Morrison as the broad framework, which comprises the perception, beliefs and understanding of several theories and practices that are used to conduct research (Cohen, Manion et al. 2007). Easterby-Smith et al proposed three reasons why the examination of research philosophy may be an important task for researchers to carry out when considering the design of research (Easterby-Smith, Thorpe et al. 2002). They stated: "the examination of philosophy can help researchers to refine and identify the research methods they can utilise in their research; knowledge of research philosophy will enable the researcher to assess different methodologies and methods and avoid inappropriate use; and, it may help the researcher to be creative in the selection and/or the adaptation of methods that may have previously been outside their knowledge". These reasons highlight the need and positive outcomes that can be achieved when research philosophies/paradigms are carefully considered; therefore, it is in the interest of the research project that this is carried out when considering the design of the research proposal.

Crotty (1998) suggests that in designing a research proposal we must consider four questions (Crotty 1998):

- what **epistemology**, theory of knowledge embedded in the theoretical perspective, informs the research;
- what **theoretical perspective/philosophical stance**, lies behind the methodology in question;
- what **methodology**, strategy or plan of action that link methods to outcomes, governs our choice of methods; and,
- what **methods**, techniques or procedures, do we propose to use

These four questions illustrate the levels of decisions that are involved in the design of research and how the choice of a research methodology, and hence the research methods, can be influenced by the knowledge being created as well as the philosophical viewpoint assumed. Gray (2004) backed up this concept by stating that the choice of a data gathering method is influenced by the research methodology employed; the research methodology is influenced by the theoretical perspective adopted, which in-turn is influenced by the epistemological stance adopted by the researcher (Gray 2004). The four questions proposed by Crotty (1998) were adapted and added to by Gray (2004) to illustrate this relationship as well possible selections for each category, as shown in Figure 1.

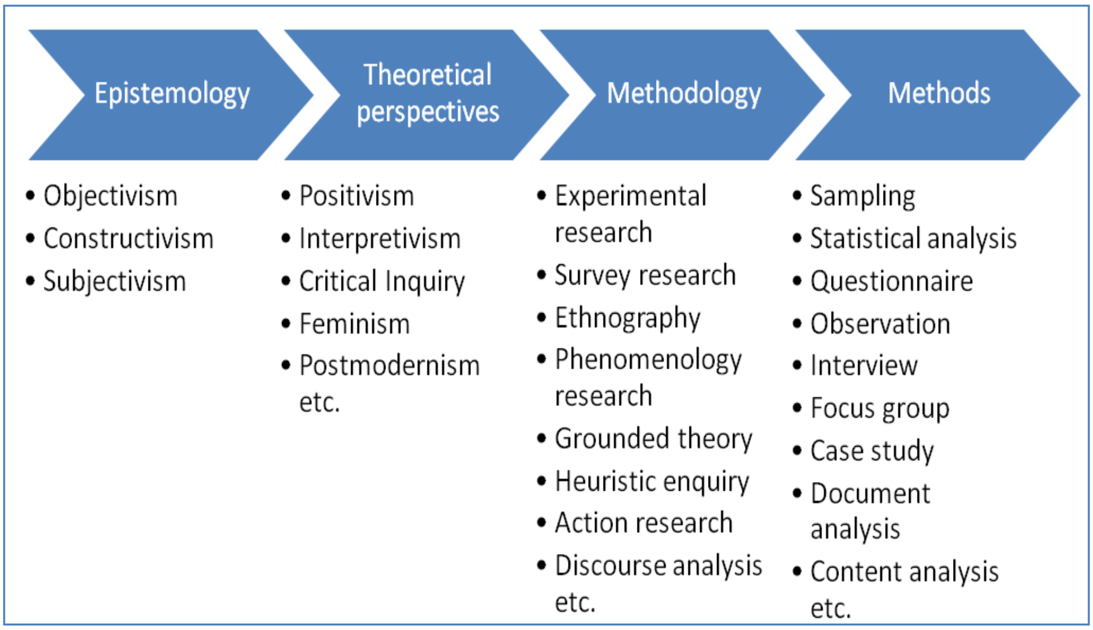

Figure 1 - Relationship between epistemology, theoretical perspectives, methodology and research methods (Gray 2004)

The four categories described in the questions proposed by Crotty (1998) and the description by Gray (2004) are commonly utilised by researchers in defining, describing, and evaluating the range of research philosophies that exist. These terms can be easily misunderstood and are often inconsistent or even contradictory within literature in the field (Gray 2004). In general throughout literature, the philosophical stance/perspective (otherwise referred to as the "ontological perspective") refers to the nature of reality assumed; epistemology refers to the nature of knowledge which is being created; methodology is the strategy or plan towards the research (sometimes referred to as an approach), and finally methods are the tools and techniques utilised (Gray 2004).

Due to the relationships between these concepts and also the array of possibilities for a researcher to choose from, the design of research can become a complex task (Gray 2004). It is therefore necessary to explore the range of theories available in order to establish where and how the research fits with respect to these concepts. This will enable the researcher to effectively position their research and clearly justify the choices made in relation to the methodology and the associated methods applied in the research.

It is in the interest of the research that a review of available research philosophies is undertaken, with the aim of assessing the appropriateness of these philosophies to create the type of knowledge outlined in Section 2.1. Research philosophies can be broken down into two main groupings i.e. positivism and post-positivism (Collis and Hussey 2009, Kumar 2010). These groupings have a number of differing names within literature, as well as sub groupings, as illustrated by Gray (2004). For example, these main groupings are also commonly referred to as Positivistic and Phenomenological (Collis and Hussey 2009), Positivistic and Interpretivism (Gray 2004), and Positivistic and Social Constructivism (Easterby-Smith, Thorpe et al. 2002). In general, positivistic research assumes that two independent researchers can arrive at the same conclusion using the standard research methods to study a phenomenon (Bryman 2001). This therefore deals with precise measurements whereas post-positivistic research stresses the subjective aspects of human activity by focusing on the social reality hence the meaning rather than the measurement of a social phenomenon (Collis and Hussey 2009).

Positivism is often criticised for being over simplistic and has a tendency to lose any meaning of results gained due to the reductionist approach that it adopts i.e. cutting systems down into their smallest parts and studying them in isolation (Creswell 2003). However, Positivism is generally accepted as the best possible approach for understanding causal relationships between a small number of well-defined constructs (Easterby-Smith, Thorpe et al. 2002). On the other hand, Post-positivism has been disapproved of as it has been seen to develop theory that is too specific to the individual cases, therefore the meaning of the research is lost as well as the potential practical implications which it may have. Nevertheless, Post-positivism is found to be vital in understanding the in-depth nuances, relationships and meanings of phenomena in specific cases (Easterby-Smith, Thorpe et al. 2002).

These two groupings illustrate the two extremes of the research philosophies available; there is however middle ground where these philosophies meet. Creswell (2003) proposed that at a high level there are essentially three main types of approaches to research i.e. Qualitative, Quantitative and Mixed methods (Creswell 2003). Positivistic research promotes a deductive quantitative approach and post-positivistic promotes an inductive qualitative approach, however mixed methods can be described as a combination of the two. In a mixed methods approach, researchers tend to apply pragmatic principles where the problem is seen to be more important that the method utilised. Pragmatism has been illustrated to be one of the most appropriate philosophical approaches that advocate the need for mixed methods research (Johnson and Onwuegbuzie 2004). Pragmatism is not committed to any one philosophy or reality, researchers have the freedom to choose the methods, techniques and procedures of research that best meet their needs and purposes (Creswell 2003). The goal of mixed methods research is not to replace either of the quantitative or qualitative approaches but rather to draw from the strengths and minimize the weaknesses of both in a single research study (Johnson and Onwuegbuzie 2004). Taking a mixed position allows researchers to mix and match design components that offer the best chance of answering their specific research questions (Johnson and Onwuegbuzie 2004).

A consequence of mixing methods is that triangulation can used, which can be defined as the use of a variety of methods or data sources to examine a specific phenomenon either simultaneously or sequentially in order to improve the reliability of data (Gray 2004). A pragmatic mixed method approach encourages the between method, methodological triangulation (Gray 2004), where a variety of methods are used, for example quantitative data from a survey and qualitative data from observations.

Table 1 summarises the main characteristics of the three research philosophies discussed in this Section from the four aspects utilised by Crotty (1998) i.e. ontology, epistemology, methodology and methods. The pragmatic approach to research rejects the idea of reductionism (Johnson and Onwuegbuzie 2004), where a problem is reduced to its smallest pieces and studied in isolation, and it is therefore more in line with the ideas held by systems engineering, where a problem is best addressed as a whole. Also, the pragmatic approach advocates the need to hold multiple viewpoints, as it does not prescribe to one philosophy of reality, it believes this adds value to the outcomes of the research. This is also mirrored in systems engineering where multiple viewpoints of a problem are encouraged to improve insight.

One other aspect of pragmatism which makes it more appropriate for the research is the fact that it does not limit the researcher to what type of methods they may utilise, opening up many possibilities and providing the flexibility which may be required when conducting research in a business context. For these reasons stated, it can be said that the pragmatic approach to research more appropriately fits with the systems engineering/thinking context of the research work over positivism or post-positivism.

	Positivism	Post-Positivism	Pragmatism
Epistemology	Knowledge and facts are objective obtained through observation and best understood through reducing the problem into smaller parts	Knowledge and facts are subjective and cannot be understood in isolation but as a part of an inter-related whole	Knowledge is viewed as being both constructed *and* based on the reality of the world we experience and live in. Generally, rejects reductionism
Ontology	Reality exists independent of human behaviour	Multiple realities which are subjective and mentally constructed by individuals	Is not committed to any one philosophy or reality
Methodology	Quantitative	Qualitative	Mixed
Methods	Deductive approaches	Inductive approaches	Triangulated and Mixed

Table 1 - Research philosophy summary

The knowledge that is being created in the research will be primarily procedural, relating to the development of an approach to methodology tailoring, which will be based on declarative knowledge, relating to the requirements for developing complex systems in a business context. Both these types of knowledge cannot be described as being objective due to the fact that they are created through the experiences the researcher has with the outside world, ruling out the appropriateness of positivism. Therefore, the knowledge being created is more in-line with the post-positivistic view that knowledge is subjective and constructed by individuals, who may have different viewpoints. However, this view of knowledge promotes the use of a qualitative inductive approach, constraining the research to a set of methods that may limit the potential creativity required when considering the development of procedural knowledge. As procedural knowledge can be complex and very difficult to both develop and describe, when compared to declarative knowledge, it requires a degree of flexibility in the methods that can be applied, promoting a higher level of creativity. The pragmatic approach does not constrain itself to one philosophical view or set of prescribed methods, therefore the options and potential for creativity in developing procedural knowledge are widened, making the development and description of this knowledge much more straightforward.

For the reasons discussed in the previous paragraphs, it can be said that the pragmatic approach to research has been found to be the most appropriate, from both a systems engineering/thinking standpoint as well as the knowledge that is being generated. Therefore, the research will adopt a pragmatic mixed methods philosophical standpoint towards the research.

2.4 Research Methodology

Having established that the research will follow a Pragmatic Mixed Methods philosophy, it is necessary to define the stages and structure the research will adopt. This Section will therefore firstly review the potential approaches the research may adopt and discuss their strengths and weaknesses. From this review and from the consideration of how well each approach matches the requirements of the knowledge being created, a choice of the most appropriate approach will be established.

2.4.1 Review of potential methodologies

The research methodologies were selected due to their potential appropriateness for application in the research, with respect to knowledge that will be developed, discussed in Section 2.

Therefore, methodologies that adhere to the following criteria were considered;

- Includes the user/host company as part of the development
- Promotes a systematic and holistic view of the system of interest
- Addresses practically relevant problems in a pragmatic fashion
- Does not promote a strictly qualitative or quantitative tools set
- Ensures rigorous and valid research outcomes
- Will support the development of procedural and declarative types of knowledge

The approaches that were found to potentially fit these criteria were: action research, construction, and case studies. Therefore, these potential approaches will be reviewed in the following Section.

2.4.1.1 *Action research*

Action Research (AR) can be described as an approach to research that aims to both take an action and to create knowledge or theory about that action. The central idea of AR is that it utilises a scientific approach to study the resolution of important social and organisational issues together with those who experience these issues directly. Also AR aims to make an action more effective while simultaneously building up a body of scientific knowledge (Coughlan and Coghlan 2002). Brydon-Miller et al. (2003) supported the use of AR and stated that "theory can and should be generated through practice" and that "theory is really only useful insofar as it is put in practice focused on achieving positive social change"(Brydon-Miller, Greenwood et al. 2003).

The AR approach challenges the traditional positivistic view of knowledge, which states that in order to be credible, research must remain objective and value-free. Instead AR embraces the notion that knowledge is socially constructed (Brydon-Miller, Greenwood et al. 2003). AR is generally considered as being appropriate when the research at hand relates to the description of a series of events occurring over time within an organisation with the aim being to understand how a particular intervention can change, or improve, the operation of the system under investigation.

The practice of taking an AR approach works through a cyclical four step process of consciously and deliberately: planning, taking action, and evaluating the action, leading to further planning and so on (Coughlan and Coghlan 2002). Zuber-Skerritt (2001) backed up this vision of AR and described it as "spiral of cycles" where the learning and reflection from previous cycles was utilised and built on in following cycles.

As the research is based in a company context, there will be a high degree of interaction between those experiencing the system under investigation and the researcher, therefore AR can be seen as a rational and easily implementable research approach. As previously discussed the research is primarily focused on the development of an approach to methodology tailoring i.e. procedural knowledge, AR in this context would have to aid in the development of this type of knowledge. The business context has established only requirements relating to system development and not the associated tailoring approach required to develop a tailored methodology, which was later found to be essential to the development of such a tool. This will mean that AR is not appropriate for the creation of the procedural knowledge in this case and context, due to the fact that the business context will interact on the basis of tool building and not tailoring approach building, which will occur at a higher level. However, scope exists for the use of the AR approach for the implementation and therefore testing/evaluation of the tailored methodology in the business context. In the case of the development of the declarative knowledge, i.e. the key considerations required when developing a complex system in a business context, AR would also be seen as being inappropriate, mainly because AR operates by implementing a change and then assessing the effects of this change, for the purpose of learning. It therefore aims to describe a series of events and not to provide declarative facts from which procedural knowledge can be based.

2.4.1.2 *Construction*

The constructive approach to research can be described as problem solving through the construction of models, diagrams, plans, and organisations (Kasanen, Lukka et al. 1993). Constructive research is primarily focused on the development of solutions, which are aimed at tackling a particular problem. For example in medicine, construction research can be utilised to produce new pharmaceuticals, or in business the creation of a new budgeting system (Kasanen, Lukka et al. 1993). Construction can therefore be described as "the development of a theoretical solution derived from the researchers understanding, practical experience and theory, which is utilised to propose a solution to the problem that is then tested" (Kekäle 2001). The constructive approach promises that the resulting new theory will be "relevant, easy to implement and simple" (Kasanen 1991), which adds to the popularity of the utilisation of this approach.

Construction research is commonly utilised in technical sciences, mathematics, operations analysis, and clinical medicine, where problems are solved through innovative thinking (Kasanen, Lukka et al. 1993). A key aspect about construction is how it differs from conventional problem solving in the fact that it aims to tie the problem and its solution with an accumulation of theoretical knowledge (Kasanen, Lukka et al. 1993). Constructive research may be viewed as a type of applied study, where the production of new knowledge is key, this is distinguishably different from basic studies that aim to increase understanding of already known circumstances (Kasanen, Lukka et al. 1993). Kasanen et al proposed six main stages which constructive research should progress through (Kasanen 1991);

- Find a practically relevant problem which has research potential
- Obtain a general and comprehensive understanding of the topic
- Innovate i.e. construct a solution
- Demonstrate that the solution works
- Show the theoretical connections and the research contribution of the solution
- Examine the scope of applicability

Kasanen and Lukka et al. stated that in the process of construction, the innovation phase is the core element of a successful study, due to the fact that if no new solution can be generated there is no point to carrying on with the research. They claim that to ensure quality, the outcomes of constructive research should: be relevant; simple and easy to use; possess practical relevance; have practical utility; be proven to be useful; be theoretically novel; be linked to theory; and; be applicable in other environments, demonstrating the "generalisability" of the research outcome(s)(Kasanen, Lukka et al. 1993).

When considering the production of declarative knowledge, the constructive approach deals with this in the second of the six-stage process; obtaining a general and comprehensive understanding of the topic. Due to the high-level nature of the approach, this stage can be interpreted as the point at which knowledge is either gathered or created for use in later stages of the process. The approach then goes on to the next stage; innovate - construct a solution, where the knowledge gained in the previous step can be utilised. In the case of this research, this stage would be where the methodology is developed i.e. the procedural knowledge. As the procedural knowledge is the primary knowledge claim of the research, it would be correct to make this the focus of the approach, where the innovative aspects of the work are highlighted. Therefore, the production of both declarative and procedural knowledge can be supported through the utilisation of the constructive approach, as well as the validation and evaluation of the knowledge through the assessment of its application.

2.4.1.3 *Case study*

Stake defined a case study as a study in which a researcher explores in depth a programme, an event, an activity, a process, or one or more individuals. The cases(s) are bounded by time and activity, and researchers collect detailed information using a variety of data collection procedures over a sustained period of time (Stake 1995).

Once the purpose and structure of the case study are understood, the next stage is to design and conduct the case study itself. Eisenhardt (1989) tackled this issue through the development of a framework for carrying out case study research outlining a step-by-step approach. The framework describes the key steps involved in the process and the activities required to complete each step, as well as providing the reasoning behind conducting the activities discussed (Eisenhardt 1989). The aim of using such a framework is to give guidance towards the stages and steps required as well as to contribute towards the overall research quality established through strengthening the constructs, evidence, theory and internal/external validity (Bititci and Ates 2008).

One strength of utilising the case study approach towards research is the increased likelihood the novel theory will be generated (Eisenhardt 1989). This is established through the process the researcher has to go through i.e. creating insight arising from often contradictory or paradoxical evidence, and creatively reframing it into a new theoretical vision (Eisenhardt 1989). However, a drawback of this is that such intensive use of empirical evidence can result in the development of overly complex theory that can be hard to understand and apply. Another drawback often found in utilising the case study approach is that the results can be described as being narrow and only found to be applicable in the context of the case under examination and there is, therefore, an increased emphasis on the need to establish external validity.

As the research to be carried out does not relate to the primary work function of that business context, there may be little scope to carry out the case study approach to develop the declarative knowledge required. In general, the case study approach may be an appropriate means of developing this knowledge if the context in which it was applied supplied the required knowledge. As the research does not have the facilities nor the time scale to branch out in this fashion, the case study method can be seen as inappropriate in developing the declarative knowledge element required by the research. Hence, a more appropriate method to develop this knowledge is required.

When considering procedural knowledge development, the case study approach may not be appropriate for the same reasons. There needs to be an innovative leap to develop new procedural knowledge which cannot be supported by the case study approach, which commonly deals with describing or building theory around events, occurrences or relationships. However, there is an option to utilise the case study approach as the means to validate the procedural knowledge, therefore adopting a “theory testing” approach. The case study would aim to prove whether the procedural knowledge added any benefit to the development of a complex IT system in a business context. For example, if there is a causal relationship between the application of the approach and the production of added value.

2.4.2 Research approach analysis and selection

In this Section, the three potential research approaches discussed previously will be reviewed in relation to their ability to fulfil the criteria highlighted at the start of Section 2.4. This will highlight the main aspects of the approaches and appropriateness, taking into consideration the knowledge development and the boundaries experienced within the research. The assessment will be carried out in a tabular form where key information for each approach, against each criterion, will be scrutinised. The outcomes from this analysis can be found in Table 2.

From Table 2 a number of key findings were established that will aid in the decision making when considering the most appropriate research approach to adopt. Firstly, all approaches discussed accommodated for the research to be conducted in a business context and also promoted a systematic process or a step-by-step repeatable manner to carry out the research.

The differences in the approaches were highlighted when considering how each approach addresses relevant problems, which is a key requirement when conducting research in a business context. For example, action research and case studies do not offer any direct advice to the researcher that a practically relevant question/problem should be tackled. This fact is either implicit or not considered in their processes. This is in contrast to the construction approach where this issue is highlighted as the starting point of the process.

	Action Research	Construction	Case Study
Includes user/host company	Business directly incorporated in research through collaboration	Not specifically specified in the approach but can be accommodated	Business directly incorporated in research as source for knowledge or application
Promotes Systematic and holistic views	Supported by a systematic cyclic approach	Promotes a step by step method towards problem solving with capacity to include holism	Well established understanding of systematic procedure provided in literature
Addresses relevant problems pragmatically	No guidance to what problem to solve, does not promote specific tool set	Explicitly refers to practical relevance and does not confine tool set	No guidance to what problem to solve, generally promotes a softer tool set
Ensure rigour and validity	Ensured through the adherence to cyclic process, struggles with generalisability	Issues highlighted and tested through examination against quality check list	Suffers from results being too narrow, is tested through construct, internal, external validity checks and reliability measures
Development of declarative and procedural knowledge	No opportunity for declarative knowledge or procedural knowledge development	Supports development of both declarative and procedural knowledge in the research context	No opportunity for declarative knowledge or procedural knowledge development in the research context, although supports the approach to testing procedural knowledge

Table 2- Research approach assessment

The contrast may be explained by the fact that the construction approach is more problem orientated and less inductive than the other approaches, which may assume the issue has already been found or it will be found through the application of the approach. When considering this issue, it is clear that the Construction approach is more appropriate as it promotes a top down, problem centric approach. Another issue highlighted in this area is the fact that the constructive approach does not adhere to any tool set, being hard or soft, qualitative or quantitative. This fact can also be said of the action research approach, whereas case study research tends to be more in line with the qualitative tool set. This highlights the fact that Action Research and Construction offer more flexibility and are therefore more attuned to the pragmatic research philosophy.

The key consideration is how the approaches support knowledge development. As discussed earlier in this Section, the research will develop declarative knowledge that will be utilised in the development of procedural knowledge. Therefore, the approach must be able to support this development in the business context within which the research will be conducted. Both action research and case study research fail to support the development of knowledge regarding the development of a methodology due to the fact that the business context in which this research will be based does not deal directly with developing approach to tailoring system development methodologies or systems for business use. Therefore, the business context alone cannot provide the required input to develop procedural knowledge through the use of relevant declarative knowledge. However, both these approaches provide interesting options when considering the application of the procedural knowledge in the business context. This is especially true with the Case Study approach, which could potentially be utilised to support the testing of the procedural knowledge in the business context. The only option that does support the knowledge development within the research is the Construction approach, where declarative knowledge is developed in the "Understanding" phase, and procedural knowledge is developed in the "Innovation" stage.

Taking into consideration all these facts, it can therefore be said that a Construction approach to the research is the most appropriate. It offers the correct support to the development of knowledge, is rigorous and can ensure valid solutions, focuses directly on relevant problems, does not promote or restrict the researcher to a single tool set, and offers a step by step repeatable approach which has the potential to include the host company in research efforts in the application of any knowledge generated through testing. Overall. the positive aspects of this approach outweigh any positives of the other approaches and will therefore be adopted in the research.

2.5 Research design and methods

Having discussed the research methodology being adopted, the research design was created. The research design describes the steps that will be taken and the associated methods that will be utilised.

Find relevant problem: The key method that will utilised in this stage of the research will be an exploratory literature review, backed up with industrial research conducted within DePuy regarding system development. The outcome from this initial review and company review will be an understanding of the problem area and the gap in knowledge that exists.

Research problem: Further research will be carried out regarding the gap in knowledge to ensure that knowledge proposed is novel and to place it within the state of the art. This will develop an understanding of the contributions the research is expected to make. The methods that will be utilised in this stage will be a critical review of literature specific to the problem highlighted in the first stage of the research.

Knowledge accumulation and development: Utilising an exploratory approach, the researcher will gain insight into the complex environment of DePuy Orthopaedics in an effort to gain understanding of the complexities evident when developing and implementing a system. This will involve Interviews, observation and direct participation of the researcher in DePuy's processes. This information will be used to generate research findings that will be utilised in development of the procedural and declarative knowledge required.

Validation and Evaluation; To ensure the knowledge developed is valid and also to provide DePuy with demonstrable benefits, the knowledge developed in the previous stage of the research design will be applied in DePuy's business context. Further to this, the knowledge developed will also be externally evaluated to further evaluate its validity.

The research methods that will be utilised will primarily be exploratory and critical literature review, company review through the use of interviews, observation and participation, as well as external evaluation.

3 Literature review

As a basis for understanding the domain problem, it is necessary to review existing literature in the areas of resource management systems and their development, particularly in the business environments such as NPD. This literature review will focus on the development of a basis of knowledge from which a research problem can be formulated.

3.1 Literature review methodology

To ensure that the literature review is conducted in a robust and logical manner, it is essential that a systematic approach is taken. The approach adopted in this review has been summarised in Figure 2. This shows how key search terms were identified and utilised to perform searches that were then refined. An amount of further reading was also done to embellish the discussion and analysis of the findings to formulate a problem statement, finally, the assessment of the novelty of the problem was carried out.

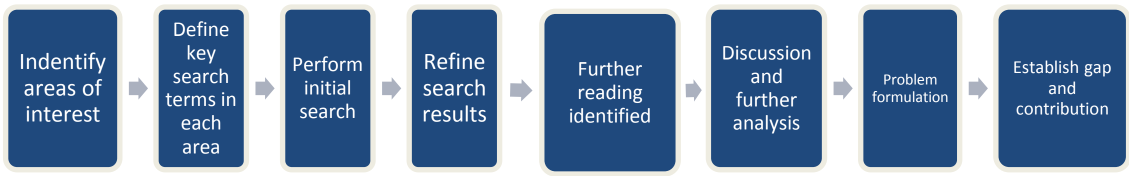

Figure 2 - Lit Review methodology

The goal of this literature review is to provide a critical discussion of the body of knowledge in relation to the research field and to establish a focus and gap in knowledge for the further development of the research contribution. The focus identified will be actively researched in a business context to provide a significant contribution to the field in question. Therefore, the areas of interest to be reviewed are summarised in the below questions;

Q1. What resource management systems are available and how do they support decision making in NPD business contexts?

Q2. What considerations impact the development of resource management systems in NPD business contexts?

Q3. What methodologies exist that support the development of resource management systems in NPD business contexts and how do they incorporate key considerations?

Q4. How are methodologies applied in an industrial context and how does this impact the development of resource management systems in NPD business contexts?

These high-level questions will allow the researcher to develop a deep and wide review of literature that will inform and add to the formalisation of the problem that the research will ultimately strive to address.

3.1.1 Search terms

The search for literature sources and information that will form the basis of this review was grounded by the use of a number of key terms. These key terms enabled the researcher to focus the literature search in areas that were found to be relevant when considering answering the above questions.

The terms used in search for literature for each question are as follows;

Q1. " new product development" and "resource management" and "decision support systems"
Q2. "resource management" and "system development" and "business context"
Q3. "system development methodology" or "system development lifecycle model" and "business context" or "New Product Development"
Q4. "system development methodology" and "utilisation or use" and "tailoring or modification"

To ensure that the review focused on good quality results and to maximise the relevance of the results returned, the search was focused on peer reviewed journal articles and conference papers. The search would include references found in the title and body of the text, published between 1980 to present day.

3.1.2 Search results

The search was undertaken using ProQuest; this enabled the researcher to search many publications consistently in one search across a number of topics and subject areas. ProQuest was selected as an appropriate database due to its wide-ranging coverage of subjects, ensuring a comprehensive and robust literature search. The searches were conducted per question and tailored, utilising the function within the search tool, to ensure relevant results were established.

Once the responses had been collected, the results were filtered to remove any papers from journals out with the scope of the review. This was achieved by initially reading each abstract to assess the paper's applicability, as a result of the initial review a number of the results were found to be unrelated and/or duplicated and were therefore removed. The remaining search results were read by the researcher from which it was possible to derive which results were of more relevance and utility than others, and what impact they would have on the progression of the research. The search outcomes from the search can be found in Table 3.

To ensure that a breadth of knowledge was discussed and represented in the review, an amount of further reading was required. This further reading was focused on developing the background knowledge or further developing themes presented in the initial search. The researcher carried out this search by firstly identifying areas of focus that required further investigation. From this further reading individual literature searches were conducted that provided specific required input for the review.

Question	Number of results returned	Number of relevant results
1	141	58
2	30	13
3	184	65
4	44	10

Table 3 - Search results

3.2 Literature discussion and analysis

The following Sections of the literature review will discuss and analyse the literature that was produced from this search, with an aim to answer the high-level questions. The analysis will aid the researcher in framing and establishing a basis from which the problem formalisation can be derived. As the research is based in a business context i.e. DePuy orthopaedics, reference to this will be made throughout the review, and will be used to analyse the applicability or influence this context may have on the research that has been presented.

3.2.1 Resource management systems

This Section of the literature review will focus on answering the following question;

Q1. What resource management systems are available and how do they support decision making in NPD business contexts?

By answering this question, the researcher will develop a greater understanding of what resource management systems exist and therefore what is available for use in a company context. From research of applied examples, the researcher will gain an understanding of the positives and negatives that may occur through the application of these systems. This information will aid the researcher to make an informed analysis when considering the use of such a system in the business context within which this research is based.

Resource management systems vary in many ways, often with differing focuses either on data, models, or communication. These systems also differ in scope, with some intended for a primary user and used stand alone, while others are intended for many users (Power 2002). With this wide variety, there is a clear issue with complexity, which is especially evident when attempting to review such systems. Complexity in this context refers to the complex nature of both the content held in the systems and the design, development and maintenance of the systems themselves.

To address this complexity there is a need to structure and categorise the tools and techniques under review into a taxonomy or framework, which will enable a better understanding of the applicability. This statement is supported by Sprague and Watson who argue that typologies, frameworks, or conceptual models are “often crucial to the understanding of a new or complex subject” (Sprague Jr and Watson 1996). It is therefore essential that the tools and techniques reviewed in this Section be well structured, with the aim of managing complexity.

One of the most referenced and highly regarded categorisation of Decision Support Systems (DSS) was proposed by Alter, which shows a spectrum of generic operations that can be performed by the DSS ranging from extremely data-oriented to extremely model orientated (Alter 1977). Alter's taxonomy assumes that DSSs could be categorised in terms of their operations, independent of the type of problem, functional area, or decision perspective (Power 2002).

The taxonomy was constructed through a field study where 56 DSS's were analysed, resulting in the identification of seven distinct types of DSS;

- **File drawer systems** – provides access to data items, such as values which are used straightforwardly to make a decision;
- **Data analysis systems** – support the manipulation of data utilising computerised tools tailored to a specific task and setting;
- **Analysis information systems** – provide access to and combines multiple data sources for analysis;
- **Accounting and financial model** – calculate the consequence of possible actions based on accounting information;
- **Representational models** – estimate consequences of actions on the basis of simulation models that include causal relationships;
- **Optimisation models** – provide guidelines for action by generating an optimal solution consistent with a series of constraints;
- **Suggestion models** – perform the logical processing leading to a specific suggested decision for a well-structured task such as credit scoring.

With respect to the problem area of resource management decision making, where a resource is a person who has skills to perform a task, it is important to assess wither the DSS categories highlighted by Alter are applicable when considering this context. This is particularly true when considering the 'Accounting and financial model' category which refers directly to accounting based measures, such as break even points and investment portfolios, which are not traditional dealt with in the management of human resources. It is also true when considering the "suggested models" category, which deals with highly structured and well-understood tasks where a logical answer is easy to obtain, which is in stark contrast to the problem of resource management. Therefore, these two categories will be omitted when considering the structuring of the reviewed knowledge. The categories of "File Drawer" and "Data Analysis" systems will also be omitted; as these systems are not specifically resource management systems. Their general nature will mean that resource management may be achieved through their use, but these systems being more general and not designed explicitly for that application. The outcome from this could be a false positive and the inclusion of speculative results when assessing that application to the context of resource management.

3.2.1.1 *Inclusion criteria*

The tools and techniques that will be reviewed will be formalised through the use of Alter's taxonomy but will be selected for inclusion based on their fit with a set of criteria. The aim of the criteria is to ensure only literature relating to relevant tools and techniques for resource management decision-making are reviewed. With this aim, the inclusion criteria were developed by the researcher in reaction to the area of focus that the research has established i.e. Resource Management systems in NPD business contexts. Four criteria were established that covered the main points of focus: IT, context, resources and decision-making. The outcome from this was the following criteria; implemented and utilised in an IT system; used in and applied in a business context; stores and/or manipulates resource data; and used to support the making of resource based decisions. The criteria have all the same level of importance and are listed in relation to the complexity of the function described, from highest to least.

Therefore, the systems that satisfy these criteria and are to be included will be:

- Analysis information systems
    - Enterprise resource planning
    - Skill/Capability management software
    - Project portfolio management tools

- Representation models
    - System dynamics simulation
    - Discrete event simulation
    - Agent based simulation
    - Hybrid simulation
- Optimisation models

3.2.1.2 *Analysis information systems*

An analysis information system can be described as providing users access to multiple data sources in a combined format that allows for comparisons to be made. With access to a number of different types of information, regarding the topic they are interested in, decision makers have increased ability to make more informed decisions. For example, a project manager may want to address a skill gap evident within their project team; they may then want to search to identify existing staff members with that skill set, as well as consider the cost this addition would realise in financial terms. They may also want to consider if it would be more cost effective to train an individual who is already a team member and then be able to identify the right person for this training. This type of decision-making requires information regarding staff members' skill sets, costing the allocation and training of staff to projects, and project budgets.

Enterprise Resource Planning

Enterprise Resource Planning (ERP) is an information system designed to integrate and optimise the business processes and transactions in a business (Moon 2007, Shaul and Tauber 2013). ERP systems are designed to address the problem of fragmentation of information or "islands of information" within a business context (Muscatello, Small et al. 2003). An ERP system is delivered as a packaged business software system that enables a business to manage the efficient and effective use of resources (materials, human resources, finance, etc.) by providing a total integrated solution for the business's information processing needs (Nah, Lau et al. 2001). Among the most important attributes of ERP are its ability to automate and integrate business processes, to share common data and practices across the entire enterprise, and to produce and access data in a real-time environment (Nah, Lau et al. 2001). ERP systems are comprised of a suite of software modules, with each module responsible for gathering and processing information for separate business functions(Muscatello, Small et al. 2003, Shaul and Tauber 2013). Software modules may include accounting, inventory, forecasting, finite scheduling, distribution planning, and others (Muscatello, Small et al. 2003).

Holsapple and Sena (2005) stated that ERP offers managers features that effectively support decision making, although decision support is not stated or explicitly recognised as a major reason for implementing an ERP system (Holsapple and Sena 2005). ERP provides decision support benefits mainly based on its integrated knowledge repository, which gives decision makers the means for enhancing knowledge processing, making more reliable decisions, making decisions more rapidly and gathering evidence in support of their decisions (Holsapple and Sena 2005). Although there are obvious benefits to implementing ERP from a decision support standpoint, there are several reasons why businesses may not be keen to invest in it. Trunick (1999) reported that 40% of all ERP installations only achieve partial implementation and nearly 20% are scrapped as total failures (Trunick 1999). It is clear that the implementation of ERP systems is not a simple matter of purchasing and installing the technology, considerations such as managerial issues, from planning to implementation, present major barriers to the effective adoption of ERP systems (Muscatello, Small et al. 2003, Tarhini, Ammar et al. 2015).

Melin (2010) presented a case called “the Engineering Firm” where the organising process and implementation and use of an enterprise system were discussed. The firm was a global supplier of production equipment and had a turnover of more than $200 million, and approximately 700 employees (Melin 2010). The enterprise system that was utilised by the firm was Movex supplied by Initia, one of the top ten ERP systems suppliers. Movex was seen by the engineering firm’s chief information officer as “organisationally ungainly, but at the same time indispensable” (Melin 2010). The main conclusions of the study where that the ERP system maintained and reinforced existing administrative organisational structures, enabling centralised control, creating norms and enhancing the power of actors (Melin 2010). What this case study highlighted was how organisations utilise these systems to concurrently search for both the flexibility to adapt and manage the current situation, as well as to mitigate and adsorb uncertainties to maintain a stable competitive advantage (Melin 2010). It also highlighted how ERP systems are an all-encompassing IT infrastructure that is utilised in all areas of a business, from R&D through to the supply chain and sales units.

Another case study of ERP implementation that provides insight is the application within Rolls-Royce, described by Yusuf, Gunasekaran et al. (2004). Before ERP, Rolls-Royce used over 1500 systems, many of which were developed internally over the last two decades. These legacy systems proved expensive to operate and maintain, and did not provide accurate, consistent, and accessible data that was required for high-quality and timely decision making (Yusuf, Gunasekaran et al. 2004). Rolls-Royce adopted a phased approach to the introduction of ERP and encountered a number of cultural, business, and technical problems along the way, such as poor acceptance and interoperability issues. The end result was the implementation of a three suite system which managed the business process from supply chain down to the factory operation (Yusuf, Gunasekaran et al. 2004). The system architecture for the integration of these three suites is very complicated and involves the core business operations supported by the ERP software, such as finance, programme management, human resource, product and process development, supply chain planning, procurement and inventory sourcing, and order management. The full benefits of the implementation of the system were not expected to be experienced until the system becomes stable and users have had time to adjust to new working practices. However, the immediate results such as the ability to promise and deliver to customers on time may be visible (Yusuf, Gunasekaran et al. 2004). Rolls-Royce believe that the ability to deliver on time will improve customer satisfaction and improve confidence, leading to an increase of orders in the future. What this case study highlighted was the potential that can be sought by companies who successfully plan and implement ERP on a large scale within their business, taking into consideration the possible problems that could arise.

ERP has had both positive and negative impact regarding its implementation, although clear positives regarding decision support are attainable. What has been made clear is the complexity and level of integration the ERP brings; this is shown through the business wide application most ERP systems achieve. For smaller less integrated companies, the application of ERP in this manner would be extremely daunting, resulting in smaller companies only opting to take on smaller ERP sections rather than a company-wide approach (Muscatello, Small et al. 2003).

Skill/Capability management software

The skills people possess are one of the most important foundations in a business, due to the fact that they impact every aspect of corporate process and, ultimately, profit (Homer 2001). Therefore, the efficient use of the skills evident within a business, i.e. the human capital, is one of the most important factors in the business's ability to compete (Gronau and Uslar 2004, Karatop, Kubat et al. 2015). It has been stated that skills management has become a ”major management trend”, in particular the use of IT software and computer programs to manage the knowledge of employees i.e. to record, diffuse and support the creation of new knowledge (Dingsøyr and Røyrvik 2001, Burney 2016).

Skill and competency management utilising IT software is more than just the creation and use of a database to record and track the skills and competencies of a business's employees. It is a combination of knowledge management and resource management (Gronau and Uslar 2004). The real aim of such systems is to provide the ability to offer benefit to the company through the proper and best use of its skills and competencies (Gronau and Uslar 2004). A benefit that can be sought through the correct use of such software would be primarily a reduction of cost through more effective resource management (Homer 2001). This fact is highlighted by Homer (2001) through the use of an illustrative scenario where the process of recruiting staff (advertising, CV review, Interviews), is compared against using a IT system to review current staff and implementing a training initiative to develop an existing employee (Homer 2001). From this scenario, it is inferred that the use of an IT system would take less time and would aid in the development of already employed staff, overall cutting costs (Homer 2001).

DingsØyr and RØyrvik conducted a study into the use of knowledge management systems within software consulting companies, within which they also highlighted the use of skills management systems for solving skills gaps and developing employees (Dingsøyr and Røyrvik 2001). Another use they observed was the active use of skills management IT systems when identifying and allocating resources to projects. It is a commonly known scenario that managers will ultimately pick and choose the staff they would prefer on a project, utilising their knowledge of past events and skill sets (Dingsøyr and Røyrvik 2001). However, in the test company, where the study was conducted, this was not the case. They utilised a skills manager system which highlighted the skill sets of each individual and rated their experience of each skill, this was then used when considering the allocation of an individual to a project (Dingsøyr and Røyrvik 2001). This case study highlights how the use of an effectively implemented tool can alter cultural and behavioural processes in a positive manner.

An example that describes the application of a competency management support tool is presented by Corallo et al. The case study was carried out within an Italian aerospace company where a tool for competency management, and its associated methodology, were implemented (Corallo, Lazoi et al. 2010). The tool's purpose was to allow the collection and analysis of relevant data regarding competence areas, activities to be performed, actors available, and activity evaluation. The tool could then utilise this data to provide functions to managers such as: providing a capability scoring and performance score to each actor for each activity; visualisations of complex outputs; and, warnings of potential competency gaps (Corallo, Lazoi et al. 2010). This is in contrast to the previous example where individuals are the centre point of analysis, in this case the project is key and individuals are assessed on their fit with the project and are given a rating based on that, and not their individual skill level. Through the implementation of the tool the business achieved three major benefits in terms of mitigating competency gaps, actor allocations, and overall performance improvement.

It can be seen from the literature presented, and the examples of its application, that skill/capability management software can provide managers with a base of knowledge from which resourcing decisions can be made. The main challenge with such software utilisation is how to combat the "picking and choosing"' culture where a manager chooses who they want and makes this fit with what is being displayed in the software. If implemented well and taken seriously by all those utilising the software resource management, advantages can be sought such as improved resource allocation and skill/capability gap identification, which reduce the time and effort required in the process.

Project portfolio management tools

Cooper, Edgett et al. (1999) stated that portfolio management focuses on how a business should most effectively invest resources to achieve the business's objectives (Cooper, Edgett et al. 1999).

They went on to define portfolio management as:

> *"Portfolio management is a dynamic process, whereby a business's list of active new product projects is constantly updated and revised. In this process, new projects are evaluated, selected, and prioritised; existing projects may be accelerated, killed, or de-prioritised; and resources are allocated and reallocated to the active projects."(Cooper, Edgett et al. 1999)*

A common theme that is highlighted in literature is the importance of utilising portfolio management in the difficult task of allocating resources to multiple, often interdependent, projects (Platje, Seidel et al. 1994, Cooper, Edgett et al. 1999, Cooper 2001, Reyck, Grushka-Cockayne et al. 2005, Browning and Yassine 2015). With an aim to aid managers in the process of making resource allocation decisions at a portfolio level, a number of tools, as well as software applications, have been developed (Cooper, Edgett et al. 1999, Cooper 2001, Browning and Yassine 2015). These tools can be implemented in a number of different ways; what is common between them is that they all aid in resource management through the realisation of the main goals and objectives of portfolio management.

Through an extensive review of literature in the field of portfolio management, Reyck, Grushka-Cockayne et al. highlighted and discussed constituents of portfolio management, and hence the management of resource within a business (Reyck, Grushka-Cockayne et al. 2005). A key element they highlighted was the production of a centralised view of the project portfolio, i.e. the preparation of an inventory of current and proposed projects, through a central area responsible for collecting, analysing and distributing project information. Financial analysis of portfolios was also identified as being important and was described as: the adoption of a valuation methodology such as Return on Investment (ROI), Internal Rate of Return (IRR), Net Present Value (NPV) or Economic Value Added (EVA), against which projects can be valued (Kuster, Huber et al. 2015). Reyck, Grushka-Cockayne et al. (2005) also highlighted the need for risk analysis and the appreciation of interdependencies between projects, they stated that the risk of each individual project as well as the aggregated risk of a portfolio of projects as a whole needed to be noted. Prioritisation, alignment and selection of projects within a portfolio was also highlighted and described as the process of manipulating a portfolio so it appears well balanced i.e. it addresses all areas of the business's strategy. Grushka-Cockayne et al. (2005) also discussed the need for specialised software as a key element and stated that although there has been debate to how necessary software is to the process of portfolio management there is a claim that benefits can be sought from its application, primarily the reduction in time and effort required when updating information for decision making (Reyck, Grushka-Cockayne et al. 2005).

A tool developed for portfolio management that addresses one of the key elements discussed by Grushka-Cockayne et al. (2005) was proposed by Ghasemzadeh and Archer for prioritisation, alignment and selection of projects. Ghasemzadeh and Archer took a particular interest in project portfolio selection as they found this be a crucial decision made in businesses due to its complexity, relating to the levels of risk involved, resource requirements, and interactions between projects. Ghasemzadeh and Archer developed and implemented an organised framework for project portfolio selection through a Decision Support System (DSS), referred to as Project Analysis and Selection System (PASS). The proposed framework combined methods grounded in theory which were easy to understand, and applied them in a logical manner. The framework aims to assist decision makers in finding a satisfactory portfolio, which is near optimal, whilst satisfying all resource constraints.

One other example from literature which tackles a key element discussed by Reyck, Grushka-Cockayne et al. (2005) was proposed by Dickinson, Thornton et al. (2001) for financial analysis which will be utilised for portfolio optimisation. Dickinson, Thornton et al. proposed a quantitative method that enables a team to evaluate and optimise a portfolio where the projects are highly coupled and are funded from different budgets. The first tool which is developed is a Dependency matrix which documents and quantifies financial interdependencies between projects. This information is then utilised in an 'Optimization Model' and is integrated with existing data in a spreadsheet format. The goal of the optimisation is to maximise a portfolio's NPV subject to budgetary and portfolio balance constraints (Dickinson, Thornton et al. 2001).

From the literature reviewed, it is apparent that portfolio management tools support the process of allocating resources to multiple interrelated projects (Platje, Seidel et al. 1994, Cooper, Edgett et al. 1999, Ghasemzadeh and Archer 2000, Dickinson, Thornton et al. 2001, Reyck, Grushka-Cockayne et al. 2005, Browning and Yassine 2015). Complexity is experienced within businesses when they consider the adoption and utilisation of these tools, often due to the large and varied problem space, highlighted by the key areas discussed by Reyck, Grushka-Cockayne et al. (2005), and the equally large and varied base of tools that propose benefits to a business in these areas.

3.2.1.3 *Representational models*

A representational model can be described as a system that utilises quantifiable models to simulate and solve decision problems and forecast potential outcomes. The models operate through the inclusion of causal relationships between factors as well as the introduction of uncertainty. This type of system would be mainly used to visualise the dynamics of a process under certain conditions, and also to ascertain the outcomes from a planned course of action. The benefit of using representational models is that plans can be tested and experimented with, prior to application in the field, giving managers greater insight and ability to make more informed decisions. For example, an engineering manager may want to understand the effect of reducing the amount of resources available over a period of time. The manager would then require a representational model which characterised the effect that this reduction would have on a number of aspects of the system found to be of interest i.e. work in progress, schedule slippage, output quality. From this model, the manager would be able to experiment with resourcing levels to assess the effects and then make more informed decision based on this.

A number of software packages, tools, and languages exist that are used on a day-to-day basis when developing and implementing simulations (Jansen-Vullers and Netjes 2006, Dagkakis and Heavey 2015). In a business context the implementation choice will be highly dependent on the organisational environment, as well as the way in which it will be used (Attia, Hensen et al. 2012). Therefore, this Section will review representational with respect to four different implementation techniques: system dynamics; discrete event; and agent-based, as these are the most commonly found decision making techniques be used in business contexts.

The techniques discussed in this Section are those that are most commonly used in industry and referred to in literature when developing representational models. This Section will draw on examples of implementation in industrial applications that will be reviewed and critiqued, highlighting strengths and weaknesses.

System dynamics simulation

System dynamics simulation models portray the effects that dynamic behaviour has upon a system. In system dynamics, processes are represented in terms of stocks (e.g. material, knowledge, people, and money), flows between these stocks, and information that determines the values of the flows. System dynamics takes an aggregate view, not concentrating on single activities and entities. Overall it describes the system's behaviour as a number of interacting feedback loops, balancing or reinforcing, and delay structure (Borshchev 2004, Khan, Flanagan et al. 2015).

An, Jeng et al. (2007) used system dynamics modelling and simulation in the development of a novel concept to address workforce management. An, Jeng et al. tackled this by considering demand i.e. project management, and supply i.e. human resource management, as separate issues (An, Jeng et al. 2007). System dynamics was used to capture the causality relationships and feedback loops within the system, this was then simulated to show dynamic behaviours of the system. An et al. (2007) mainly focused on the planning and scheduling of projects based on the availability of human resources. They considered three main factors for each project: project lead time, the difference between project start time and current time; required skill set, the range of skill and knowledge participants should possess; and, project duration, the horizon between project start and finish. It was made clear that these variables are different from project to project, are often not pre-determined, and are dynamic in nature. Also, unpredictable events and resource constraints within the system can affect projects often resulting in the required skill set changing, through project evolution and requirement understanding. This model was used to examine effects such as sudden demand change, and show the gap between project backlog and available skills.

Hafeez et al. developed a systems dynamics model and simulation of human resource management related to company staff recruitment and attrition rates, which was used to develop human resource planning strategies (Hafeez, Aburawi et al. 2004). The desired result was to provide guidelines to reduce unwanted scenarios such as staff surplus and/or shortage. The model employed in the study is a Skill Pool Model (SKPM), which was used to assess the dynamics of a staff pool by tuning parameters such as recruitment averaging time. The model provided support to minimise the current and future staff shortages by selecting an appropriate recruitment policy. This type of model can guide management to develop improved human resource policies, for example by reducing the hiring and firing rates.

From the research reviewed, it can be stated that system dynamics simulations can be utilised when there is a need for representing the effects of uncertainty through the manipulation of the flows and feedback within a system. A significant drawback with this type of simulation implementation technique is that the simulation model produced cannot represent defined process steps or entities which can be programmed to have skills or requirements and show their availability to be allocated individual tasks.

Discrete event simulation

Discrete event simulation is a dynamic representation that supports the evolution of a process, reacting and transforming in response to its environment. In this type of simulation, the state of the model changes at discrete intervals, at points within the process, which are of interest to the analysis of the problem (Kang, Aboutaleb et al. 2015). Transactions or entities in the simulation flow from one point to another while competing with each other for the use of scarce resources. Discrete event simulation has the ability to represent random behaviour within models, representing both steady state and transient phenomena and can also lend itself well to animation providing insight to those using a simulation tool. For example, a user could see where bottlenecks occur in a system. Animation is also a benefit when considering the validation of the behaviour of a simulation. Discrete event simulations utilise programmable entities that can easily be programmed to incorporate the competition for resources experienced within companies. This fact has made discrete event simulation an appropriate simulation techniques for process modelling and analysis (Harrington and Tumay 2000).

Greasley and Barlow (1998) utilised discrete event simulation to analyse the process of resource allocation in a police custody process. The simulation model that was produced had the ability to measure the performance of the present and proposed systems, the ability to try alternatives, and also the ability to communicate the process through full screen animations (Greasley and Barlow 1998). The practical focus of the simulation was to investigate the use of human resources within the custody process with an aim of improving this process through allocating work more evenly to the staff available. This would effectively reduce the bottlenecking that is apparent within the system. Although this case is not within

NPD, it does highlight how this type of implementation can be used to improve resource allocation. Resource availability was taken into consideration through entities in the simulation being shown to be in work or ready for allocation, this was backed up through a visual representation of the current state. Perez-Escobedoa et al. developed a product portfolio management discrete event simulation that models the underlying structure of a pharmaceutical enterprise portfolio with an aim to evaluate a large set of scenarios in a holistic fashion to avoid local optima (Pérez-Escobedoa, Aguilar-Lasserreb et al. 2008). The model considers the whole life cycle of a pharmaceutical project, from discovery to mature sales. Task prioritisation is taken into account by using a general rule that events which release resources have priority over others, and when events are the same type, the First in First out (FIFO) rule is applied. To take account of uncertainty, the model was repeated a number of times selecting random sampling values from the probability distributions, which were then used to represent uncertainty in the system. The key finding from this simulation was the identification of the sequence that maximises profit while minimising the probability of failure using a Genetic Algorithm (GA).

Discrete event simulation has an advantage over the other techniques, such as system dynamics, in that it can detail entities with properties, enabling the ability to program skill sets and profiles of the requirements to fulfil tasks. Discrete event simulation is not the only technique that allows for this, agent simulation also allows for this type of programming. A drawback is that discrete event simulation steps from one event to the next, disregarding the occurrences happening in the time in between the process jumps. This fact has been considered with the combination of the continuous method of simulation, whereby the continuous uncertain environment can be modelled and included in simulation observations. Another drawback is the fact that more complex human factors, such as personality profiles and working routines, are hard to represent in this type of simulation.

Agent based simulation

Agent based modelling and simulation focuses primarily on individual actors, and the behaviours of these actors are modelled which dictate how they interact with other agents in the system. Since each agent is seen as an individual aspect of the system, an agent can continually adapt to its environment at its own pace in its own unique way (Garcia 2005, Hsu, Weng et al. 2016). Agent modelling is useful when analysing social systems that can be described in “what-if” scenarios, when emergent phenomena may exist, where learning and adaption occurs, and where the population is complex. Possible applications of agent based modelling exist within three main areas in NPD: diffusion of innovations; organisations; and, knowledge/information flows (Garcia 2005, Hsu, Weng et al. 2016).

Zhanga proposed an agent based simulation model that evaluated and improved organisational planning in complex product development projects (Zhanga, Le Luoa et al. 2009). The simulation has the ability to explicitly represent human behaviour, organisational interactions, and task networks. The agents of the system are the human actors/resources within the product development process. The assumption was made that the design process could be simulated through the continuous interaction between design agents and the objects within the design environment, such as design tasks, product information, and design resources. This is of particular interest as only the knowledge base of the agent and the understanding of the relationships and knowledge transfer between the associated agents would be required. The main finding from this simulation application was the development of an approach that would improve organisational performance predictability and shorten process duration of a collaborative product development project. A drawback of this simulation is the fact that it only addresses a single project; further work suggested that a multi project simulation may be the next step in this research (Zhanga, Le Luoa et al. 2009).

Joslin and Poole describe preliminary attempts to adapt a simulation based planning algorithm developed for the Mars rovers to the problem of planning for software project management (Joslin and Poole 2005). The simulation utilised agent simulation to model the way agents behave in project development, and the way a manager might adapt the project plan based on the project status. The work of individuals was broken into work units that were equivalent to one week. During the start-up of a task a worker would contribute at a reduced rate; this is referred to as the start-up phase. The only resources that are represented in the simulation are developers. The developers were characterised by the probability distribution of their contribution to their assigned task in any given week, and a factor representing how readily they can be expected to become fully productive on a newly assigned task. The revision of estimates of the required effort and schedule of tasks were incorporated into the model, this was incorporated as estimates tend not to change gradually over the course of a project, but at points close to the original value of estimate set. For example, the estimated time taken for a task may not change as the task is being carried out but at the point of realisation that the task will not be completed, only at this point in time the estimate is revised in the simulation. The estimate is revised based on the remaining number of work units outstanding. It was found that when resources are allowed to move from low priority tasks to high priority tasks already in their allocated tasks, it was not necessary to move resources to a new task, therefore not incurring a start-up penalty. With the ability for agents to move between tasks it was found that estimated risk of project failure was 2% or less. In contrast without this allowance of task prioritisation the estimated risk of failure ranged from 5% to 20%.

Agent simulation has proven in literature to be an area of research as the vast majority of applications of this type of simulation technique are based in academic areas and not applied directly to industry. From the examples reviewed it has been seen that agents within simulation have been programmed with a number of attributes that control their behaviour, which has opened up the ability to include a number of human factors and working routines. Also, with the unscripted nature of the agent's behaviour, uncertainty can be introduced naturally and portray real world effects. This can result in a stochastic representation of the process, which may produce a different answer each time the simulation is run.

3.2.1.4 *Optimisation models*

An optimisation model aims to generate the most favourable outcome based on the constraints placed on it. For example, an engineering manager may want to assess the optimal level of resources to have working over a period of time while experiencing constraints such as budget, number of available resources, work load to be completed, acceptable amount of slippage etc. The model would then utilise computer programming to work within these constraints to suggest a feasible solution for the optimal resource level.

Through a review of literature in the area of Research and Development (R&D) programme planning Mathieu and Gibson reported four broad categories of decisions made by managers in R&D i.e. resource allocation to projects, establishing objectives, determining the number of programme areas, and finally the determination of the sequence and/or schedule of projects (Mathieu and Gibson 1993). Mathieu and Gibson also stated that R&D programmes present significant difficulties during planning as they involved multiple projects over multiple technologies that often have interdependencies. They highlighted the difficulty experienced by decision makers at a programme level by describing the constraints that are commonly experienced, for example lack of detailed technical expertise to make decisions, interdependencies between projects, and qualitative directives. Brown stated that when there are many projects to consider and more than one constraint, such as resource availability and budget, the solution space gets to be so large as to not allow for optimisation without the help from computer systems (Brown 2008). Therefore, when considering the allocation, scheduling and planning of multiple projects at a programme level, as discussed by Mathieu and Gibson, there is a need for sophisticated optimisation techniques that aid in the decision process.

Although there are systems available which exclusively deal with optimisation in its own right, optimisation is often incorporated as a feature to other systems, this is particularly true when considering the area of resource management within businesses utilising information technology (Ghasemzadeh, Archer et al. 1999, Hegazy 1999, Liu and Wang 2011). For example, spread sheets have the ability to incorporate optimisation into the analysis of data; this is also available in simulation, ERP systems and portfolio management software. Therefore, in the case of resource management through the utilisation of IT based tools, optimisation models effectively transcend the other model types already discussed i.e. data analysis systems, analysis information systems and representational models. Due to this fact the literature and examples, which will be discussed here, will be sourced from the use of the technique of optimisation within the other system types discussed, and not as a standalone system.

An example of the utilisation of optimisation in resource management is proposed by Hegazy who discussed an improvement in resource allocation and levelling heuristics utilising the GA technique, which searches for a near-optimum solution while considering allocation and scheduling simultaneously (Hegazy 1999). Heuristics are rules that are based on activity characteristics to prioritise activities, which compete for limited resources; the outcome is the allocation of resource to the top-ranked activities while the others are delayed. When considering the scheduling process, heuristics ensure that all project activities are scheduled without violating the logical relationships or the resource constraints (Hegazy 1999). Heuristics have many advantages, such as being simple to understand and use, and the fact they are commonly included in most commercially available planning software, however heuristic rules perform with varying effectiveness and cannot guarantee optimum results (Hegazy 1999). Therefore, Hegazy utilised a GA technique, which simultaneously searched for a near optimum set of activity priorities that minimise the project duration under resource constraints, effectively combining the two heuristics, of allocation and scheduling. One of the main outcomes sought from this work was the improvement of project planning software abilities to allocate and schedule resources, which decision makers have in the past only utilised based on its powerful presentation capabilities, reserving savings to be made in the implementation phase (Hegazy 1999).

Another example of the use of optimisation for resource management was presented by Liu and Wang (2011) who utilised optimisation, in particular Constraint Programming (CP), for project selection and scheduling problems with time dependent resource constraints (Liu and Wang 2011). The optimisation model developed by Liu and Wang (2011) integrated a project selection mechanism, scheduling precedence, and relationships between projects. From the application of the model to a number of scenarios it was found that the model allowed decision makers to determine an optimal portfolio with specified resource constraints according to various time intervals, benefiting decision-making for project selection and scheduling (Liu and Wang 2011). Liu and Wang (2011) stated that future work will extend this research to build a management system which uses project information to analyse resource utilisation to allow decision makers to better observe resource usage (Liu and Wang 2011). Although not explicitly stated, the themes of project selection and scheduling, as well as the development of a management system, indicate that this optimisation example falls within the portfolio management tools heading.

Although optimisation has been shown to be of benefit in the complex resource planning and scheduling process from literature and examples discussed (Hegazy 1999, Brown 2008, Liu and Wang 2011), optimisation techniques have largely failed to gain industry acceptance (Mathieu and Gibson 1993). This perceived failure may be due to the fact that traditional optimisation techniques prescribe solutions to problems without allowing for the judgement, experience, and insights of the decision maker, promoting a lack of trust in the outcomes produced (Mathieu and Gibson 1993, Sampath, Gel et al. 2015). If optimisation was to be utilised in a resource management capacity through its inclusion in a decision support tool, it would need to provide a decision maker with an element of manipulation so that they can utilise their experience and add to the optimality of the results provided.

3.2.1.5 ***Summary***

All systems reviewed carry their own benefits, drawbacks, level of complexity and decision support capabilities for making resource base decisions. As the system types increase in complexity the level of decision support that can be provided also increases, due to the amount of information that can be provided and manipulated, possibly utilising more sophisticated computer programming or integrated systems. An important aspect to highlight here is the transcendence of the optimisation system type over the other system types. This is experienced due to the fact that optimisation is considered as a technical discipline that can be added on to these types of systems, for example optimisation in project management software, and simulation optimisation techniques.

Although all systems discussed in this Section can provide NPD businesses with some degree of benefit, in relation to resource management decision-making, this is ultimately dependent on the decision-making context. For example, the focus of the problem under consideration and the environment it is experienced within will all impact the type of system that would be deemed most appropriate. Therefore, there is a requirement for an appreciation of the implementation environment, when considering the matching of a resource management system to the resource management problem being experienced.

3.2.2 Development and implementation considerations for resource management IT systems

This Section of the Literature review will focus on answering the following question;

Q2. What considerations impact the development of resource management systems in NPD business contexts?

By answering this question, the researcher will have established the considerations that make an impact on the acceptance, adoption and sustainment of resource management systems in NPD business contexts. The considerations discussed in this Section will influence resource management system development for use in a NPD business context, and will impact its acceptance, adoption and sustainment.

The below list summarises the considerations that are required to be made when developing a system for use in a business context, such as resource management in NPD. The considerations are summarised here and are discussed in more detail in the following subsections:

- **Business requirements:** What is expected and/or needed, at a functional and non-functional level, by the customer for a system to fulfil its purpose (Nuseibeh and Easterbrook 2000, Nance and Arthur 2006, Shukla, Pandey et al. 2015)

- **Culture**: Willingness to change or adopt new ways of working can have an effect on how well a system is adopted (Knoll and Heim 2000, Melao and Pidd 2003, Sheu and Kim 2009, Lindgren and Münch 2015, Altamony, Tarhini et al. 2016)

- **Technology**: Technology that is currently used can be a restrictive factor when considering implementing a system (Jenkins and Chapman 1998, Knoll and Heim 2000, Morgan, Anokhin et al. 2015)

- **Complexity management**: There is a need for understanding the appropriate scope and level of detail required for analysis of the problem of interest (Flood and Carson 1993, Brooks and Tobias 1996, Chwif, Barretto et al. 2000, Kim and Wilemon 2003, Sommerville, Cliff et al. 2012)

- **Uncertainty management**: Representing and taking account of the uncertainty present in a business system in a number of different forms and elements that make it hard for managers to plan ahead of time (Brooks and Tobias 1996, Meyer, Loch et al. 2002, Oh, Yang et al. 2012)

- **Human factors**: Human resources have differing needs, personalities, circumstances, and capabilities/skills which need to be considered in planning efforts which should be highlighted in analysis efforts (Hafeez, Aburawi et al. 2004, Jenkins and Rice 2007, Teixeira, Saavedra et al. 2016)

3.2.2.1 *Business requirements*

The primary measure of success of a system is the degree to which it meets the purpose for which it was intended (Nuseibeh and Easterbrook 2000). This statement holds true for any system of interest; a system is only successful, and of high quality, if it does what it is required. A requirement of a system can be defined as a singular documented need that a system/product functionally needs to do or be. Requirements are essential for initially capturing the customer expectations, all the way through to the delivery of the system/product itself (Loucopoulos and Karakostas 1995). A system development project will traditionally have many requirements that may be expressed in a number of different forms. Some of these requirements will be obvious and can be easily defined; others may be assumed to be obvious and are therefore not explicitly stated (Loucopoulos and Karakostas 1995, Shukla, Pandey et al. 2015). This mix of requirement types necessitates a mix of elicitation techniques that work together to draw out and define the requirements of the system in question (Pohl 1996, Jiang, Eberlein et al. 2008).

Jiang et al. stated: "the complexity of software projects as well as the multidisciplinary nature of Requirements Engineering (RE) requires developers to carefully select RE techniques and practices during software development" (Jiang, Eberlein et al. 2008, Shukla, Pandey et al. 2015). They went on to state that there are numerous techniques that address different aspects of the RE process and provided an extensive documentation and analysis of the techniques commonly utilised, such as: prototypes; Joint Application Design (JAD); state diagrams; and the Analytic Hierarchy Process (AHP). The outcome of this analysis found that most existing RE techniques only address some of the key attributes required, as a result of common practice for requirement engineers to combine several techniques in order to adequately address the different attributes they are capable of eliciting (Jiang, Eberlein et al. 2008).

A method which is widely used to ensure successful development and implementation of systems within a business context is to determine and document the constraining conditions that a system has to work within (Chung and do Prado Leite 2009). In this process, non-functional requirements of a system are collected and analysed to provide an understanding of the constraints the system may have. Cysneiros and Prado Leite stated that non-functional requirements are the properties and qualities that a system must possess while providing its intended functional requirements or services (Cysneiros and do Prado Leite 2001). They went on to suggest that non-functional requirements need to be considered in development activities and that they greatly affect the design and implementation.

There are a number of ways which non-functional requirements can be represented, this fact was reviewed in depth by Chung and do Prado Leite (2009). The most common method of representing non-functional requirements is through writing a requirement statement, which highlights the need that had been elicited. Non-functional requirements may also be illustrated in a tree structure, expressing the concept of non-functional requirement clustering and decomposition (Chung and do Prado Leite 2009).

It is important to consider both functional and non-functional requirements in the early stages of development, and throughout the process, to facilitate system success. In relation to the development of a system for use in NPD resource management, an understanding of the functional requirements and bounding conditions a system must achieve and work within is a significant factor that works to guide development efforts and help scope a project. As model development involves the formalisation of mental models, customers, stakeholders, and developers may have different viewpoints of the same system of interest, and different methods to represent that system. It is in this process of scoping and focusing a system that requirements play a major role.

3.2.2.2 *Culture*

The cultural environment in which a system is intended to operate may constrain the development, implementation, and operation of a system. This means that the culture of the business in which the system is being developed for will need to be considered during development activities (Grabau 2001, Lindgren and Münch 2015).

Jenkins and Chapman researched the area of system adoption and proposed four influencing factors which have an effect on the implementation and utilisation of a system in a business context, their example was focused on the successful adoption of discrete event simulation (Jenkins and Chapman 1998). Although this research focuses on IT systems, the findings are applicable to systems in general. The factors identified were: level of sponsorship; perceived complexity of the solution; risks involved; and adoption advantage. Jenkins and Chapman identified that the sponsorship that a new system gets, particularly from management, can determine how successful it may become. If management make a conscious decision to back development efforts, the system will have a greater chance of being successful and accepted. The perceived complexity of a system can be a massive drawback when users are unfamiliar with the technology involved, this can easily put people off adopting the system. The risk involved is also a constraining factor due to the amount of time and resources needed to develop a system that in the end may not be accepted (Jenkins and Chapman 1998).

Adoption advantage is where stakeholders are shown the advantage of having the system in an effort to promote buy in. The identification of these four aspects gives clarity to developers who wish to manage cultural issues to ensure the progression of their system from a potential to an implemented solution, however the four factors identified are not an exhaustive list.

Sheu and Kim conducted 50 case studies involved in researching the correlation between user readiness and the success of information system development (ISD) projects (Sheu and Kim 2009). Their main finding was that user readiness directly correlated to the success of IT projects, but was not the sole contributory factor. Sheu and Kim used four criteria to assess user readiness: decision; expectation; attitude; and, concern. The decision criteria examined whether users contributed to the initiative, expectation assessed the user's initial perception of change resulting from the system. The attitude criterion measured the general feeling of a user in response to a system and finally concern referred to the personal concerns about an announced system. Sheu and Kim found that user readiness was the highest influencing factor to the success of an ISD project but had a number of complex interactions with other types of readiness such as process, data, and cultural readiness.

Fundamentally, the introduction of a system within a business is a process of change management. If a business does not have the culture required for a system to be successful, the potential for utilisation will lessen (Sheu and Kim 2009). There is a need for a better understanding of how this issue of business culture can be overcome and successful development and therefore implementation delivered. The issue of culture is of particular interest when considering the development of a resource management system as culture plays a significant role in understanding the constraints in place. The culture evident within a business will define their attitude towards changing working styles, methods and associated It solutions that are presented (Altamony, Tarhini et al. 2016). If methods are used in a decision support system project which are seen to be questionable by a business, such as unfamiliarity or previous poor executions, the overall solution may not generate a high enough degree of confidence (Altamony, Tarhini et al. 2016). These potential attitudes towards elements in a system need to be considered and managed to ensure that not only the system that company wants is produced but also what the company is ready for.

3.2.2.3 ***Technology***

To ensure a system is correctly aligned to the needs of the customer, a consideration has to be given to, not just what the user wants, but also what the customer can maintain and use. For example, if a user required a highly complex system with state of the art technology, but the organisation did not have the capabilities or technology available to use and implement such a system, there is a noticeable difference between what is required and what the business can realistically provide and sustain (Morgan, Anokhin et al. 2015). This highlights the role which technology can have on the choices businesses have when considering system development.

Knoll and Heim (2000) reviewed this consideration and proposed four main issues prior to starting the development of a system within a business context (Knoll and Heim 2000). These considerations were in relation to the business use of an IT system and the adoption of simulation in a manufacturing environment. They argued that to successfully develop and implement a simulation system within a business context, awareness and ability to deal with the following considerations is necessary: which is the right software package; how will senior management approval be procured; how will models be created that can be used by everyone; and who should be creating the models. The issues described by Knoll and Heim (2000) look into the operation of a system within a business, taking into consideration the implementation techniques and how the system will be used on a day to day basis. From these considerations, it can be seen that the technology adopted and how it is used by a business will have an impact on how the system is adopted and should be considered in development.

Baird and Meshoulam (1988) stated that human resource management activities move through stages, in sequence, in response to increasing complexity in the organisation and that each stage incorporates and builds on the previous (Baird and Meshoulam 1988). They went on to say that human resource management activities are most effective when their stage of development matches the overall stage of development of the parent organisation. These facts highlight the need to consider the current company technology state in relation to resource management in the early stages of developing a system for use in human resource management. Baird and Meshoulam (1988) also stated that if human resource management activities skip a stage, they will be ineffective and it will be necessary to revisit the earlier stages to regain effectiveness. Therefore, it is essential that companies pace their development of their human resource systems and continuously align the stage of the companies' development with the development of their systems.

Overall, a business's current technological state needs to be taken into consideration at the forefront of the development of an IT system, alongside the elicited user requirements for that system. This is particularly true when considering the development of a complex IT system for the use in a business context i.e. resource management systems. The technology utilised by a business can critically constrain and hinder development efforts if not considered fully at earlier stages. It is clear that a business's technology and technological applications should grow at a steady state alongside the growth of the business itself. Overstepping the boundaries of the technological constraint could lead to the development of an overly complex system that, although highly useful and well developed, cannot be utilised or implemented in the host business.

3.2.2.4 *Complexity management*

Representing a high level of detail within a system can often lead to it becoming highly complex and un-manageable (Chwif, Barretto et al. 2000, Sommerville, Cliff et al. 2012). The complexity inherent within a system is a trade-off between utility, maintainability, ease of use, and customer requirements. Complexity can be broken down into two main aspects: the scope; and the level of detail (Chwif, Barretto et al. 2000). Robinson and Bhatia (1995) defines scope as "the breadth of detail required" (Robinson and Bhatia 1995). Within the context of resource management, this would describe the number of functional areas which are included in a model, or the number of roles portrayed. Robinson and Bhatia (1995) advise that only the minimum scope should be included to avoid excessive detail. However, this could be to the detriment to otherwise useful functionality. The scope of a system should be dictated by the requirements set by the user of the tool, if this scope is unmanageable or unfeasible in the constraints of development, then reducing the scope of application may be necessary.

The depth of a model has previously been described as "an assessment of the extent to which the observable system elements and assumed system relationships are included" (Brooks and Tobias 1996). Often the depth of a model is assessed qualitatively, and is related to the system which the model represents rather than the way in which the model is implemented

(Chwif, Barretto et al. 2000). The depth of a model can then be defined by how much data and description is given to the aspects within the scope of a model. The overall complexity is therefore influenced by the interaction between the depth and scope of a model.

Robinson and Bhatia (1995) stated that the basic rule for determining the depth required in a model is to include only the minimum level of detail required in meeting the objectives of the project. Sturrock (2008) supported this suggestion by proposing that developers should try to keep models simple (Sturrock 2008). Nordgren (1995) also shared this view and stated that highly detailed data is discouraged when defining the scope of the data required in a study (Nordgren 1995). Pidd (1996) added to this by proposing principles of modelling, such as “model simple, think complicated” which stated that the user must be considered as an aspect of the system and that a simple model can be supplemented by highly critical thinking and analysis (Pidd 1996).

With higher complexity comes greater validity and ability for analysis but has a higher likelihood for errors and also affects development times (Chwif, Barretto et al. 2000, Sommerville, Cliff et al. 2012). Smaller less complex IT systems on the other hand take less time to produce and are easier to implement, but can lose detail and the ability to carry out flexible analysis (Chwif, Barretto et al. 2000). The challenge is in achieving the appropriate level of detail and complexity required in the development of a system for the problem specified.

When considering the context of developing an NPD resource management system, complexity needs to be considered throughout the development phase. There needs to be consideration of a large number of factors along with knowledge as to how these factors interact and affect each other. Such factors include the number or resources available, the capacity of those available to take on new work, the characteristics of the work which needs to be carried out i.e. level of novelty, size, the current economic climate, and human factors i.e. motivation and skills sets. Including all these aspects within a model may result in a very large model with multiple interactions between elements and subsequently high levels of complexity.

It is important to consider both the breadth and depth of complexity required to be incorporated in a system so that it delivers the required and adequate result to a user. This factor is constrained by the analysis requirements of the user and will enable a developer to define the overall scope of a system. A clear definition of scope will enable a developer to constrain their model to only what is seen to be functionally required for the purpose of analysis.

3.2.2.5 *Uncertainty management*

Ward and Chapman (2003) stated that most project management activities are concerned with managing uncertainty due to ambiguity from lack of data, lack of detail, lack of structure, assumptions, and sources of bias (Ward and Chapman 2003). They went on to say that uncertainty can be experienced in five main areas: the variability of estimates of project parameters; the basis of estimates of project parameters; design and logistics; objectives and priorities; and, the relationships between project parties. Incorporating uncertainty, such as described by Ward and Chapman (2003), into a decision support system requires an in-depth understanding of the system's dynamic behaviour. Oberkampf (2002) defines this type of uncertainty as "aleatory uncertainty", also referred to as irreducible uncertainty, inherent uncertainty, variability and stochastic uncertainty (Oberkampf, DeLand et al. 2002). Aleatory uncertainty is the inherent variation associated with a physical system or the environment under consideration.

Taking account of uncertainty within a system never fully represents what happens in real life within a given system (Greasley 2004). Both the model and the uncertainty within the model will always be an approximation of the system and will differ from what actually happens. Oberkampf (2002) defines this type of uncertainty as "epistemic uncertainty" which is the potential inaccuracy in any phase or activity of the modelling process that is due to lack of knowledge (Oberkampf, DeLand et al. 2002). This type of uncertainty is also referred to as reducible uncertainty, subjective uncertainty, and cognitive uncertainty.

One technique which is used within system development to portray the effects which aleatory uncertainty has on a system is through shifting and changing variables at different times (Greasley 2004). The effect is a view of a dynamic changing environment where variables are not set but change with time. Greasley (2004) stated that it is important that randomness in variables be incorporated, since taking an average value for will not provide an accurate enough representation of the real world behaviour (Greasley 2004).

Uncertainty is ubiquitous within NPD due to the novelty within the projects being carried out (Meyer, Loch et al. 2002, Oh, Yang et al. 2012). One area that contributes to the uncertainty experienced is the inability of managers to plan for the unforeseeable issues that are common within NPD projects. This relates to issues such as resource bottlenecks, anticipating regulatory barriers, mistakes, and re-work, which can have negative impacts on projects extending lead-times or stopping them completely (Meyer, Loch et al. 2002, Cooper and Edgett 2003). The ever changing and evolving project structure, in relation to the changing environment, makes it hard for managers to accurately assign resources over time. This means that even well thought out and managed resourcing plans can become out of date very quickly and require continual updating.

It is essential that appreciation of this type of uncertainty is taken into consideration at decision making stages within the resource management process. Managers will then be able to understand the effects of the uncertain environment on their decisions and have the ability to foresee the potential changes in their system. The result of this is a more proactive, rather than reactive, management style.

3.2.2.6 *Human Factors*

NPD is an inter-disciplinary activity requiring the contribution of a number of functions within an organisation, which will have highly complex and dynamic relationships between these functions and the individuals within them. With the introduction of team work through cross functional teams, and managerial task allocation; human factors can potentially affect the performance of an individual, group, and/or function in question (McDonough III 2000, Teixeira, Saavedra et al. 2016). Managers are therefore required to understand issues relating to the human aspect of resource management. Consequently, the challenge here is to understand what aspects of human factors need to be considered; how they affect the resource management process, and to what level of detail they need to be considered.

Jenkins and Rice (2007) state that project managers concern themselves with acquiring and scheduling resources which was defined by Lock as being "...any person, object, tool, machine or sum of money needed for work on a project" (Lock 2003, Jenkins and Rice 2007). Jenkins and Rice (2007) went on to say that resources differ in many ways and proposed a typology, which can be used to describe resources. This was based on who the resources were; when they provide their services; what they do; how well they do it; and how they do what they do. This typology describes a number of resource attributes and is broken down into four main categories of description; this can be seen in Table 4. These resource attributes provide an opportunity to guide the development of resource profiles, from which resource models can be developed.

Yahaya and Abu-Bakar (2007) state that NPD human resource management issues are often "soft" issues that relate human factors with business aspects and have a significant impact on the capacity to plan and execute NPD projects (Yahaya and Abu-Bakar 2007). This is often thought to be a negative impact, as human factors are perceived to complicate the management process, for example: sick days; variable productivity; learning curves; and motivation and skills training to improve performance (Engwall and Jerbrant 2003).

Existential	Identity, Origin, Living, Consumption, Make-up, Traits
Availability	Status, Location, Schedule, Delivery mode, Failure mode, Selectivity, Exclusivity
Utility	Competencies, Size, Performance, Deliverability, Reliability, Effectiveness, Cost, Quality, Cognition
Implementation	Adaptability, Activity, Interactivity, Autonomy, Coupling, Isolation, Discoverability, Composition, Centralisation, Mobility, Forgetfulness, Pre-emptability, Standardisation, Risk, Policy

Table 4 - Resource Attributes (Jenkins and Rice 2007)

If human factors are not considered at an appropriate level of detail, the effectiveness of management decisions may diminish and the overall performance of the management system will be affected. The challenge is therefore to determine the scope to which human factors should be considered in order to provide the most appropriate level of decision support to managers.

Human factors are necessary when trying to understand what the resource is and how it will be described in decision-making support system (Mizutani, Tarumi et al. 2000, Jenkins and Rice 2007). This may be done through the use of object-orientated typologies that will describe aspects of the resource. For these reasons, when developing a resource management system, particular attention must be given to the understanding and description of resources.

3.2.2.7 ***Summary***

Through this investigation, it was found that the considerations discussed i.e. user requirements, culture, technology, complexity management, uncertainty management, and human factors, are important throughout the development of resource management systems in NPD business contexts. If these considerations are not suitably incorporated, there is an increased risk that the system developed would not be accepted, adopted and sustained. To ensure that this does not occur, a system development methodology that incorporates these considerations and guides developers through the complex task of developing a system for use in a business context is required.

It is now relevant to consider how a resource management system could be produced which would satisfy industrial needs. In order to do this, a review of System Development Methodologies (SDM), with an aim to examine how the considerations found to be relevant are incorporated and utilised is required.

3.2.3 System development methodologies

This Section of the literature review will focus on answering the following question;

Q3. What methodologies exist that support the development of resource management systems in NPD business contexts and how do they incorporate key considerations?

In answering this question, the researcher will illustrate how existing System Development Methodologies (SDM) incorporate key considerations, discussed in the previous Section, for the development and implementation of resource management IT systems in NPD business contexts. From this understanding, the researcher will be able to establish the strengths and weaknesses of available methodologies and potentially influence the identification of a methodology type that could be utilised.

3.2.3.1 *Why use system development methodologies?*

There is currently a large volume of literature regarding the management and development of systems and how to achieve success (Ulgen 1991, Ülgen, Black et al. 1994, Nordgren 1995, Robinson and Bhatia 1995, Hlupic and Robinson 1998, Sawyer and Brann 2008, Sturrock 2008, Dehghani and Ramsin 2015). However, the literature, which directly covers the complexity that is inherent in the management and completion of the actual project itself, is sparse.

Reeves (1992) stated that the design of a software application is itself an exercise in managing complexity, resulting in a difficult process to manage with a number of considerations that need to be continually assessed as the process evolves (Reeves 1992). Sturrock (2008) stated that the selection of an appropriate methodology and supporting tools used to develop a system will contribute to the success of the project (Sturrock 2008).

Methodologies and project management techniques are often used to give a project direction in the early stages of development, such as product development frameworks, work breakdown structures, and development time lines. Following a system development methodology can help to ensure that the solution generated is valid and answers the question required of it. If the project had been poorly managed without the use of an appropriate system development methodology, the development of the solution may fall short of the requirements set and provide an ill-defined and inappropriate solution (Loucopoulos and Karakostas 1995, Dehghani and Ramsin 2015).

The use of methodologies within system development, such as simulation and decision making support systems, is an area of research with a large wealth of knowledge and applications (Royce 1970, Balci and Nance 1987, Ulgen 1991, Smith and Thelen 1993). When considering the development of a resource management IT system for use in a business context, this research provides developers with the knowledge to manage their activities. There is however a number of methodologies from which a developer can choose to aid in their development efforts, which may help or hinder the overall success of the tool developed (Sturrock 2008). There is a need to understand, from a developer's point of view, which system development methodology is most appropriate for the job at hand.

3.2.3.2 *System development methodology review*

This Section of the review will focus on a review of the system development methodologies that are documented and discussed in literature for use in developing systems for use in business contexts. This review will highlight the main methodology categories that exist and their associated strengths and weaknesses when considering their application in a business context.

Inclusion Criteria

The methodologies that have been considered for inclusion within this review are all related to the field of the development of complex IT systems. The methodologies were selected due to their potential appropriateness for application in a business context with respect to their ability to incorporate the considerations found to be relevant, as discussed in Section 3.2.2.

To aid in the selection of the methodologies, a number of criteria were established by the researcher. This was done to ensure methodologies that are reviewed are relevant and provide insight into system development in a business context. The criteria relate to the subject area, the ease of use, and design of the methodology, and also its perceived appropriateness. These three main areas were seen by the researcher to be the most influential areas that will determine the applicability of the methodology.

The resulting criteria that were developed from these areas are:

- Provide procedural guidance
- Cover all main aspects of the project lifecycle
- Utilised in the development and implementation of complex systems
- Focused on the development of systems within a business context
- Achieves a balance between ease of understanding and subject matter complexity
- Perceived to address the considerations discussed in Section 3.2.2.

These criteria were utilised to assess system development methodologies, to ensure that the review focused on methodologies that had potential for use in a business context or provided insight that could be utilised elsewhere in the research.

The assessment of the methodologies against these criteria can be found in Table 5, where 19 methodologies commonly utilised in system development were assessed. The next Section will discuss the analysis of the results from this initial assessment and discuss what impact this will have on the research. The researcher recognises that this is not an exhaustive list of methodologies, but through the application of the criteria, has ensured that the set analysed is representative of methodologies available to the researcher.

3.2.3.3 *System development methodology assessment*

To ensure that the methodologies were assessed in a way that represents their ability to fulfil the criteria presented, the relative importance of each criterion was built into the assessment. The percentage weighting assigned to each criterion established the level that criterion would have on the overall outcome of the assessment. For the percentage weightings assigned, please see the second column of the assessment Table 5. The importance level was established by considering the impact that criteria would have on the quality and applicability of the methodology to produce positive results in the development of complex IT systems.

As can be seen in Table 5, each methodology was then scored 0, 1, 4 or 9 against each criterion. A 0 score would indicate no evidence available to support the claim, a 1 scoring would indicate that there was a small amount of evidence, a scoring of 4 would indicate a moderate amount of evidence and a 9 would indicate there was a wealth of evidence.

From Table 5 it can be seen that the methodologies reviewed produced results ranging from 34% to 70% compliance. Out of the 19 methodologies assessed 10 scored +60%, 4 scored 50-59%, and 5 scored below 50% compliance. No methodology of the set reviewed scored over 70% compliance, highlighting the issue that no one methodology showed a high level of applicability for use in a business context. The results from the review show that more than half the results were in the higher end range of the results, making it hard to differentiate between the higher scoring methodologies. These methodologies did not all sit in the same category or methodology theme, and represented a number of approaches to system development. The methodologies that scored worst in the review were those that utilised team based software development methods, such as SCRUM, crystal clear and Rapid

Application development (RAD). The main reason for this is the lack of procedural guidance that would include dictating activities in different stages of the lifecycle.

From the assessment, it was clear that the methodologies that scored above 60% fell into four main groups;

1. Waterfall
2. Iterative/Incremental
3. Simulation development
4. Systems engineering

The remainder of this sub section will be structured to reflect this finding. Each grouping will be reviewed in general, highlighting key example methodologies and describing the concepts, strengths and weaknesses.

Waterfall

The waterfall class of methodologies are one of the most fundamental and popular methodology sets for information system analysis and development (Royce 1970). The waterfall approach to methodology structuring aims to divide the process of system development into high-level phases, each with specific tasks to be carried out before moving on to the next phase. The phases represent the logical order of activities involved in development, that are expected to be carried out in the lifecycle of the development of a system, from initiation to deployment. The main aim of this class of methodologies is to provide users with a structured and systematic approach towards system development, while ensuring efficiency. The weaknesses that have been identified with the approach are its lack of flexibility and lack of inclusion of the user in the development process.

The earliest waterfall methodology detailed in literature was produced by Royce (1970) which is described as a sequential waterfall model (Royce 1970). The sequential waterfall model is a high-level approach to the management of the activities of a system development project and covers the main aspects that need to be considered, such as validation and verification and problem understanding. It assumes a linear sequential completion of tasks that may be unrealistic in actual development.

	Weighting	SCRUM		Sequential waterfall model		Unified Process (UP)		Spiral software development model		Rapid Application Development (RAD)		Feature driven development	
Descripton		An iterative and incremental agile software development methodology for managing product development		Sequential design process which progress steadily downwards through the phases of system development		A popular iterative and incremental software development process framework		A risk-driven process model for software projects, the spiral model guides a team to adopt elements of one or more process models.		Puts less emphasis on planning tasks and more emphasis on development, uses prototypes in addition to or even sometimes in place of design specifications.		An iterative and incremental software development process. It is one of a number of lightweight or Agile methods for developing software.	
		Score	Resultant	Score	Resultant	Score	Resultant	Score	Resultant	Score	Resultant	Score	Resultant
Provides Procedural Guidance	20%	4	0.8	9	1.8	1	0.2	9	1.8	4	0.8	4	0.8
Covers all main aspects of the project lifecycle	20%	1	0.2	9	1.8	9	1.8	4	0.8	1	0.2	4	0.8
Focused on the development of systems within an IT context	15%	9	1.35	4	0.6	9	1.35	9	1.35	9	1.8	9	1.8
Achieves a balance between ease of understanding and subject matter complexity	15%	4	0.6	4	0.6	4	0.6	9	1.35	4	0.8	4	0.8
			2.95		4.8		3.95		5.3		3.6		4.2
Business Requirements	5%	4	0.2	9	0.45	9	0.45	9	0.45	4	0.2	4	0.2
Culture	5%	1	0.05	1	0.05	1	0.05	1	0.05	1	0.05	1	0.05
Technology	5%	1	0.05	1	0.05	4	0.2	1	0.05	1	0.05	1	0.05
Complexity	5%	1	0.05	1	0.05	4	0.2	4	0.2	1	0.05	1	0.05
Uncertainty	5%	1	0.05	1	0.05	1	0.05	4	0.2	1	0.05	1	0.05
Human Factors	5%	1	0.05	1	0.05	1	0.05	1	0.05	4	0.2	1	0.05
			0.45		0.7		1		1		0.6		0.45
Outcomes	Score		3.4		5.5		4.95		6.3		4.2		4.65
	% Achieved		**38%**		**61%**		**55%**		**70%**		**47%**		**52%**

	Weighting	Crystal Clear		Microsoft solutions framework		Lean software development		Structured systems analysis and design method (SSADM)		Dynamic systems development model methodology (DSDM)	
Descripton		A collection of Agile software development approaches, focuses primarily on people and the interaction among them while they work on a software development project.		A set of principles, models, disciplines, concepts, and guidelines for delivering information technology solutions from Microsoft.		A translation of lean manufacturing and lean IT principles and practices to the software development domain.		A widely-used computer application development method in the UK, is formally specified in British Standard BS7738.		DSDM is an iterative and incremental approach that embraces principles of Agile development, including continuous user/customer involvement.	
		Score	Resultant	Score	Resultant	Score	Resultant	Score	Resultant	Score	Resultant
Provides Procedural Guidance	20%	4	0.8	9	1.8	4	0.8	9	1.8	9	1.8
Covers all main aspects of the project lifecycle	20%	1	0.2	4	0.8	4	0.8	4	0.8	9	1.8
Focused on the development of systems within an IT context	15%	4	0.8	4	0.8	4	0.8	9	1.8	4	0.8
Achieves a balance between ease of understanding and subject matter complexity	15%	4	0.8	4	0.8	4	0.8	4	0.8	4	0.8
			2.6		4.2		3.2		5.2		5.2
Business Requirements	5%	4	0.2	4	0.2	4	0.2	9	0.45	9	0.45
Culture	5%	1	0.05	1	0.05	1	0.05	1	0.05	1	0.05
Technology	5%	1	0.05	4	0.2	1	0.05	4	0.2	4	0.2
Complexity	5%	1	0.05	1	0.05	1	0.05	1	0.05	1	0.05
Uncertainty	5%	1	0.05	1	0.05	1	0.05	1	0.05	1	0.05
Human Factors	5%	1	0.05	1	0.05	1	0.05	1	0.05	1	0.05
			0.45		0.6		0.45		0.85		0.85
Outcomes	Score		3.05		4.8		3.65		6.05		6.05
	% Achieved		**34%**		**53%**		**41%**		**67%**		**67%**

		System development life cycle (SDLC)		SIMILAR process		Object oriented systems engineering method (OOSEM)		Soft systems methodology		Systems engineering "V" model		Multi agent systems engineering model (MaSE)		Balci lifecycle model		Sargent simulation development model	
Descripton		Describes the stages involved in an information system development project, from an initial feasibility study through maintenance of the completed application.		Describes a logically consistent and effective means of planning and problem solving		Provides an integrated framework that combines object-oriented techniques, a model-based design approach and traditional top-down 'waterfall-style' SE practices.		An approach to organizational process modeling (business process modeling) and it can be used both for general problem solving and in the management of change		A graphical representation of the systems development lifecycle. It summarizes the main steps to be taken in conjunction with the corresponding deliverables within computerised system validation framework.		Used to guide a designer through the software lifecycle from a prose specification to an implemented agent system.		Simulation development methodology which promotes the use of Verification and Validation		Illustrated the explicit link between the system being developed and the real world system it is attemting to simulate	
	Weighting	Score	Resultant	Score	Resultant	Score	Resultant	Score	Resultant	Score	Resultant	Score	Resultant	Score	Resultant	Score	Resultant
Provides Procedular Guidance	20%	9	1.8	9	1.8	9	1.8	4	0.8	9	1.8	4	0.8	9	1.8	9	1.8
Covers all main aspects of the project lifecycle	20%	9	1.8	4	0.8	4	0.8	4	0.8	9	1.8	4	0.8	9	1.8	9	1.8
Focused on the development of systems within an IT context	15%	4	0.8	4	0.8	9	1.8	9	1.8	4	0.8	4	0.8	4	0.8	4	0.8
Achieves a balance between ease of understanding and subject matter complexity	15%	4	0.8	4	0.8	4	0.8	9	1.8	4	0.8	4	0.8	4	0.8	4	0.8
			5.2		4.2		5.2		5.2		5.2		3.2		5.2		5.2
Business Requirements	5%	9	0.45	9	0.45	4	0.2	4	0.2	9	0.45	4	0.2	4	0.2	4	0.2
Culture	5%	4	0.2	1	0.05	1	0.05	1	0.05	1	0.05	1	0.05	1	0.05	1	0.05
Technology	5%	4	0.2	1	0.05	1	0.05	1	0.05	4	0.2	1	0.05	4	0.2	1	0.05
Complexity	5%	1	0.05	1	0.05	1	0.05	4	0.2	4	0.2	1	0.05	4	0.2	4	0.2
Uncertainty	5%	1	0.05	1	0.05	1	0.05	1	0.05	1	0.05	1	0.05	1	0.05	4	0.2
Human Factors	5%	1	0.05	1	0.05	1	0.05	4	0.2	1	0.05	1	0.05	4	0.2	4	0.2
			1		0.7		0.45		0.75		1		0.45		0.9		0.9
Outcomes	Score		6.2		4.9		5.65		5.95		6.2		3.65		6.1		6.1
	% Achieved		69%		54%		63%		66%		69%		41%		68%		68%

Table 5 - Methodology assessment

The lack of detail present in this early version of the Royce methodology, and methodologies of this type, means that developers gain only a high-level appreciation of the main development phases and have no guidance on the more detailed tasks that need to be carried out within these phases. This may mean that developers overcomplicate the tasks taken on within these phases and end up with a highly complex project to manage. Conversely developers could take an overly simplistic approach, introducing a risk if not considering important elements in enough detail. There is a need for a balance of detail required that this early version may not fully achieve.

The advantage of utilising the waterfall methodology is that it allows for departmentalisation and control of the system development. A schedule can be set with deadlines for each stage of development and a product can proceed through the development process model phases one by one, each phase of development proceeds in strict order. The main disadvantage of utilising waterfall methodologies is that they do not allow for much reflection or revision; once a system has progressed to a certain stage, it can be very difficult to go back and change something that was not well-documented or thought upon in the concept stage. Therefore, it is not advised that such a model be utilised when the requirement set is uncertain or vulnerable to change (L'Ecuyer and Ahmed 2016).

Iterative/Incremental

The Iterative approach to system development suggests the development of a system through repeated cycles, allowing developer to take advantage of lessons learnt throughout the process, as well as incorporate any changes that may have occurred. Often this will involve the development of a prototype early in the process to which the user base can react and suggest improvements. Incremental development is often utilised in conjunction with this approach, where a system is broken down into sections that are delivered separately, either concurrently or sequentially. These sections are built as pieces of a greater whole an are brought together to deliver the final system.

This development style is commonly referred to as a development of the waterfall development methodology, which has been updated to take into consideration the impact of change.

An example of an iterative methodology is the spiral model. This was developed based on a number of refinements of the waterfall model and represents the concept that each iterative cycle of development will pass through the same key stages, accumulating cost while progressing the system in its maturity (Boehm 1988). The user of the model would be expected to start at the inside of the spiral and work out, undertaking the stages and associated actions, which change as the spiral runs through its iterations.

The main advantage of using this approach is that a usable system is produced earlier in the process so this can be built upon and updated. This will mean the user of the system has a chance to engage with the system and feedback earlier. Another positive is that this approach to development is more responsive to change and can build in updates throughout the process. The disadvantages associated with this approach are that the development time scale can increase and can therefore cost more money to complete, with no reassurance of a specific end date. Also, developers will need to define the system as a whole prior to section it into increments for delivery; this also limits the use of this approach to larger scale system development that may also then require stronger more in-depth management.

Simulation Development

A simulation development methodology is a structured approach that is documented to guide developers through the task of creating a simulation of a real-world system. The simulation could be utilised to carry out a number of tasks for the user so it has to be designed in such a way as it describes the real-world event accurately but is also meaningful and easily manipulated by the user. This concept has proven to be useful when considering the development of systems in general, as the usability and appreciation of the real world will impact the overall quality of a system.

Sergeant (2001) developed a model that described the evolving relationship between a system of interest and a simulation model. Although not originally presented as a system development methodology, it does offer developers guidance when considering a complex changing system (Nance and Arthur 2006). The model explicitly illustrates the link between what happens in the "real world", for example the business system being analysed, and how it is translated into a simulation. This starts off with experimenting, hypothesizing, and abstracting theories from the real-world system, essentially system understanding, defining what is relevant to be modelled to generate desired results. An area of interest is how the model shows the results of the simulation relating back to the real world, showing how the simulation is utilised. This model also emphasises the need for continual verification and validation exercises throughout the life cycle of a project and shows the need for systems thinking i.e. how it is developed as a system and how it relates to the system it is representing.

Another example of a simulation development methodology is the Balci Lifecycle model Balci (2002). This methodology has a very similar structure to that of Sargent but does not reference the different “worlds” that exist. Overall, this model progresses through three main phases from problem formulation, to model development, and concluding with integrated decision support. There is a clear emphasis on verification and validation activities as this is the trigger for progression to the next phase. The model provides an interesting focus on problem formulation and up front understanding, although there is no explicit connection made to any requirements elicitation. Also, the model makes a link to show the system will be used in practice i.e. for use as a decision support system through the inclusion of the “Integrated Decision Support” development phase.

The simulation development class of methodologies is one that specifically highlights the steps required when developing a simulation that portrays dynamics that exist in a real-world environment. Due to the fact that these types of systems are generally utilised to analyse data or to test theories, the systems that are produced can be very specific and are not aimed at the user as a tool. However, the systems that are developed are focused to represent the business system under analysis as closely as possible, therefore the outputs that are produced will provide a closer representation to the truth. The users of the system will have to fully buy in to the output from the tool as it would be predicting an outcome and may not represent actual data for managers to make decisions from.

Systems engineering

Taking a systems approach is a different way of tackling complex problems through the understanding of complexity and how systems work together via their interrelationships (Smith and Thelen 1993). A systems approach looks at the system and its environment and sees the system as a whole, which produces outcomes greater than the sum of its parts. Systems engineering has traditionally been applied to the development of complex IT systems, but its concepts are easily applied to the development of systems in general.

An example of the utilisation of systems engineering in the development of systems is the Systems Engineering (SE) process mode (Bahill and Gissing 1998). The methodology utilises systems thinking to promote the top down approach and the need for clarity in understanding the problem statement, ensuring that systems are developed that are appropriate and fit for use. The systems engineering process model, developed by Bahill and Gissing, is an example of a systems engineering methodology that highlights the main stages in a project. The initiator for the process is the documentation of the system requirements. The next step is to develop a direct statement of the problem to gain general consensus of the scope and direction of the project. After this is an investigation of the alternative course of action available to ensure that the correct progression is made. The system is then modelled to facilitate the clarification and assessment of requirements. The integrate stage refers to the designing of interfaces and the bringing together of system elements so they can work as a whole. The system is then at the point where it can be launched and its performance assessed in its entirety. At every stage of the process the system is evaluated i.e. verification and validation, to ensure the system is adhering to requirements and not veering off track.

One of the most well-known and utilised systems engineering methodologies is the "V Model" which aims to organise the development phases of a system into levels of complexity with the most complex item on top and least complex item on bottom. This arrangement places the requirements directly opposite to the product's operation at the end, and the design next to verification. The justification for taking this approach is to ensure that when an engineer is creating a system for a customer, the developer/engineer can directly link stages together that impact one another so that they can ensure that the correct method is taken towards validation and verification. For example, the overall concepts of the system that are specified at the start of the process are directly connected to the operation of that system, therefore the system will need to operate in a fashion that fulfills its stated concepts. A number of variants of the model have been developed for differing uses, all utilising this standard approach to development, validation and verification, focusing on requirements development (Forsberg and Mooz 1995, Forsberg and Mooz 1992).

The advantages of using systems engineering methodologies are that they provide developers with a holistic view of the system development process, with a clear emphasis on the need for requirements and validation and verification throughout. Systems thinking and philosophies are utilised when adopting these methodologies that ensure developers are making sound decisions and are taking in consideration a number of factors that will ultimately affect the utility of the produced system (Forsberg and Mooz 1995). Systems engineering methodologies are most applicable to highly complex and uncertain environments that will require a higher degree of management and analysis. System engineering is also backed up by a wealth of methods and tools that enable the process to be as effective as possible; this is not represented in the high-level methodologies.

3.2.3.4 *Summary*

It is clear that a system development methodology will bring needed guidance when developing a system for use in a business context. Particularly in the case where the system may be complex and uncertainty may impact the outcome. From the analysis of the methodologies available there was no clear methodology that would provide the best support for the development of a system in a business context. All methodology types discussed provide benefits and have associated drawbacks, which need to be taken into consideration when applied in a business context. Further understanding is required to establish how to best analyse and select a methodology for use that will provide the level of support required.

3.2.4 Application of system development methodologies in business contexts

This Section of the literature review will focus on answering the following question;

Q4. How are methodologies applied in business contexts and how does this impact the development of systems in business contexts?

By answering this question, the researcher will be able to understand how methodologies, such as those discussed in the previous Section, are utilised and applied in business contexts. From this understanding, the researcher will be able to consider how the business context may affect the application of a methodology for use in system development.

3.2.4.1 *System development standards*

In reaction to the growing complexity of system development and proliferation of methodologies, a common framework for process descriptions for describing the life cycles of systems created by humans was developed. This takes the form of an International Standard named “Systems and software engineering – systems lifecycle processes”. The purpose of the standard is to provide a holistic approach to system development, which does not dictate methods but the processes and the outcomes that are expected. Adherence to the processes and production of the desired outcomes will aim to ensure that systems are developed in a fashion that will ensure quality.

The users of the standard are expected to select the lifecycle and methods they deem appropriate and map across the processes within the standard to illustrate compliance with the standard. For this reason, this standard cannot be deemed as a practical methodology with procedural guidance, as those that were reviewed in Section 3.2.3. The standard clearly states the users are responsible for selecting and applying appropriate methodologies, methods, models, and techniques suitable for the project. Each process within the International Standard is defined by a purpose, outcomes, and activities. ISO 15288 comprises 25 processes which have 123 outcomes derived from 403 activities (Standards 2015).

The users of the standard can claim either full or tailored compliance to the standard. When claiming tailored compliance to the standard, it is essential that “Appendix A” of the standard is adhered to. The inclusion of this functionality in the standard shows recognition of the need for tailoring for specific contexts, as well as the fact that methods are not specified throughout the document. The tailoring process references circumstances that influence tailoring of the standard:

1. Stability of and variety in operational environments
2. Risks, commercial or performance, to the concern of interested parties
3. Novelty, size and complexity
4. Starting date and duration of utilisation
5. Integrity issues such as safety, security, privacy, usability, availability,
6. Emerging technology opportunities
7. Profile of budget and organisational resources available
8. Roles, responsibilities, accountabilities, and authorities in the overall lifecycle of the system
9. The need to confirm to other standards

The standard dictates that when making tailoring decisions, input must be obtained from the systems stakeholders, interested parties and contributing organisational functions, and that decisions are made in accordance to the Decision Management process defined within the standard. Although the standard itself, and "Appendix A" regarding its tailoring, does provide in-depth guidance regarding the processes required in the lifecycle of a system, there is little in-depth procedural guidance provided when considering the tailoring approach. As the expectation is that methodologies are commonly adapted to fit a business and the system to be developed, this guidance is critical to ensure a methodology is providing the outcomes that are required.

The standard shows that there are many other considerations that are to be made when considering the development and management of system development in a business context. It also highlights that the act of tailoring is commonplace and encouraged in order to manage complexity. However, when considering the application of a methodology that fits the user's needs, that will require tailoring, the procedural guidance provided is insufficient.

3.2.4.2 *System development methodology use in practice*

A system development methodology offers an alternative approach to the often risky, informal and intuitive system development methods, which are frequently used in practice within businesses. Many formalised SDMs available are put in place to reduce the risk of project failure, when compared to informal approaches as SDMs provide an engineering-like discipline to the development process which requires explicit deliverables that are used consistently (Roberts and Hughes 1996). One of the reasons for the formalisation of SDMs was to ensure that the burden of the development was put on the process rather than the developer, thus the developer's skills become more interchangeable and utilised more effectively (Riemenschneider, Hardgrave et al. 2002). However, with the changing nature within business environments the short-term focus often dominates, making traditional lifecycle approaches no longer appropriate, as the application of the methodology would deliver outputs after a number of years. Another reason lifecycle approaches have fallen out of favour is that a large portion of development done in businesses can be termed as configuration development, where customisation of an existing package occurs to incorporate local practices (Fitzgerald 1998). Traditional approaches do not cater for this and may not give developers the support they require.

In an empirical investigation into the adoption of system development methodologies, Brian Fitzgerald conducted extensive research into the application of SDMs in business contexts. This was achieved by carrying out a postal survey that was sent to 776 organisations, 162 responded and were used in the research outcomes. Among the main findings of the research was that 60 percent of the respondents were not using methodologies, also only 6 percent of respondents reported following a methodology rigorously (Fitzgerald 1998). In other work Fitzgerald researched the use of SDMs in practice and deduced that practitioners will not adopt formalised methodologies in their prescribed form and that they may be modifying and omitting aspects of the methodology in a very pragmatic and knowledgeable fashion (Fitzgerald 1997).

Further research in this field adds to this understanding, which consisted of a survey of over one hundred organisations indicating that nearly 65 percent of the organisations questioned developed their methodologies in house, with a further 85 percent stating they adapt the methodology used on a project by project basis (Russo, Wynekoop et al. 1995). This can be backed up by previous research which stated that the appropriate methodology for use will depend on the context i.e. the organisation itself and the users and analysts who are developing the system (Avison and Wood-Harper 1991).

This research shows that in practice methodologies are not being applied in a standard manner and are being tailored and updated to fit the context within which they are expected to be utilised. Therefore, the mandating of the use of a methodology that does not allow for this adaptation within a business context would ultimately fail and not produce the results required. This fundamentally raises the question whether mandating a methodology is the correct course of action for businesses, or is a more business context related way of managing the development of systems more appropriate.

Steven & Brook (1998) stated that the basic system life cycle is inevitably tailored from project to project as no fixed pattern is uniquely suited to develop all products. This makes the resultant life cycle created much more complex (Stevens, Brook et al. 1998). They went on to state that a life cycle matched to the needs of the project will significantly reduce development risk, yet it is often chosen casually (Stevens, Brook et al. 1998). This statement is backed up by Clarke (2012) who specified that when it comes to defining a software development process, it seems likely that the claim that "one size fits all" is myth and that one of the central reasons accounting for this is the rich variation in situational contexts (Clarke and O'Connor 2012). Within Clarke's extensive review, it is stated that there is a breadth of knowledge and contributions already evident within this field (Clarke and O'Connor 2012). He cites work produced by Cameron (2002) in relation to the identification a set of five process tailoring factors, as well as Ferratt and Mai (2010) who identify a set of six factors affecting process tailoring decisions (Cameron 2002, Ferratt and Mai 2010).

It is clear from this analysis that much work has been conducted in the field of life cycle and system development methodologies. This fact is also backed up by the extensive knowledge gathered in Section 3.2.2 of this review, that summarised the development and implementation considerations found in literature to be relevant. With this furthered understanding of the problem domain, it is clear that much work has been done in this field in relation to the factors that affect the tailoring of system development methodologies. Therefore, it was established that the contribution to knowledge to be gained in this area is very limited.

In reaction to this fact, a further analysis of literature relating to the areas of methodology tailoring and application in business contexts and was conducted through use of the search tool ProQuest. The aim of this further analysis was to establish the use of tailoring guidance within literature in practical applications and to analyse the procedural guidance offered to managing complex business contexts. This will establish how the body of knowledge has been translated into practical and applicable guidance for use in business contexts.

To ensure the search returned relevant and high quality results the search performed utilised key terms and was filtered to only include peer-reviewed journals. The key terms utilised were "Tailoring" and "System development or SDM" and "business context". Initially this search returned 25 results, these results were analysed by the researcher for their relevance and possible application to the problem domain. From this initial analysis, it was found that 3 of the results provided any insight into the problem of interest.

The references found to be relevant and their descriptions are as follows:

- **"Control of flexible software development under uncertainty"** (Harris, Collins et al. 2009)
    - This paper asks when should software development teams have the flexibility to modify their directions and how do we balance that flexibility with controls essential to produce acceptable outcomes.
    - Focuses on the development of a control theory called emergent outcome control, which is a tool for evaluating methods by focusing on types of control.
- **"Systems delivery: evolving new strategies"** (Rockart and Hofman 1992)
    - A framework for addressing decisions regarding investment in new system development tools is presented. This systems delivery framework includes 2 phases: envisioning the future environment and managing the transition.
    - Focuses on change management principles and how they are applied to changing the way IS systems are delivered.
- **"Rapid system development (RSD) methodologies: proposing a selection framework"** (Jain and Chandrasekaran 2009)
    - The primary focus of this article is to provide a framework for comparative analysis of rapid system development methodologies. The purpose of this framework is to help the project managers and systems engineers choose an appropriate rapid development methodology to suit their development context and environment.
    - Focuses on rapid development methods and approaches to system development, such as agile methods, to ensure system success in a shorter time frame.

Although all three references add to research in the area of systems development and do mention and address methodology tailoring within their research, not one of the references explicitly offers a procedural guidance for use by businesses is expected to tailor a methodology to fit their specific requirements. There is no mention of complex business contexts in any of the three references, also all three references have a very different focus and achieve very different research outcomes.

There is therefore a gap in knowledge elicited when considering the practical application of contextual complexity factors experienced within complex business contexts into the tailoring of system development methodologies. Guidance has been created in this area but the procedural element has not been developed extensively or been practically applied in an example case study. Therefore, this area of research will be utilised to focus the research and will provide a contribution to knowledge that will produce novel results not currently represented in literature. In fulfilling this contribution to knowledge, both an academic and business advantage will be delivered. The remainder of this thesis will focus on filling this identified gap and will develop and apply an approach to the tailoring of methodologies for use in complex business contexts when developing systems.

3.3 Problem Formalisation

The objective of this review was to analyse and discuss existing literature in the areas of system development in complex business contexts, in order to formulate a research problem from which the further research can be derived. Through the course of the review the research areas of complex business contexts such as resource management in NPD, systems development and implementation considerations, systems development methodologies and application of methods in business contexts were discussed.

The main outcomes of the review have been that many different resource management systems exist, as well as methodologies for their development. To ensure that a system is developed effectively, a number of consideration must be made that should be represented in the methodology that is utilised in its development. Although a number of formalised methodologies exist, no one methodology can provide the support required for the development of resource management systems in an NPD context. In general, it is an accepted concept that no one methodology can provide the guidance needed for all types of development. Literature also states that in reaction to this fact, developers on the whole do not follow formalised methodologies, and tailor these to fit the business led problem they are solving. However, they are still required to ensure that the development meets a high standard and is governed in a manner that will ensure a quality output is delivered.

Therefore, the question is that if developers are expected to develop quality results through tailoring methodologies in reaction to their context, how is this tailoring achieved effectively? A field of research exists that has interpreted the factors and decisions that are to be made when considering the tailoring of system development methodologies, offering guidance to system developers in the process of tailoring. However, there is limited knowledge regarding the application of this guidance in a procedural format with it basis in a factual case study. Without this explicit and in-depth guidance on how to achieve a tailored methodology within a complex business context, developers may be utilising inappropriate and ill-fitting tailored methodologies, or no methodology at all. This introduces a level of risk to the development that may increase the likelihood of the resultant system not being accepted, adopted, or sustained in the business.

In reaction to this, the research will focus on developing a tailoring approach and associated case study that will guide businesses when considering the use of a system development methodology for the development and implementation of systems within complex business contexts. The tailoring approach must ensure that the considerations that impact the acceptance, adoption, and sustainment of the system are taken into account and are built into the system development methodology. This will be enforced through the application of this guidance in a practical example, from which furthered understanding of the tailoring process can be achieved.

Part two: Approach and findings

4 Formalisation and application of methodology tailoring approach

ISO Standard 15288 "Systems and software engineering – systems lifecycle processes" purposes a holistic approach to system development. However, the standard does not dictate methods to be utilised, but the processes and the outcomes that are expected in systems and software engineering. ISO 15288 also advocates the need for tailoring methodologies to fit business requirements, but does not provide procedural guidance on how this is to be achieved. From a review of literature, it was also ascertained that there is little procedural guidance backed up with practical application that could offer guidance to system developers who are dealing with a complex business context.

The aim of this Section will be to introduce and discuss a formalised approach to the tailoring of system development methodologies in complex business contexts, backed up with a practical application in a complex business context. This approach will provide businesses with the guidance required to effectively tailor methodologies to fit their complex business contexts, as well as the insight into how this was achieved and the limitations that may exist.

The Section will start with a summary of the tailoring approach and will go into detail in each sub section as to its specifics as well as describing its application in DePuy. The development of this tailoring approach was an exploratory process and the researcher developed and refined the process through its testing and application in a business context. The output discussed here is the outcome of this exploratory process and is presented as one of the main contributions in this research. Therefore, the Section will be structured to highlight the way in which the approach was formalised. An overall summary will be described, then each Section of the approach will be individually considered, complimented by a summary of its application in DePuy.

4.1 Approach Summary

The tailoring approach discussed in this Section aims to utilise system development knowledge ascertained from both literature and business examples to develop a tailored methodology for use within complex business contexts. The approach, at this high-level, states the main steps that are to be completed in the process to achieve a fit for purpose tailored methodology.

- **Identify contextual factors that influence system development:** Determine what factors from both the business context and literature that will affect the development of a system, develop a synthesised list that will influence methodology tailoring, discussed in Section 4.2.1
- **Establish if a system already exists that fulfils requirements:** Asses potential systems against high level requirements to establish if a system exists that can be utilised, determine how the outcome will affect the tailored methodology, discussed in Section 4.2.2
- **Select desirable attributes from other methodologies:** Discuss relevant methodologies and the aspects that could be utilised to influence the design of a tailored methodology, discussed in Section 4.2.3
- **Formalise detailed tailored methodology:** Utilise learning from prior three steps to tailor a methodology and document its structure and approach, discussed in Section 4.2.4
- **Evaluate methodology:** Assess the incorporation of the contextual and methodology influences on the tailored methodology developed, Discussed in Section 4.2.5
- **Implement in the business:** Apply methodology in the business context to develop and implement a system, discussed in Sections 4.2.6 and achieved as an example in Section 5

Each of these steps will be discussed in more detail in the following subsections, giving more detail in how to carry out the step and the expected outcomes that it will generate.

4.2 Tailoring approach description and application

This sub section will describe each approach step sequentially, describing its purpose and structure. This will be complimented with an overview of how this was applied in practice, highlighting how this approach can be achieved practically in a business context.

4.2.1 *Identify contextual factors that influence system development*

The first step to be completed in the tailoring approach was to establish the contextual factors evident within the complex business environment that would have an impact on the development and implementation of a system. These factors will be key when considering the development of a system for the business context and should therefore be highlighted prominently in the tailored methodology utilised for its development. This will be complimented with research conducted external to the business context, to ensure that important factors, although not highlighted in the review, are being considered. From an assessment of the factors found relevant in the business and from literature and synthesis of the two can be achieved that will influence the tailoring process.

To achieve this, an in-depth review of the business context is required to be undertaken that will highlight issues and complexities that will impact system development. This can be achieved through contextual interviews, backed up with senior management decision making to highlight key areas. To gain greater insight into the complex nature of the business, it is recommended that direct experience of the processes and complexities evident be experienced by those researching it. Therefore, immersive research will aid in developing a greater understanding. To determine factors that may not have been picked up, a thorough review of supporting literature is required. This will give an insight into factors that may not have been clearly evident. In comparing and assessing the two set of factors, a synthesised list can be developed. This list is the main output of this step and will be utilised further on the tailoring approach, outputs from the interview conducted in DePuy can be found in the attached Appendix A.

4.2.1.1 ***Application in DePuy***

On consultation with DePuy, it was established that DePuy's priority and area where most impact could be made, and therefore most benefit could be realised for the company, would be in relation to system development and implementation in the management of multi-project resource allocation and scheduling. This decision was made through managerial discussion and strategy setting the business had carried out prior to the involvement of the researcher.

This focus was strengthened and made clearly evident through an initial analysis of DePuy's current resource management process and the systems that are currently utilised, which was achieved through the application of a number of elicitation techniques. The process and methods that were utilised can be seen in a summary in Figure 3.

Figure 3 – Business context research process

The research focused initially on identifying what areas of the resource management process were challenging and why, while also discussing the current resource management context. This would highlight what challenges the business context had on system development. The main technique that was utilised was interviews, which were carried out across all functions within the business at a number of levels of management. The aim of this was to achieve a balanced view of what resource management challenges existed and how they affected the business, and therefore the development of a system that would be expected to perform in that environment. The outcome from these interviews was a high-level appreciation of the main areas of concern within the business context, however this understanding was not focused enough to determine exactly what was required of a tool to provide benefit and value to the company. A further in depth appreciation was required to gain more insight.

With this information, the researcher was then able to focus their questioning of senior management to elicit which areas of concern highlighted in the interviews would provide the most benefit if addressed. At the same time the researcher also pursued discussions regarding how senior management would expect a new tool to integrate into the business and the expected barriers that would be in place. Outputs from these interviews can be found in the attached Appendix A.

The researcher also took part in an in-depth observation and participation in the resource management activities that were taking place within DePuy. From these exercises, the researcher experienced the challenges first hand and was able to understand the barriers and requirements a system would have to achieve to be successful. The researcher interacted and worked alongside key knowledge holders, discussing requirements and barriers thoroughly. The first-hand experience of the context gave the researcher the ability to understand and contribute to the elicitation of the requirements, in a manner that would have not been achievable through interview and inclusion techniques alone.

Contextual Interviews and senior management discussions

To gain an in-depth understanding of the business context and factors that will affect the development and implementation of a system within that environment a number of semi-structured interviews were conducted. These interviews were focused on individuals within the company who have direct contact with the resource management system in place and can provide insight into how it operates and the factors that impact its performance.

Over the course of 3 months, the researcher interviewed 34 people across the business, split into project managers, line managers, business leaders, section leaders and programme managers. All interviewees were selected with help from business leaders and initial contact was made prior to interview to discuss the objective and structure of the interview. Due to time and geographical constraints, the interviews were a mix of either face to face or phone conversations. All interviews covered a core set of questions regarding the uncertainty and complexity of resource management within the context of DePuy, with flexibility to explore issues that were raised in discussion. The interviewees were divided into contextual and senior leadership discussions. The leadership discussions would utilise the output from the contextual interviews to further discuss the business and its resource management approaches. The general contextual interviews were conducted with the Project managers, Line managers and Programme managers, the senior management discussions were held with the Business leaders and Section Leaders, as shown in Table 6. This list of interviewees has been anonymised for confidentiality reasons.

Due to the critical nature of the contextual interviews the direct responses from the question set were not allocated to an individual in the interviewees list. This decision was made to ensure that interviewees felt they would not be challenged on their responses by senior management when this went to review, and to ensure that the responses that were gathered were truthful. The output from the interviews were analysed and were sorted into logical groupings, this can be found in the attached Appendix A, which has been altered to ensure anonymity of those who contributed as well as to protect confidential information.

Grouping	Number of participants
Project Managers	10
Line Managers	6
Business Leaders	9
Section Leaders	3
Programme Managers	6
Total	**34**

Table 6 - Interview grouping numbers

Through the discussion and assessment of the contextual interview outcomes, senior management were able to identify and highlight areas that they believed to be more important, or in line with their strategic ambitions. They were also able to discuss thoroughly areas of potential difficulty and barriers to progression. The outcome from this was a clarity of what issues they have and an agreed plan of action to improve their business.

Resource management process observation and participation

In an effort to further understand the current resource management process, the researcher played an active role and aided managers in the gathering and manipulation of resource information for use at a portfolio level. This activity enabled the researcher to experience first-hand the complexities and barriers DePuy commonly encounter. This method of involvement was chosen because of the complex nature of the problem and the fact that the researcher would be able to learn and appreciate more readily the complexities when compared to less intrusive methods.

The process involved the researcher taking over the resource refresh process and running it in conjunction with the responsible manager. This meant that the researcher was responsible for the gathering and analysis of resource data sourced from a number of projects and departments in the business. The data was on occasion incomplete or inaccurate due to changes that had occurred, making any comparison between refreshes inconsistent. Changes that were highlighted were the addition of new project to the portfolio, as well as the removal of completed and stopped projects. Also, there was natural fluctuation in headcount across all departments. Overall this was a three-month exercise and gave the researcher the ability to understand the process and constraints that were evident within DePuy.

From this activity, the researcher developed a detailed understanding of the current process, as documented in process maps that can be sourced in attached Appendix B. The researcher also produced an in-depth analysis of the current state of the allocated resources for each department and the business as a whole. This analysis was utilised to make allocation and head count decisions within each function and for the business as a whole. This output was produced as an in-depth review and presented to the business managers as both a presentation and a business pack. The presentation of material followed a standard shown in the below Figure 4, which has been altered to ensure that confidential information has been protected.

These issues, although specific to DePuy, offer an insight into the factors that may be evident in other similar complex business contexts and should be considered as a representative sample.

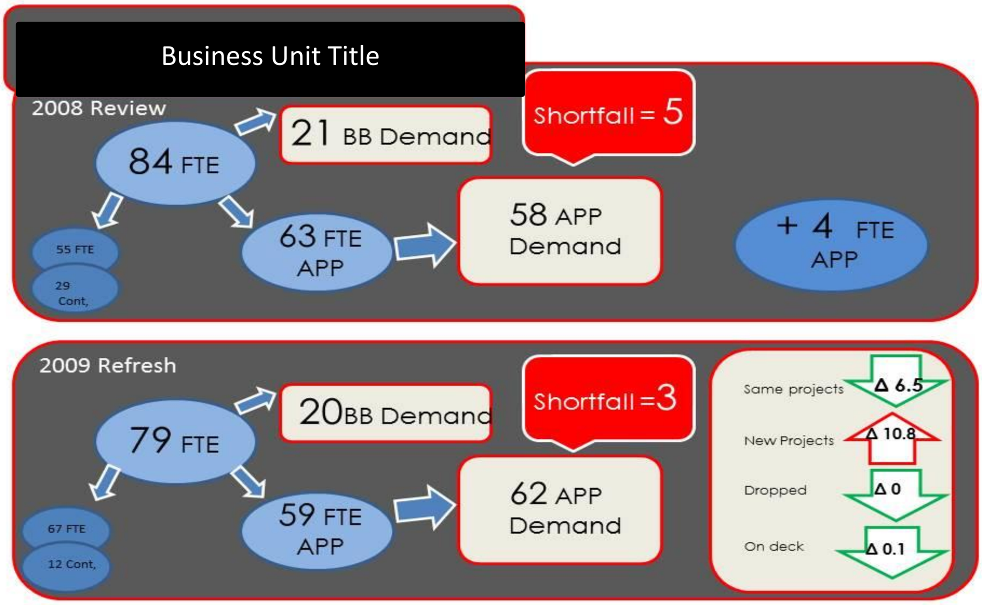

Figure 4 - Resource analysis standard

Business problem context

DePuy have a constrained amount of resources to allocate to a project portfolio, meaning that resource shortages are common place. These shortages are a source of great anxiety and frustration as they can have an impact on the quality, time scale and cost of a project, if not correctly managed. There is a reliance on contractors to fill resource shortfalls, which bring a number of other complexities such as training and skill level that require to be managed.

Currently the allocation and review of resources being managed through a resource review process, which aims to collect resource allocation information on each project from each work function, in order to analyse if any work function has been over or under allocated. This resource allocation information was then used to support decisions regarding the scheduling of projects, as well as the possibilities of altering staff levels and stopping projects. This process, although providing benefits, is far from ideal and is considered to be time consuming and complicated. There is therefore an explicit need to improve this process and aid in the improvement of DePuy’s capability to manage multi-project resource allocation and scheduling.

Businesses often experience resource constraints, especially when working within a multi-project environment when resource are shared across projects. This problem domain will have an influence on the system that will be developed for use in this business context. Therefore, a thorough and in-depth understanding of this context is required to ensure that a system that is developed can provide support to manage the problem and add value to the user group.

Software acquisition and approval

An overriding constraint experienced within DePuy’s business context is the management of software use, which aims to standardise the software tools and packages used within all Johnson and Johnson businesses. This means that only Johnson and Johnson approved tools and software can be used within DePuy. The process of getting a tool or software approved can be long and arduous, without a guarantee of a successful outcome. The software utilised in the efforts to aid DePuy in their resource management must therefore already be approved for use in order to minimise the risks associated with waiting for a proposed software or tool to be approved.

There is also a concern when considering the costing of software. Traditionally larger software suites can be very expensive to customise, integrate, and maintain, resulting in a very large bill to the end user. Therefore, the costing of such a software or tool must be taken into consideration within this approval process.

As all businesses deal with software as a means to enable the use of systems within their businesses, this factor will affect many businesses. The software utilised as a systems platform, as well as the systems within the business it will have to interact with, will hugely influence the systems development and implementation.

Analysis requirements

DePuy's analysis requirements for a resource management system are all related to portfolio management. These requirements were collected through observation of, and inclusion in, the current resource management process.

These were supplemented by interviews with process owners, and are as follows:

- Review all resources requirements for each project, over all work functions – highlight the resources required by each work function at a point in time to complete the work that has been set.

- Compare resource required against resource available – illustrate the over or under allocation of resource in a function when comparing what is needed against what has been allocated.

- Make customised portfolios by easily including and excluding projects from analysis – enable managers to make real time changes to what projects are included to comprehend the impact of adding or taking away a project.

- Alter project start dates – ability to move back the start date of a project to either postpone its start or pause an in-flight project, to assess the impact that this may have on resources.

- Enable live analysis in meeting context – Promote live use of the system so that managers can contribute in a team meeting context.

These analysis requirements highlight DePuy's need for the ability to manipulate data quickly and easily. The aim of doing this will be to establish more effective and efficient scenario analysis that will enable better decision-making. The analysis will focus on the resource loading of projects, from a multi-functional standpoint, so that resourcing issues can be highlighted, for example the over allocation of resources or the consistent lack of resources in a work function that could indicate a bottleneck. This analysis alone will allow managers to assess the current as-is resource situation, through the inclusion of user manipulated factors such as start dates of projects, as well as the inclusion or exclusion of projects, managers will be able to assess potential future resource scenarios.

A key requirement discussed by DePuy throughout interviews and managerial discussions was that for a resource management system to succeed in DePuy it must be able to be utilised in a meeting context. This will mean that managers can discuss alternatives and come to informed decisions quickly, instead of searching for data that will take months to detail and then ultimately making decisions based in their gut instinct.

The requirements for analysis expressed by DePuy will impact the development of a system dramatically and should be investigated thoroughly to ensure that a system is developed that will meet the need expressed by the customer.

Development/implementation requirements

When considering taking on a task such as system development and/or the implementation of a commercial of the shelf system it is practical to consider the skills, resources and time frame you require through the course of the activity. An understanding of the skills required would give you an appreciation of any skill gaps that may exist and will aid in your assessment of individuals who will be able to carry out the work required. Also, an appreciation of the resource requirements of the activity will enable mangers to effectively manage the allocation of resources to the project to ensure that the task can be managed effectively. Lastly, the time frame of the task will have an effect on how long the resources will be allocated to the task, effectively taking up business time and expense.

It is crucial that in the development and implementation of systems in a business context that the development/implementation requirements are realistically taking account of to ensure the business can realistically sustain the activity. If there is a considerable skills gap, lack of dedicated resource or a constriction on time the task can be allocated this must be taken into consideration.

Usability

The overall usability of a system can be a major factor when considering the development and implementation of systems within business environments. This is mainly due to the fact that systems that are perceived to be overly complex or hard to access and use may be perceived to make the operation of that person's job more difficult, making it less likely for them to accept, adopt and sustain that system. In this instance, an individual will either struggle or find another method, resulting in a system that is not accepted or adopted. Usability can be broken down into two main areas i.e. the clarity of the results presented to the user, and how easy the system is to use. The level of usability of the system is often down to the design and implementation of the system within the business, which can be dictated by the technology utilised, as well as the task it is to operate. For example, systems developed for general use tend to be very easy to use and accessible, making the assumption that there is no need for any specialised knowledge to use the system.

However, this may provide an overly simplistic view of the requirements promoting a negative image of the system among demanding users. More in-depth and advanced applications may require more sophisticated and complex functions, therefore requiring more complicated systems. These systems may overwhelm the basic user but provide the functionality and rigour a more demanding user would expect. It is therefore required that the usability of a system is effectively tailored to the requirements of the intended user group, and is presented in such a way to ensure the appropriate level for that user group has been achieved.

4.2.1.2 *Review of system development and implementation considerations found in literature*

In this sub section, the research findings from the business context will be discussed in line with the development and implementation considerations found to be relevant in literature.

This assessment will strive to either substantiate or disprove their influence on the development and implementation of system in complex business environments. From this analysis, a wider set of general influences can be determined based on a real business context and examples. Through their discussions suggestions for the mitigation and management of these influences through the development and implementation will also be discussed, based on research findings from DePuy's business context.

Business requirements

When considering the development of a system, it is essential to first reflect on the purpose of that system, and its objectives, which will need to be met to be successful in its application. Therefore, in the development of a methodology this consideration is often included as one of the upfront activities, where information is gathered for utilisation later on. The information gathered at this point will direct and shape the type of system that is developed, so the methods and approaches taken towards this activity are particularly influential. For this reason, it is crucial that information gathering and the understanding of requirements is incorporated in a way that will reflect the complexities evident within a complex business environment.

Due to the fact that DePuy is a NPD company, they have had exposure to the importance and influence that requirements have on the success of a system. This meant that naturally they initiated their resource management system development with information gathering, with particular interest around how information is displayed for decision-making purposes. However, due to the fact that the development was carried out by those close to the process, the bigger picture could often be neglected, although implicitly understood. This would mean that development would become isolated, working around issues as they developed or became evident. This may be due to the fact that the NPD influence meant that DePuy focused on the functional aspects primarily, working around the business constraints as they arose. This business context means that there is a clear need for a higher level of guidance given in the upfront steps to consider the wider implications which the business context will have on the development of a system.

Therefore, when considering the development of a system within a complex business environment, it is important that this issue be addressed accordingly as it will have an impact on the development and implementation of a system, as discussed in Section 4.1.2.1. In reaction to this fact, the methods and approaches included need to be designed to draw out not only the functional requirements, but also give the non-functional, business related, requirements that will have influence.

Culture

An influential factor when considering the adoption and acceptance of a system in a complex business environment, is the culture that is evident. This culture will define the willingness of those who are expected to take on the system, and their potential attitude towards the system itself. Therefore, when considering the development and implementation of a system, those who are expected to use the system need to be considered to ensure they develop buy in and understand the benefits that the system will provide them.

As the system being developed for use in DePuy was addressing the long-standing issue of resource management, the attitude towards change was overwhelmingly positive. DePuy would readily question and change when faced with potential to improve. This meant that the promotion of a newly introduced system in this context would not require as much management. However, the issue in this context is the management of expectations. Therefore, for DePuy's case, a clear and honest understanding of what could be produced and what it would achieve, was a requirement.

In other business contexts however, the idea of an accepting and positive culture may not be the case, and more management may be required in other areas i.e. promotion. It is therefore essential that when considering the development and implementation of a system this issue of culture needs to be addressed. The means of doing this will require particular focus on the management of the balance between promoting adoption as well as managing expectations.

In development of the system this will be evident within the initial stages, where the context within which the system is to be developed will be described. Culture, in particular the attitude towards change, should be taken account of and mitigation efforts for any negative eventualities be suggested.

Technology

As most systems utilised in businesses now depend on technology, the consideration of how these technologies not only work for the purpose proposed but also how they interact and work with existing technologies is highly important. The choice of technological implementation can affect the potential success of the system, for example a computer program will be run by an operating system or software package. If a chosen operating system or software package cannot run the programme this is an issue, but issues can also be found if that software does not work on the computers purchased, and cannot connect to other software packages i.e. integration. When developing a new methodology, implications of a technology choice needs to be highlighted, discussing both its individual capabilities and its interoperability with the wider technological landscape.

In relation to resource management, DePuy did not utilise any specialist technology, and relied heavily on manmade systems based in Excel spread sheets. The main reason for this choice was that the resource management process was often ad hoc in nature, which lends itself easily to Excel's flexible and quick user interface. Another issue that had influence was the control of un-licenced software usage throughout the company. This was put in place as an effort to provide a level of consistency across all business units. Therefore, as a resource management system was to be implemented it would have to be procured and added to the system through a lengthy and arduous procurement process. For this reason, the use of specialised technology was extremely limited.

These limiting factors experienced in DePuy highlight the need to assess and take consideration of the technological landscape to ensure the system developed fits. When considering the development of a new methodology this issue should be considered as one of the up-front assessments which are taken place. This will ensure that the technological constraints are incorporated into the decision-making process regarding the allocation of a technological solution to the system proposed.

Complexity management

The level of complexity experienced in any project will require an appropriate level of management. Therefore, when considering the development of a new methodology an appreciation of complexity identification and management needs to be included. This will require the creation and maintenance of an appreciation of the level of detail required in the system to be delivered, as well as the complexity experienced in the management of the process itself, meaning that the management of complexity will have two aspects to include in methodology development.

When managing resources in DePuy, emphasis was put on the high-level picture i.e. the portfolio view of the projects. This meant that the level of detail regarding resources was broader than it was deep, meaning that there were a lot of information regarding project allocations, but no detail regarding resource identities, capabilities, and other commitments. These issues were dealt with at a different level of management. This scope meant that any system developed for the management of resource would have to take account of this level of detail.

From this example, it can be said that the scope of the system to be developed is an integral part of managing the complexity of the system to be developed. Therefore, a thorough and in-depth understanding of this scope, and the implications of what is in and out of scope, is essential. This influence would have to be considered in the upfront stages of system development, to ensure that the understanding gathered at this stage could be utilised in the development of a solution.

Uncertainty management

The level of uncertainty that is evident within a management system will have an impact on the level of management that is required to mitigate any possible negative effects. Therefore, when considering the development and implementation of a system that manages any function of the business and appreciation of uncertainty within its analysis of data needs to be developed. This will mean that uncertainty within the problem domain will have to be identified, in DePuy this will mean understanding both in the affect which uncertainty has on the decision-making abilities of managers, and in the management of projects.

Within DePuy, uncertainty manifested itself in a number of ways; where it had a large impact was in decision-making processes regarding resource management. For example, there was a degree of uncertainty regarding the resources that would be available and when, as this information was not managed and shared a high level for visibility. Uncertainty was also experienced in the ever-changing project environment, as with the continual learning and updating of project requirements, resources would be impacted. This uncertainty led DePuy to become more ad-hoc in nature and manage resource issues as they arose, to maintain a level of resource balance over the business.

An appreciation of the uncertainty experienced, in the scope of the system under examination, is required when considering the development of a solution. The uncertainties will determine what the solution needs to do to provide the information the user will require to manage the system of interest. For example, in DePuy's case, managers were uncertain as to the impact their resources requirements would have on the performance of other projects, as resources were sourced from a constrained centralised resource pool. A management system would provide information around this issue in an effort to provide managers with information to make better decisions.

Human Factors

As resource management generally involves the management of human resources, this can mean that a number of personal factors can influence the management process. These factors need to be considered as there is a risk that any decisions or plans made will not be effective. When considering the development and implementation of a system, human factors may not traditionally be incorporated, only when introducing the requirement for the methodology to develop resource management systems does this factor become relevant. In particular, this aspect will have the most influence on the design and development of the system under consideration, as there will be a sliding scale of inclusion of human factors dependent on the need expressed.

In relation to DePuy, human factors were an issue that they considered on a daily basis, but not on a formal level. They also did not directly give human factors enough consideration for the influence it can have on the resource management process. Human factors were mainly considered through the assessment of training requirements and career progression of individuals at a line management level, and did not relate to project requirements. Often the management of human factors, in relation to project requirements, was done through on the spot firefighting, once an issue had been raised. In general, there was a disconnect between the human factors management and the project management, that meant that human factors were not considered in enough time so that they cause as little amount of disruption as possible.

As human factors have such an influence on the process of resource management it needs to be considered as a factor which could be included in the design of a system, so that it can be included in the management process to reduce potential impact of decisions made. Therefore, human factors can be included to a degree that is appropriate for the system that is being developed, at the discretion of the developer, in relation to the requirements and scope of the system under development.

4.2.1.3 *Synthesis of influencing factors*

The main findings from this analysis were that a number of factors are evident that will impact the development and implementation of systems within a complex business environment, which should be represented in a tailored methodology, found in Table 7. Factors found in the business context were related specifically to that business context but provided insight as a representative example. Also, it was established that factors found in literature were all evident within DePuy's business context, and proved to have an influence on the development and implementation of a system for use in resource management within the company.

There were also noticeable overlaps between the business factors and literature sourced factors. To manage these overlaps between the two sets of factors the findings from the business study and literature were synthesised into one list. This list highlights the main areas that will impact the development and implementation of a system and the suggested actions that need to be carried out to ensure it is effectively managed.

This is not an exhaustive list of influencing factors; a number of other factors exist that will impact the development and implementation of systems within businesses. However, this list provides greater insight into the factors that will require management when considering complex business contexts and business problems. This list will be utilised when considering how a methodology can be tailored to represent and manage the issues highlighted.

Factor	Observations
Business context	• Clearly define the business problem/need • Understand the software usage and acquisition processes • Understand the culture of the business that may impact and influencing acceptance, usage and sustainment
General system requirements	• Determine analysis required for business to solve problem • Highlight any technological issues that may impact • Elicit both functional and non-functional requirements
Complexity	• Develop a clear scope definition and manage throughout development • As a system requirement - Understand complexity factors within the problem area and build into system so that they can be managed
Uncertainty	• As a system requirement - Understand uncertainties in business and build into system so it can represent them and promote discussion
Human Factors	• As a system requirement – Understand what human factors impact the problem area and the level they should be incorporated to provide insight

Table 7- Influencing factors synthesis

4.2.2 Establish if a system already exists that fulfils requirements

Prior to tailoring a methodology for use in a business context, it must be established what type of development activity is to be carried out. For example, if a system already exists that can fulfil requirements potentially no development is required, or a methodology for system adaptation may be required. If, however, no system can fulfil the requirement set, there is a need for a full system development lifecycle to be carried out. Therefore, an assessment of available systems against the business requirements is needed to establish what type of system development activity will be expected.

To achieve this, firstly a set of high level business requirements need to be derived, these will align to outcomes sought from research done in the first step of the approach. To understand how existing systems fulfil the requirements, a scoring matrix will be used. To highlight the priority of each of the requirements a weighting mechanism can be applied. To determine if a system is applicable in the business context a level has to be set that states that it can be altered to fit, or be applied as is.

For DePuy, these levels were agreed as the following; if a system type shows a high fulfilment of the criteria over 85% it can be easily implemented, over 75% an adaptation process will be required, anything under this will require a full system development. Through discussion within the business context experienced these levels should be agreed in relation to their acceptance of a system.

4.2.2.1 *Application in DePuy*

To develop an understanding of the systems that are currently available an assessment of each system type against DePuy's high-level requirements was carried out. The outcomes from the assessment assisted in decision-making and development focus, enabling the researcher to clearly understand the correct path forward.

The main inputs to this assessment are the systems to be reviewed and the requirements against which they will be assessed. The systems were sourced through a thorough review of available technology from both literature and business examples. These were selected due to their previous utilisation in business contexts for resource management. The requirement set that the systems were assessed against were established through analysis of interview scripts and further discussion with process owners. Both the requirements and the systems selected for analysis can be seen in Table 8.

The assessment was achieved through the use of a decision matrix, commonly referred to as a Pugh matrix (Pugh 1990). The decision matrix works by assessing each alternative against a set of criteria, in this case the high-level requirements elicited from DePuy. In the assessment, it can be seen that each requirement has given a weighting in accordance to their relative importance so that more important requirements had more influence on the overall outcome. Each requirement was assigned a percentage relating to the percentage importance; with the sum of all requirement weightings percentages is 100%.

The weightings that are utilised in the scoring matrix were developed in conjunction with the researcher and key knowledge holders within DePuy. Each requirement was assessed on its overall impact on the procurement of a resource management tool within the business. It is important to mention that all weightings and scorings are qualitative, captured in a quantitative manner through discussion and agreement within DePuy. Therefore, the outcomes, although based in numerical form, are judgements based on knowledge gathered from literature and the experience of the researcher and should be perceived as such, which is in line with the pragmatic constructive methodology utilised in the research.

Once the weightings had been assigned, the scoring of each resource management system against the weighted requirements was carried out. The scoring was achieved using a low, medium, high scoring system, which has a respective score of 1, 4, and 9. Using this scoring system helped establish a definite difference between each alternative, as scoring using a 1-10 scale has the potential to produce ambiguous results with no clear favourite. Therefore, when scoring the system, a score of 1 would signify very little fulfilment, 4 some fulfilment, and 9 complete fulfilment of the requirement.

Requirements were arranged into their relative four high level groups, but were individually weighted. Each system was scored 1, 4 or 9 against each requirement in the matrix. This score was then multiplied with that requirement's specific percentage weighting, producing a resultant outcome, which was then collated across all requirements to produce an overall score for that system. That process was carried out for each system in the matrix so that the scores could be compared highlighting the best and worst cases.

Following this, a number of outcomes regarding the appropriateness of each resource management system, in relation to DePuy's business context, were highlighted. The discussion in this sub-section will review these findings with an aim of ascertaining if any of the systems presented would be appropriate for use within DePuy.

Assessment Outcomes

Analysis Information Systems

Within this group of systems, ERP, skill set management, and portfolio management systems were assessed. When considering software limitations, these systems all scored identical results of 4 for approved to be used by DePuy and 1 for Expense. It had been identified that all systems referenced had been utilised at some point in Johnson and Johnson and were on the approved system list, but they had never been utilised in DePuy. The reason the systems did not achieve 9 was that, although they were approved, this had been for individual or special cases, not business wide. There was therefore still a risk that the systems would not be approved for use by DePuy for use in their resource management process. In comparison with all the systems that were considered, the analysis information systems were considered to be the costliest. This was particularly true of the ERP system, where the cost to implement it would have outweighed any perceived benefit.

The risk of spending the amount of money to achieve even one licence posed such a risk to DePuy that these systems were not considered to be sustainable. Therefore, all systems were scored a 1, highlighting this fact and the risk associated.

In the next section of the assessment, the systems were assessed against DePuy's analysis requirements, which produced varied results in the analysis information system set. The system that scored the highest was ERP with an overall score of 2.85.

This high score can be attributed to the fulfilment of the resource specific requirements, and the fact that it can manipulate data effectively, such as project start dates. Where the system failed to achieve full marks, this can be attributed to considering the use of the tool in a live meeting environment to promote discussion through manipulation of a portfolio of projects; this is not what ERP is designed for and would struggle to achieve desired results. A close second in this group was Portfolio management systems scoring an overall 2.1 in this section.

The high score was achieved due to the ability of the tool to manipulate project data, however, when considering the use of the tool in a meeting and for analysing resources it was not found to have the capabilities required. The lowest scoring system was Skill set management, which scored 1 for all requirements, except for meeting context where its visual outputs may have been utilised. The low score was attributed to the fact that these systems focus on skill identification and management, not the management of the project. For this reason, the system would not be able to achieve the requirements that had been identified.

			Analysis Information						Representation						Optimisation	
			ERP		Skill set management		Portfolio management		Systems dynamics		Discrete event		Agent based			
		Weighting	Score	Resultant	Score	Resultant	Score	Resultant	Score	Resultant	Score	Resultant	Score	Resultant	Score	Resultant
Software limitations	Already Approved for use in DePuy	20%	4	0.8	4	0.8	4	0.8	1	0.2	4	0.8	1	0.2	4	0.8
	Expense	10%	1	0.1	1	0.1	1	0.1	4	0.4	4	0.4	4	0.4	9	0.9
				0.9		0.9		0.9		0.6		1.2		0.6		1.7
Analysis requirements	Reviews all resource allocation to projects	10%	9	0.9	1	0.1	4	0.4	4	0.4	4	0.4	1	0.1	4	0.4
	compares resource available against required	10%	9	0.9	1	0.1	4	0.4	9	0.9	9	0.9	4	0.4	4	0.4
	make customised portfolios	5%	4	0.2	1	0.05	9	0.45	9	0.45	9	0.45	9	0.45	9	0.45
	alter project start dates	5%	9	0.45	1	0.05	9	0.45	9	0.45	9	0.45	4	0.2	9	0.45
	enable live analysis in meeting context	10%	4	0.4	4	0.4	4	0.4	1	0.1	1	0.1	1	0.1	4	0.4
				2.85		0.7		2.1		2.3		2.3		1.25		2.1
Development	Skills required	5%	4	0.2	4	0.2	4	0.2	1	0.05	1	0.05	1	0.05	4	0.2
	Resources required	5%	1	0.05	1	0.05	1	0.05	4	0.2	4	0.2	4	0.2	4	0.2
	Time	10%	4	0.4	4	0.4	4	0.4	4	0.4	4	0.4	4	0.4	4	0.4
				0.65		0.65		0.65		0.65		0.65		0.65		0.8
Usability	Clarity of results	5%	9	0.45	9	0.45	9	0.45	4	0.2	4	0.2	4	0.2	4	0.2
	Accessibility	5%	9	0.45	9	0.45	9	0.45	4	0.2	4	0.2	4	0.2	4	0.2
				0.9		0.9		0.9		0.4		0.4		0.4		0.4
	Outcomes	Score		5.3		3.15		4.55		3.95		4.55		2.9		5
		% Compliant		58.89%		35.00%		50.56%		43.89%		50.56%		32.22%		55.56%

Table 8 - System assessment against requirements

In the development section of the assessment it was established that all three systems would require the same level of skills, resources and time to develop and/or implement in DePuy. All three systems scored low at 0.65; this was due to the fact that DePuy had no experience of using any of the systems and the perceived complexity of the systems.

The final section of the assessment was the usability of the systems, where all three of the systems were scored 9 on each of the requirements. These high scores were achieved due to the amount of consideration that has been put into the user interface design of such systems as well as the functions that it provides.

Representation Systems

In the first section of the assessment, it was established that all three of the representation systems were found to be fairly costly, but not as costly as the analysis information systems. The expense was found to be less as user accounts and packages for simulation are readily accessible and can be bought off the shelf for a relatively small fee. However, this would only offer one user access, and if discussion and experimentation were to be achieved multiple users would require obtaining a licence. For this reason, all systems were scored 4 to highlight the issues of multiple users and their impact on the cost of the system. When assessing the approval of the representation system, it was found that only discrete event simulation had previously been utilised and approved for use, system dynamics and agent-based simulation had never been utilised in Johnson and Johnson. However, discrete event simulation had been approved, but only as a one-off case, which meant that licence fees for the application were considerable. Therefore, when scoring against the requirement of approval both system dynamics and agent based simulation scored 1 and discrete event simulation scored 4.

When assessing the representation systems against the analysis requirements, it was clear that one particular requirement would not be achievable, i.e. live analysis in meeting context. Although a system could run a simulation in a meeting and members could watch its movements, members could not interact with it to change it while it was running. They would have to wait and alter it after it had finished, then run it again to find out if the change had made an effect on the outcome. This stop/start methodology would not work well in a meeting context; all 3 systems were therefore scored 1 for this requirement. Due to the differing approaches towards simulation between the systems, it was expected that the systems would score very differently when compared. However, it was established that system dynamics and discrete event, even though they worked in very different ways, achieved identical scores on each of the requirements in the analysis section of the assessment. Due to the level of control that these systems offer, the systems were scored 9 on the requirements regarding the manipulation of data; also as each system was capable of highlighting shortfalls the comparison requirement was also met. However, when considering the allocation of resources, it was not clear how the two system would achieve an overview of each project and its allocation, as the system would focus on the flow and change of the resources rather than highlighting a final state. Therefore, system dynamics and discrete event systems were scored 4 for this requirement. When considering agent based simulation systems, it was clear that the function of the system would not allow for much control over any element in the system as each element is autonomous. It was unclear how agent based simulation would be able to achieve any of the requirements stated, resulting in a relatively low score in this section.

When considering the development/implementation of the systems, it was stated that all three systems would require a great deal of skill, which was currently unavailable in DePuy. By skill this is meant as both the skill involved in the management of the system and the skill required in the creation of the resource management models within the system. Therefore, all representation systems were scored 1 when considering the skill requirements. For the requirements of resource and time, all systems were scored 4, highlighting the fact that a lot of time would be required in developing the management models but with less resource requirements that would be expected for analysis information systems.

In the last part of the assessment, all systems were scored 4 in relation to the clarity and usability of the results of the systems. This score was achieved due to the novelty of the systems and the fact that managers may not have been exposed to simulation in a management arena before. A simulation may not provide the high-level overview of the as-is situation that would be required for reporting purposes, therefore developing confusion. Although the user interfaces for these systems are very advanced and easy to use, the outcomes themselves may not be in the form required.

Optimisation systems

When considering an optimisation system, it was assessed that optimisation had been used in the business before, but not for managerial data. Optimisation had been used when considering the material use and other design criteria, but never to maximise the output of a business process. Therefore, although optimisation had been approved, there were no tools available that were suitable for use in DePuy and applicable to resource management, other than a spreadsheet add on application. For this reason, the availability of the system was scored a 4 and the expense was a 9 as these systems are usually add-ons to already existing systems and are inexpensive.

As optimisation is primarily a function that manipulates a model to obtain maximised result, a base model to optimise is required. On the assumption that this base model would be available, the analysis requirements were assessed. The requirements on which optimisation scored high was the manipulation of start dates and customisation of portfolios as these could be factors that could be manipulated in the optimisation process. However, the optimisation process is very similar to a simulation, in that it runs and develops an answer and is very hard to interact with and gain insight from, explaining the lower scores of 4 for the remaining requirements.

When considering the skills, resource, and time requirements for the development/implementation of an optimisation system, it was established that this would score 4 in DePuy. This is largely as optimisation was a familiar concept and had been applied in other areas, meaning that skills were present to utilise existing understand and carry out the development of a model within the system. However, as the application was in a new area of business process the score was reduced to a 4 to highlight the impact the learning curve would have on these requirements.

When considering the usability of an optimisation model, the function that is being carried out must be considered, as this will carry out a manipulation of a number of variables to seek a maximised outcome. It is hard to understand exactly what the system is doing to achieve the results, and therefore comprehend if this would be achievable. Therefore, the results are limited in their accessibility from a managerial standpoint. This fact also impacts on the clarity of the result as it is hard to appreciate from a model what has been changed to achieve the optimised outcome. For these reasons, both requirements in the usability section were scored 4 to highlight the lack of clarity that would be apparent when involving managers in the process.

Overall

From the analysis shown in Table 8, it can be seen that, although all systems reviewed fulfilled a number of the requirements that were stated, no system managed to score over 60% compliance with the requirement set. The percentage outcome was achieved by taking into account the weighted importance of each requirement, and dividing it by the maximum score achievable; the outcome is a percentage compliance of the overall requirement set. The overall percentage can easily show how each system scored at a high level, from which an assessment of the appropriateness of that system can be made.

As no system achieved over 60%, it is clear that out of the systems that were assessed, no system could be found to be completely appropriate for use in DePuy. Therefore, a new system that does fulfil the requirements is needed that can be accepted, adopted, and sustained. The next logical step will be to consider the development of a new system for use by DePuy, and how this would be carried out to ensure success. As a new system will be required, a full system development lifecycle methodology will be required to manage the system development.

4.2.3 Select methodology desirable attributes

To ascertain the attributes that a tailored methodology would need to possess for it to be found appropriate for its application in the business context, an assessment against the influential factors and the available methodologies is required. This will highlight the strengths and weaknesses of the methodologies and will highlight the aspects of each methodology that would be considered when tailoring a methodology for use in system development.

4.2.3.1 ***Application in DePuy***

To determine what aspects may be deemed desirable in the functional composition of a methodology, there is a requirement for methodologies to be reviewed in relation to their strengths and weaknesses, which may necessitate the creation of a tailored methodology for developing resource management systems in a complex business context. Each methodology will be discussed to determine the strengths of the methodology that could influence or be incorporated into a tailored methodology. Also, the negative aspects of the methodologies will also be discussed, so these can be avoided in the tailoring process.

In this assessment, three methodologies were selected for discussion i.e. the sequential waterfall methodology, Sargent simulation development methodology, and the systems engineering V model. These were selected due to their perceived ability to manage the influencing factors evident within the business context. A deselection process was carried out to understand which methodologies would contribute the most to the tailoring process. This was achieved within the business by the researcher and referenced earlier in the thesis in Section 3.2.3.3 within previously discussed Table 5, where system development methodologies were assessed against ability to include relevant influences and attributes. It is suggested that this activity be replicated in this step of the approach to select methodologies that will deliver insight and desirable attributes. The methodologies that were selected are those that scored the highest in the assessment process. This will involve the creation of a list of inclusion criteria, selecting a number of methodologies and assessing them against these criteria. In an effort to minimise repetition in the thesis this exercise will not covered again and the analysis repeated. For insights into the deselection process please see Section 3.2.3.3.

The first methodology that will be discussed is the sequential waterfall model that covers the lifecycle of an average development project, meaning that those utilising it will gain an appreciation of the main stages that are required to be carried out. However, the terminology that is utilised in the description of the stages does not promote its use in any other context other than IT system development and may confuse those new to the area. A positive aspect of the use of terminology is that it is kept very minimal and easy to understand, promoting simplicity throughout. However, this could also be perceived as a drawback to this approach, as there is a lack of detail provided regarding the activities that need to be carried out which may leave users vulnerable to straying off path. The methodology does not consider that there may be a feedback cycle between the stages; if for some reason scope requirements change, this cannot be fed back to influence change in the previous stages of the methodology. This, therefore, promotes the idea of linearity between the stages, which does not represent the reality of system development in a business context.

The second methodology for discussion is the Sargent simulation development methodology, which is utilised in the design and development of simulation for use in experimenting with real world hypothesis and circumstances. The main strength of this methodology is how it highlights the barrier between the real and simulated world, and how information is gathered and used to develop the simulations. There is also a reliance on verification throughout the methodology that ensures that at each stage the outputs are vigorously assessed to ensure they are fit for purpose and meeting aims and requirements. Overall, the methodology is clear and concise with minimal wording, promoting ease of understanding. One thing that the methodology does lack is an appreciation of a process flow as there is no clear start and finish points highlighted. The developer is encouraged to transition from the real to the simulation world via the simulation development loop, the outcome being simulation results that are validated against the real world and are used to update theories or develop new experiments. Another aspect that is not made clear enough is the re-work or feedback cycle that would be evident if requirements were to change or update through the process of development. This is an important issue that needs to be included to manage the possibility of requirements or even scope change.

The third and last methodology that will be discussed is the Systems Engineering V methodology, which is a model aimed at the effective and efficient development of systems, while managing the interactions that complexity and uncertainty may have on that process. A strength of the model is that it promotes continual re-assessment of each development stage and utilises the feedback between each stage. This is a principal that will ensure that a system is developed correctly and will aid a business to find a solution they can accept, adopt and sustain. However, the V model does promote the idea of developing sections of a solution that can then be integrated together. This idea, which may be relevant in complex developments, goes against the holistic systems thinking approach that would be required when developing a system for use in a business context. Breaking it down in sections may encourage developers to lose sight of the combined vision.

This information will be utilised in the tailoring of a methodology and will directly influence its design and development. The strengths will be built into the solution and the weaknesses will be mitigated against. References will be made back to this guidance in the later Sections of the approach application. An overview of the strengths and weaknesses of the methodologies discussed in this Section can be found in the below Table 9.

Methodology Class	Strengths	Weaknesses
Royce Sequential waterfall model	• Includes main stages • Promotes simplicity • Easy to understand	• Lack of detail • Terminology • Lack of feedback • No environmental consideration
Sargent lifecycle model	• Real and system world separation • Use of verification	• Lack of process flow • Feedback cycle not clearly incorporated
Systems engineering V model	• Alternative investigation • Promotes feedback • Highlights need for performance assessment • Verification and validation	• Promotes the development of integrated sections rather than one solution

Table 9 – Methodology strengths and weaknesses

4.2.4 Formalised tailored methodology

In this step of the approach, the learning from all previous steps will be combined to create the tailored methodology. Firstly, the high-level understanding of the tailored methodology will be formalised, from which more detail will be added. Design decisions will be made regarding the requirements for the tailored methodology and learning that has been made from the context and methodology examples assessed in the previous step. In this step, the experience and decision making ability of the researcher and stakeholders within the business will be utilised to promote a creative approach to the tailored methodology development, ensuring scope is well managed.

4.2.4.1 ***Application in DePuy***

High level model development

The tailored methodology developed will detail the aim and expected outcomes that are required for the development of a resource management IT system within a complex business environment. The development of the tailored methodology will take a top-down approach, starting from a high-level understanding and then expanding into more detail. The reasoning for tailoring in this way is so that complexity can be managed by promoting an appreciation of the overall aim, which is expanded with greater detail in each of the steps. This rationale is representative of the sequential approach utilised in the Royce waterfall model, highlighted as a strength in the previous approach step.

The high level tailored methodology describes what needs to be achieved, not how to achieve it. This lower level of detail is built on top of the high-level model, effectively building up the knowledge in layers. This approach is supported in Systems Engineering, where it advocates the management of complexity through the use of a top down approach, which is explicit within the Systems Engineering V model (Forsberg and Mooz 1992). The addition of further detailed information will also mitigate the weaknesses of the sequential waterfall approach.

Similar to the sequential waterfall methodology, the high level tailored methodology was structured as a series of steps making reference to the procedural element that also needs to be developed through the implicit suggestion of sequentially moving between the steps. The rationale behind using a series of steps was to ensure that the development of the methodology is carried out in a rigorous fashion and to avoid going straight into detailed design and development without fully considering what needs to be achieved overall. This is analogous with the Royce waterfall model where a simple step-by-step approach guides you through the main stages of the process (Royce 1970). The steps provide the framework from which a more detailed and in-depth procedural knowledge was developed to fulfil the requirements of each step identified. The high-level steps that were identified are:

1. **Understand the baseline** – Understands current performance i.e. determine the “AS-IS” state
2. **Envisage the future** – Detail where the business wants to get to i.e. determine the “future” state
3. **Pinpoint leverage** – Pinpoint where the business is going to focus their energies
4. **Develop solution** – Develop a solution appropriate for the business’s needs
5. **Implement in business** – Roll out solution in a manner appropriate for the business and solution developed

The high-level steps were developed around the principal idea that before any system is created, an in-depth understanding of the environment within which it was required to function must first be established. This will effectively build in the need to understand the system of interest, highlighted as a strength in the Sargent lifecycle model. From this understanding, the company would then be able to develop a view of their AS-IS state. The next logical step is to consider the TO-BE final state that the company wishes to drive towards, essentially a goal that they are aiming to achieve. Once the AS-IS and TO-BE states have been explicitly described, the next activity will be to detail the steps that need to be achieved to accomplish the end goal. This will form a time line/roadmap of events or required transformations that need to be achieved so the company can achieve the desired TO-BE destination. The company will decide how they will approach the tasks/transformations identified, requiring the company to focus their efforts on key tasks and pinpoint the areas they wish to make progress on. Enabling the company to develop an accurate understanding of the scope of the project, and also crucially what is out of scope.

As companies have a finite supply of resource, it is essential that they take on projects that will most effectively utilise their resources and provide the biggest return on investment, as well as considering what is fundamentally required by the company at that point in time. Therefore, a conscious effort should be made to justify what actions are being taken and how these can be achieved and sustained to completion. Ideally, all tasks identified would be carried out but this is sometimes unachievable so a pragmatic approach must be taken to justify what is done and how. Once this scope has been established, the company can then go on to utilise all the information gathered in the entire process to develop a solution that will fulfil the business need that had been elicited. This step will involve developing a comprehensive understanding of what that system will be required to do and how it will achieve its requirements. In this step, the company will be required to develop ideas and concepts into a detailed design, all the time ensuring that it is fit for purpose and will be accepted and utilised in the context for which it has been designed.

Once the system has been developed and tested, it is then ready to be implemented in the business. The manner in which this is achieved must be appropriate to the context within which the system will be expected to function. Therefore, a company will be required to take account of the context and prepare for and manage the introduction of the system. Even though a system may be designed and developed proficiently, if it is introduced in an inefficient and ineffective manner, that system may fail to be adopted.

These high-level steps cover the lifecycle of a system development process, with a specific focus on ensuring that the system is developed in a manner that will ensure, so far as reasonably practicable, the acceptance, adoption, and sustainment of the system once rolled out in the company context. At a high level, these steps could be utilised for any system development, but the methodology under development in this thesis is particularly focused on the development of resource management systems for use in complex NPD companies.

To promote a level of consistency within the methodology it is essential that a standard set of visual elements are defined and discussed prior to introducing the model. This will not only state what each element means, but will also define how each element is used in relation to each other. Figure 5 illustrates the elements that will be utilised in all methodology images; this will serve as a key for reference purposes. These elements will be linked together through the use of a number of coloured arrows, each with a different use. Orange denotes a process flow, blue an input/output to the process, and red dotted will show where a dependency or relationship has an impact. Figure 5 also states how the high-level methodology will be used as an overarching methodology from which more detailed task descriptions will be derived from.

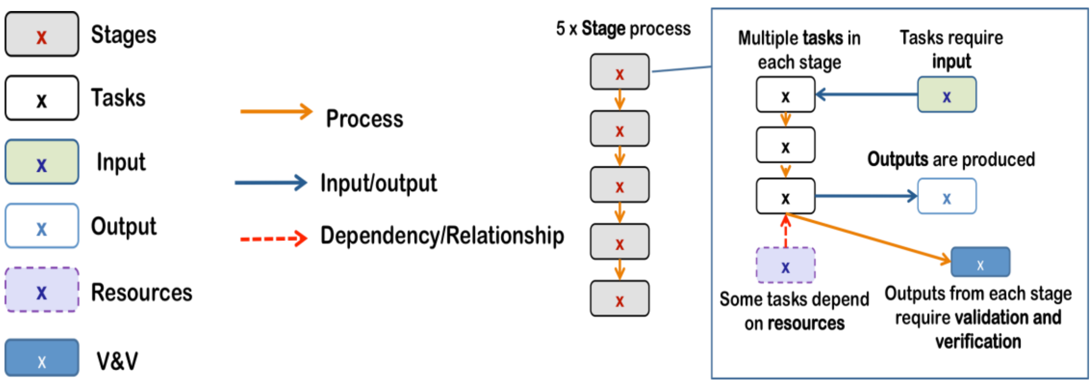

Figure 5 – Methodology key

Figure 6 illustrates the completed high level tailored methodology showing the five high level steps as well all the relevant inputs and outputs and validation and verification steps required. The aim of the high-level tailored methodology is to indicate the steps that need to be carried out and the expected inputs and outputs. It also advocates the need for continual verification and validation exercises between stages to ensure quality is built into the process.

The inputs to the tailored methodology were incorporated from the understanding developed through the discussion of the contextual influences. Effort was made to incorporate these influences into the tailored methodology at an appropriate level of abstraction to bring awareness to their importance and influence the development of the system accordingly. The influences discussed in Section 4.2.1 were assigned to the steps as an input, to illustrate where they would make an input. From these inputs expected outputs were then defined for each step. These outputs would then be used to influence the next step in the process. The tailored methodology emphasises the use of validation and verification, as it states that this needs to be carried out between each stage before you can carry on with the process.

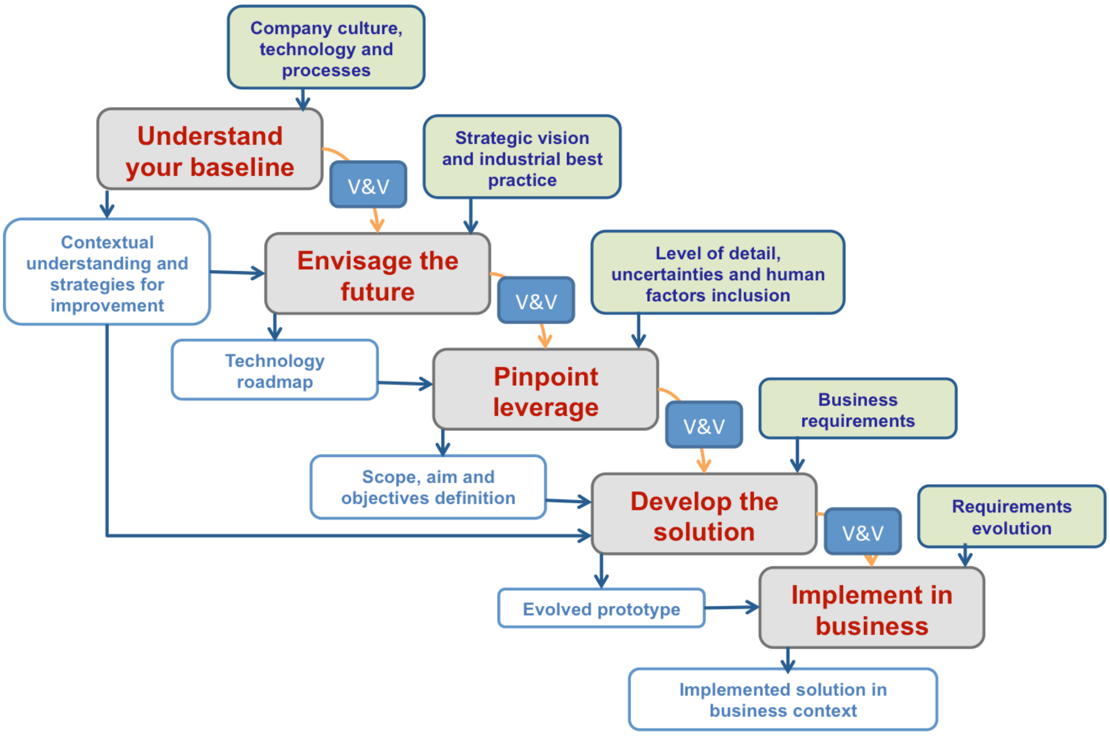

Figure 6–High-level methodology

Detailed descriptions of tailored steps

In this Section, each high-level step will be described in more detail, describing the inputs, outputs, tasks, and resources that are involved in the step. This will involve a second level of tailoring within each step of the high level tailored methodology.

Understand your baseline

The aim of the first methodology step is to establish the AS-IS current state of the organisation from which further development can be progressed, as illustrated in Figure 7.

Before promoting a solution, the problem area must be understood and what the attributes of the problem are. It would be illogical to start with a solution and work backwards fitting it into a problem context, which may not be accepting, for example buying a COTS solution and trying to fit it around your current business structure. With particular reference to resource management, critical influences that require to be taken into context at this stage are business culture and technology. These influences are therefore used as the main inputs into this step of the tailored methodology, along with business processes that require to be documented and understood to aid in understanding the business context. Developing a system in this way will allow the system to be developed in line with the business context and requirements.

These inputs are utilised in the first task of the stage, the company review. In this review, business processes, technology and cultural issues need to be detailed and discussed. This will serve as a baseline document that states what is in place now and will be built up in conjunction with key knowledge holders in the business context. The accumulation of knowledge will enable the company to develop an awareness of the complexities and their interactions and how these will possibly constrain any future development. The outcome of the baseline stage is an overall contextual understanding of the business, detailing the issues found to be important when considering resource management systems in complex NPD contexts.

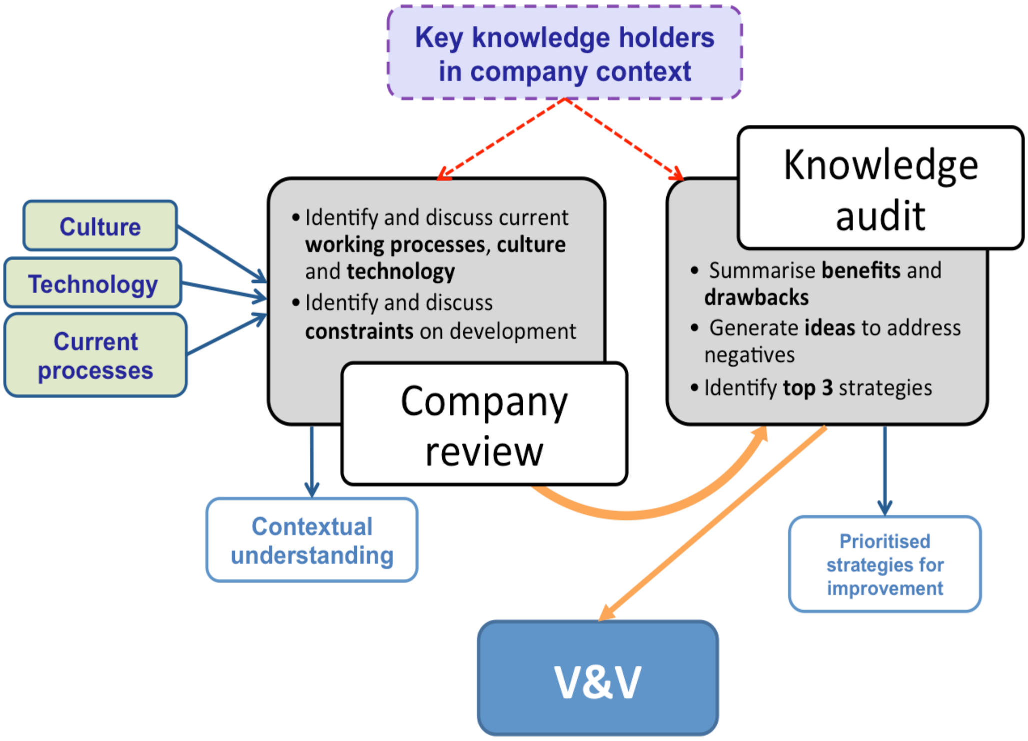

Figure 7 - Understand your baseline

Once the company review has been completed and an awareness of the context has been created, the next task is then to conduct a knowledge audit. The aim of the knowledge audit is to identify the key areas of improvement that exist within the business context. Firstly, a list of the benefits is collated which states the benefits that could be realised if an improvement programme were to be put in place. In response to the benefits a list of the possible associated drawbacks can then be collated, to understand the risks and manage any potential trade-offs. For example, a benefit that could be realised may be "timelier reporting of resource requirements"; the drawbacks of this may be "increased admin". Once these drawbacks are detailed the next stage is to generate a variety of ideas that could address the negatives listed. From the example previously used the improvement option could be "promote use of automation".

The options can then be prioritised in relation to the achievability and perceived need for each of the ideas suggested. These options will form a basis for the initial strategies that could be utilised and will be taken into consideration in the next stage when the future state of the business context is envisaged. In addition to this, discussing the potential for change within the base lining methodology step is intended to promote buy-in and will facilitate the management of expectations, as not all ideas can be taken forward. The idea here is to stimulate ideas and focus the minds of the organisation on what is possible for them before moving on to discuss the future. No solutions will be discussed here, in order to avoid fixation, only potential strategies to improve the current drawbacks that exist.

The final stage that needs to be carried out is Verification and Validation (V&V), which will ensure that the information collected and developed in this methodology stage is representative of the company context. This can be achieved through a stage gate style review by senior management bought into the process, or by wider presentation to the organisation for feedback. Methods for V&V will be dependent on what is seen to be appropriate for the company context and an effort should be made to establish what this is and how this will be achieved. If the outputs cannot be verified or fail for any reason, the stage may have to go through another iteration, dealing with issues that have been brought up. It is essentially that issues are dealt with prior to carrying on so that their impact can be removed from the development process.

Envisage the future

In the second stage of the methodology, the future of the business context will be developed, as illustrated in Figure 8. Inputs to this stage will be the main outputs of the prior stage i.e., the contextual understanding and strategic vision. In addition to this, other inputs that will be influential will be industrial best practice and advancements in technology in the field of resource management. This mix of inputs will provide a holistic view of what the company needs, and what is available from external sources. These inputs are utilised in the first task where key knowledge holders are utilised to develop a strategic goal for the system, which will serve as a primary vision for improvement for the company. This should be a high-level statement of what the company are seeking to achieve in relation to its IT based resource management, grounded by their AS-IS state.

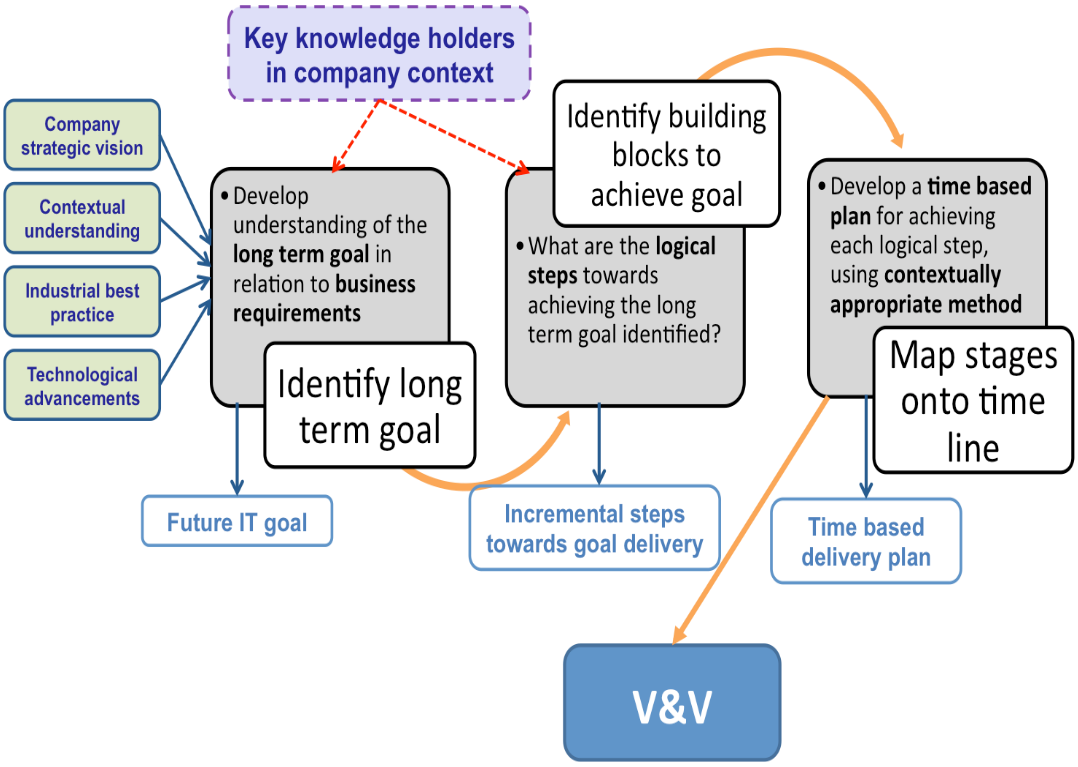

Figure 8 - Envisage the future

Once this overall goal has been developed, knowledge holders were then required to describe the logical steps, in greater detail, that would be required to achieve this goal. The number of steps and level of detail achieved in this stage is dependent on the goal set and the requirements of the business, as well as the complexity of the challenge. For example, a long-term goal may be to introduce ERP into a company, logical steps toward this would be to develop a relationship with a system provider, agree a system for use, train staff in the system, implement a test system, further develop system, and then finally continue to a full roll out.

Although detail is important in the overall process, at this stage information is still held at a high level of abstraction, so steps towards improvement may be quite general. Once these steps have been detailed, it is then essential that these be put on a time-based plan for achievement, or a roadmap that shows the relationship between the stages. This plan must be appropriate for the business context within which it is being utilised; for example, this plan can be on a long, medium, short-term timescale or even financial years. The reasoning for this decision may be company specific based on the organisation's reporting practises or current strategy development system. This is dependent on what is deemed appropriate at the time, so an effort must be made to ensure this plan fits with the company context and shows information in a way that can be easily interpreted. Once again, the final task in this stage is V&V, which will be in the form that is seen to be the most appropriate for the company context. It is however essential to note that V&V at different stages may require different methods to be utilised, in reaction to the type of information created. This fact should be taken into consideration when planning V&V effort to ensure the methods utilised are appropriate.

Pinpoint leverage

Once the context and the goals for the company have been understood, the next stage in the methodology is to pinpoint and detail what stages in the roadmap, detailed in the previous stage, will be taken on in this single improvement initiative. This ensures that the overall initiative has a clear aim but can be decomposed into interrelated schemes that can be conducted separately but managed as a whole. This offers companies the choice of how to roll out their improvement initiative, either a stage at a time or as a coordinated effort on a bigger scale. However, this is coordinated, work packages need to be defined and each should be taken through the tasks highlighted in Figure 9. It is not in the focus of this methodology to define what is appropriate for a specific business context in relation to how an initiative is managed, it is however to define at a level of detail what is required to progress within a single package of work.

The main inputs for this stage are highlighted as the level of detail required in a solution, uncertainties to be included and managed, and human factors that could cause issues in development. The level of detail refers to the amount and type of information that will be incorporated into the system, considering both the breadth and depth of the information. For example, when considering a business, how many business operations would be included and to what level. The more detail included the more complex the system will be, requiring a more strict and managed development. When considering uncertainty in the system this refers to how the system will aid decision makers when the decision process reflects a changing and uncertain environment.

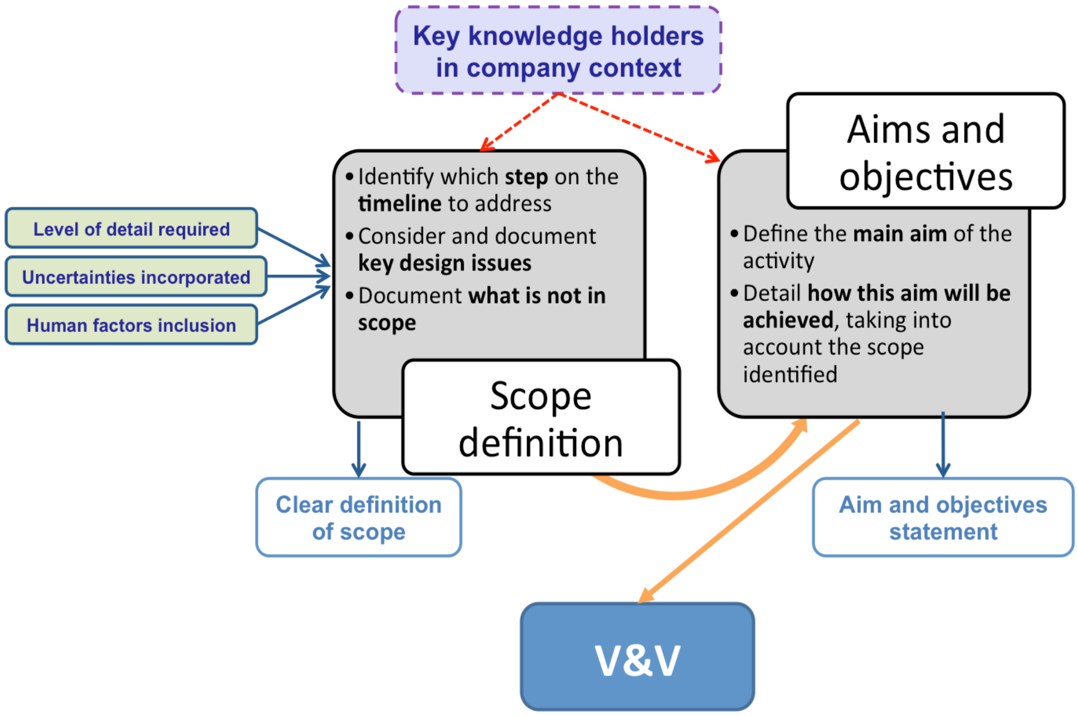

Figure 9 - Pinpoint leverage

In this instance, the system will have to give the decision maker an appreciation of the consequences of their decisions in a multiple of scenarios. Human factors inclusion will reflect how humans interact with the system and as the system is a resource management system, it will also have to consider how human behaviour may impact decisions that will be made.

Key knowledge holders will be utilised in the first task where they will decide on the key work packages and what stages will be progressed in the form of a project plan, from this each work package will have a detailed scope developed, incorporating aspects identified as required from the previous stages and the inputs stated in the methodology. This scope will clearly define what is to be achieved and critically what is not in scope, to manage the possibility of scope creep. From this scope definition aims and objectives can be developed, this will detail what will be done and how, using what resources. Once this has been achieved the combined scope, aim and objectives must be verified and validated to ensure that they are achievable and accurate.

Develop the solution

Once all the contextual and strategic vision tasks have been completed, and a clearly scoped work package has been put together, the next step is to move on to solution development, as shown in Figure 10. The methodology has made an effort to avoid jumping into the solution phase too early and has emphasised the need to do a lot of preparation in the early stages, to ensure that the work carried out is correctly understood, ensuring a high level of acceptance, adoption and sustainment of the proposed solution. Therefore, in this stage the main inputs required are the scope, aims and objectives, contextual understanding and finally problem knowledge. This is utilised by key knowledge holders in the company context to go ahead with developing a requirements specification for the solution i.e. what the solution must achieve to be successful.

To achieve this requirement, elicitation activities will need to be carried out; this may take a number of forms in reaction to what is appropriate for the company context. For example, single interviews may be more appropriate in smaller cases, however on a larger scale workshops and surveys could be used. Therefore, thought must be given to the methods that are utilised and this should be thoroughly planned so as to achieve a fully robust documentation of requirements. Requirements elicitation is not carried out earlier in the process so as to avoid introducing the solution space too early. The requirements can only be introduced when the business have a clear focus for their energies so that the requirements that are elicited are focused on the task and not on the high-level goal. Requirements will be gathered from multiple areas to ensure all aspects have been considered, this will mean that functional and non-functional requirements must be collected.

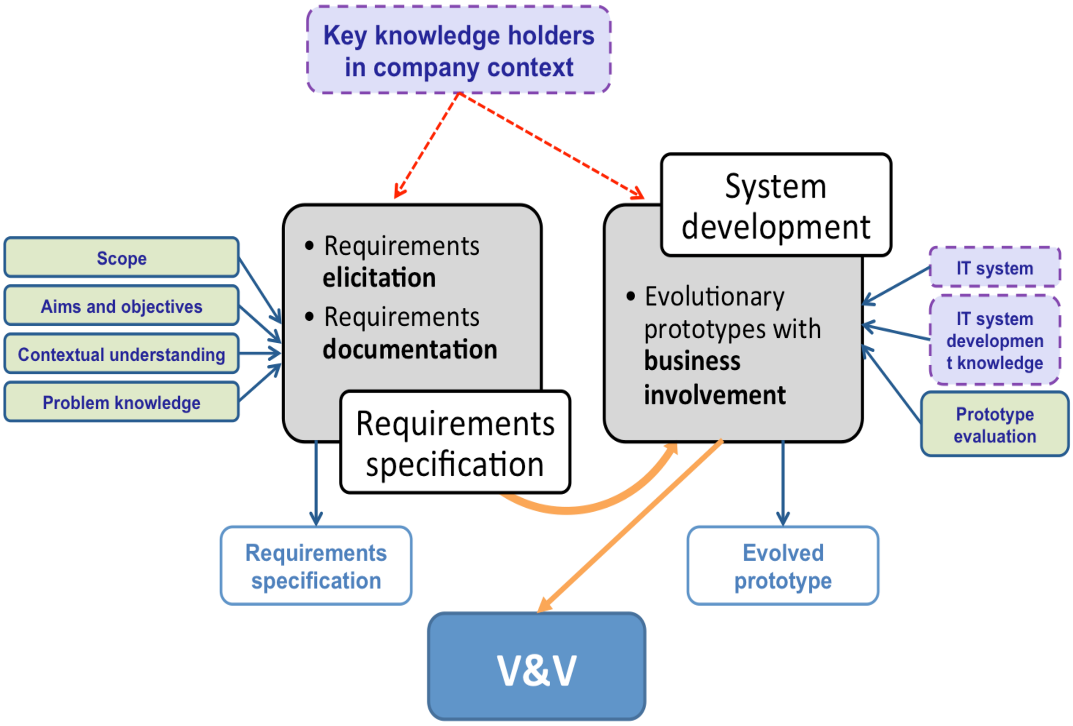

Figure 10 - Develop the solution

Once the requirements specification has been developed, the next task is to start the development of prototypes for use within the company context. The use of prototypes will allow developers to test ideas on a smaller scale and will allow individuals to physically interact with a system. This will enable the developer to elicit possible hidden requirements or gauge the need for previously demanded requirements that may not actually be a need for. Prototypes will enable developers to design and build a more robust system, and will also promote business involvement in the process. If a business is engaged in all aspects of the design and development of a system, they are more likely to accept, adopt and sustain the solution that is presented to them as their own and worthwhile. For this reason alone, prototyping in this context is essential to ensure successful delivery.

At this stage, verification and validation is used to test the system itself in relation to how it has accomplished the requirements that were set in the specification. The developer must first test if the system is the "right system" and if the system has been "implemented right". This will require a number of tests and assurances to be made that will check the basic functionality of the system and how the system delivers the outputs that have been requested of it, while working within a number of constraints. This can be achieved through a number of methods, for example Expert user interviews relating back to the requirements that were originally specified for the system. It is expected that the system that has been developed will fulfil the majority of the requirements that have been stated; if this is not the case, re-development may be considered. Once again, how this is achieved must be appropriate for the context experienced but should be thoroughly planned and take into consideration how the system meets the requirements specification and how people expect to use the system.

Implement in the business

Now the business has developed a final evolved prototype system, the system can be rolled out in the business context for use; this methodology step can be found in Figure 11. As with all new systems, it is essential that the first roll out be carefully managed to ensure that the system is utilised in the correct way and performs in the manner in which it was designed. For this reason, the first roll out of the system should be known as the pilot from which any further changes or lessons can be learnt. The first task is to limit the scope of application to address a relevant and specific business challenge. Once this has been identified and achieved, the system needs to be monitored and controlled to assess how it is performing against the requirements specification, quite similar to the V&V carried out at the end of the development stage. The difference here is that the system should experience the complexities and uncertainties in the business context that could not be easily anticipated in the earlier stage.

Piloting the system in this way will allow developers, or those who are found to be most appropriate to carry this activity out, to run the system live and make note of any emergent defects of evolution of requirements that may occur. Utilising key knowledge holders, the evolution of the requirements and any changes that are required can be gathered that could be utilised to update the design specification. This will mean that the requirements specification will have to go through another round of V&V to assess if the changes add value and are in the scope of the project. If this is the case, the prototype can be updated for a final time, which can then be implemented fully into the business.

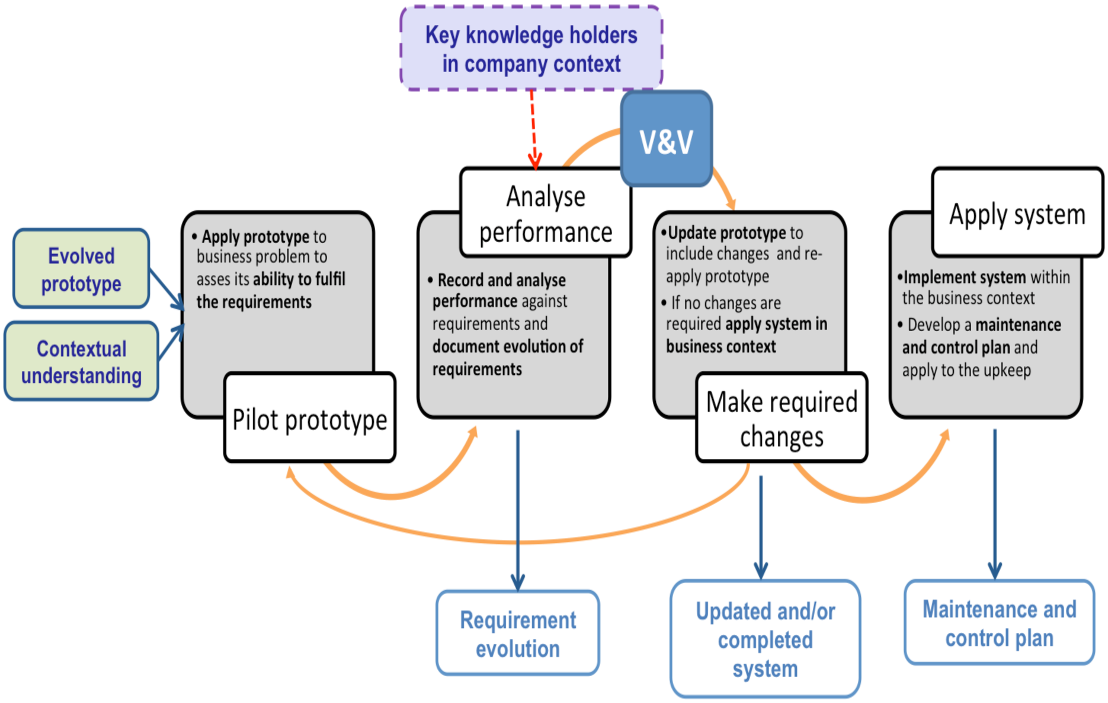

Figure 11 - Implement in the business

To ensure that the system is effective within the business context, it must be monitored and controlled, therefore a plan for how this is to be achieved must be developed. This will detail how the system is to be maintained and what procedures should be in place to ensure that it is being utilised properly, such as training, drop in sessions, design reviews, error reporting and change requests. Now the system is live within the business and fully accepted and adopted it is essential that it sustains and remains in use, so effort must be put into the management of the system to ensure that it doesn't fall out of favour or become obsolete. This will mean that the system is in line with the strategic objectives of the business and works well with the structure and culture of the business.

4.2.5 Evaluate methodology

To ensure that the tailored methodology developed through the application of the approach has utilised the learning from previous steps, and evaluation is required. This evaluation will explicitly state where and how each influencing factor and methodological influence has been built into the tailored methodology, as these are the main inputs to the development of the tailored methodology. This will be an appraisal of the tailored methodology's attributes and not an assessment of its validity, which can only be ascertained through its application.

4.2.5.1 *Application in DePuy*

To ensure that the tailored methodology developed in the previous step of the approach has incorporated the desired influences and attributes, an assessment is required. This assessment took the format of a review of the inclusions in the tailored methodology and the decision made in the design of the methodology.

An overview of the influencing factors, as discussed in Section 4.2.1, to be included and taken account of in the tailored methodology, as well as how they have been built into the methodology, can be found in the below Table 10. From this assessment of the influencing factors it can be established that all factors have been incorporated into the tailored methodology, primarily in the first three stages. This is understandable as influencing factors will define the context within which a solution will be delivered, and should be considered upfront to ensure that the system is developed correctly.

Influencing factor	Where it was taken account	Benefits derived
Business context	• Covered in its entirety in the "understand your baseline" step • This is also taken into account when deciding the future vision of the company and aligning its priorities in the next 2 steps	All design decisions subsequently made are based on the outputs of the first 3 steps
General system requirements	• Explicitly covered in the "develop a solution" step	Dictates the elicitation and documentation of requirements
Complexity **Uncertainty** **Human Factors**	• Utilised in "Pinpoint leverage" to define the scope of the problem being addressed	Will impact the development of requirements against these attributes

Table 10 – Influencing factors assessment

The impact of the influences will accumulate in the requirements specification in stage 4, where the systems function and non-functional attributes will be defined. It is logical to assume that as the requirements set has been defined through the careful consideration of the influencing factors, the resultant requirements will represent the actions required to manage those influences.

Table 11 details how each system development methodology discussed in Section 4.2.3 influenced the development of the tailored methodology, detailed in Section 4.2.4. This assessment highlights that the tailored methodology is structurally a mix of the sequential waterfall model at a high level and the iterative Sargent lifecycle model within each step. There is also the inclusion of the verification and validation element present in both the Sargent and Systems Engineering V models. The contextual influence is highlighted in the first three stages of the methodology where the company review, business roadmap and scope definition are delivered.

Methodology	Aspects utilised	Impact
Royce Sequential waterfall model	• Sequential nature of steps • Simplicity in design • Flow of inputs and outputs	Simplistic high level design with added detail where required, highlighting a stage gated approach
Sargent lifecycle model	• Appreciation of real world context • Utilisation of feedback between activities within steps	Solution based on business need Combined sequential and iterative approach
Systems engineering V model	• Use of verification and validation throughout each stage	All deliverables are verified and validated throughout prior to moving on to next stage

Table 11 - Methodology attributes assessment

Overall, the tailored methodology developed incorporates the factors found to be influential, as well as methodological attributes assessed as desirable. The evaluation has highlighted that influencing factors predominately impact in the first three stages of the methodology, with their impact being appreciated further into the development and implementation phases.

4.2.6 Implement in the business

Once the methodology has been evaluated, thee outcomes will be utilised to further develop the methodology based on any feedback that the assessment has delivered. If the tailored methodology is found to be fit for purpose, it can be implemented within the business context.

The implementation of the methodology in the business context of DePuy involved the development of the associated resource management tool and is described in detail in the following Section 5. The application of the tailored methodology highlights its strengths and weaknesses, and the validity of the approach taken towards its development. An in-depth assessment of the tailored methodology and tailoring approach taken will be conducted in Part 3 of this Thesis.

4.3 Summary

This Section discussed the development of an approach to methodology tailoring, developed in the complex business context of DePuy. The approach involves six main steps i.e. identifying contextual factors, existing system analysis, methodology assessment, methodology tailoring application, tailored methodology evaluation, and finally tailored methodology application.

In this Section, the first five steps of the approach were described and applied in the complex business context of DePuy. The main outputs from the application of the approach were:

- A synthesised list of influencing factors from both the business context and literature
- An understanding that no resource management system exists that fulfils DePuy's requirements
- An overview of desirable methodology attributes to be utilised in the tailoring process

- Formalised high level tailored methodology and accompanying detailed tailored methodology stages
- An assessment of the tailored methodology against the influencing factors and methodology attributes to ascertain how these were incorporated into the tailored methodology

To establish the validity of the tailored methodology, it will be applied in DePuy's business context in the development and implementation of a resource management system. This will fulfil the final step of approach, as well as offer insight into the validity of the approach taken towards the tailoring of the methodology.

5 Tailored methodology implementation in a complex business context

This Section will detail the process of applying the tailored methodology that was developed and described in Section 4 by discussing its application in the business context within which this research has been based. The aim of applying the methodology in the business context is to establish the validity of the tailored methodology and to ascertain its strengths and weaknesses. In turn, this will highlight the appropriateness of the approach taken towards it tailoring. The application of each stage of the methodology will be discussed, describing the resource and information requirements, as well as discussing the main outputs that were achieved.

The methodology was applied in DePuy's business context with the aim of improving the support for resource management decision making within the company through the development and implementation of a new resource management IT solution. The application of the methodology within DePuy achieved a high level of commitment from senior management and key knowledge holders, who made provisions for allocating both their own time and the time of their human resources. The application of the methodology was managed and carried out by the researcher as a single point of contact within the company context for the improvement process involving the development of the IT system.

In Section 5.1 the process and outcomes from the application of the "understand the baseline" stage of the methodology is described, discussing how DePuy underwent a company review and audit to establish their problem space. Section 5.2 moves on to the application of the "envisage the future" stage where DePuy determined their long-term goals. Section 5.3 discusses the "pinpoint the leverage" stage and how it was utilised in DePuy to develop their aim and scope for a proposed solution. Section 5.4 then goes on to detail the "develop the solution" stage and how it was applied in DePuy to create a resource management system for use at portfolio management level. Section 5.6 states how the "implement in the business" stage was realised in DePuy through the realisation of the change in requirements and its application in the business. Section 5.6 will provide an evaluation of the solution that was developed from the point of view of the main stakeholders in DePuy, where they express their opinions on how well the solution fulfilled their requirements.

5.1 Understand your baseline

The stage of the methodology will be used to aid in the discovery and documentation of working processes, cultural issues and constraints experienced within DePuy, with particular interest to their resource management efforts. This stage of the methodology will be broken up into two tasks; firstly, contextual understanding utilising a company review, followed by a knowledge audit.

The contextual understanding will focus on identifying current working practices, giving an in-depth understanding of the problem area and develop the AS-IS description. The knowledge audit was conducted with resource management process owners within DePuy. This audit aimed to generate a list of all the possible tasks that could be undertaken which would prove to be beneficial to DePuy, in relation to their current resource management efforts. The list was then prioritised to highlight the top three tasks that will aid in developing focus in the project, so as to focus efforts and reduce complexity. The remainder of this Section will discuss the implementation of this methodology and the results found from its utilisation.

5.1.1 Company review

A number of knowledge gathering activities were carried out in an effort to gather knowledge regarding the as-is state of DePuy, regarding their resource management activities. The aim of these activities was to establish a basis from which a vision of possible future improvements could be developed. The methods that were used in this Section were found to be the most appropriate within the context of DePuy, in reaction to a number of factors such as resource availability, complexity of the business, and the perceived size of the problem. The activities, and the reasoning for the activity, that were carried out were as follows; Contextual and managerial interview, resource refresh involvement and resource management observation. The outcomes from these activities can be found in the attached Appendices A & B.

The following Section will take the outcomes achieved in these separate activities and combine them to provide a collective view of the company with respect to resource management. This will provide a clearer and more concise discussion when compared with detailing the outcomes sought from each individual activity. Only those outcomes considered relevant, which aid in the discussion of the resource management context experience within DePuy, will be discussed.

Outcomes from contextual knowledge gathering

DePuy Orthopaedics are a Johnson & Johnson company who specialise in the development of orthopaedic implants and technologies that strive to help surgeons achieve excellence, resulting in a positive impact on the lives of their patients. DePuy Leeds is a member of the DePuy orthopaedics family, and is the business context within which the research has been based. DePuy Leeds is a complex business split up into a number of functions that work together on concurrent projects, often in collaboration with DePuy USA. This fact can often make it difficult when considering the allocation and balancing of resources across multiple concurrent projects over a number of businesses. The business structure is represented in Figure 12, which illustrates how the elements of DePuy's business work together.

DePuy Leeds has a four business groups which each have their own projects i.e. Knees, Hips, Trauma & Extremities and CMW (bone cement), all of which rely on the utilisation of functional groups to undertake tasks, such as HR and business support functions. In most cases the business group will have established a ring-fenced supply of development resources solely utilised in that business group. However, supporting functions such as clinical, testing and regulatory, as shown in Figure 12, are not ring fenced and are shared among the business groups.

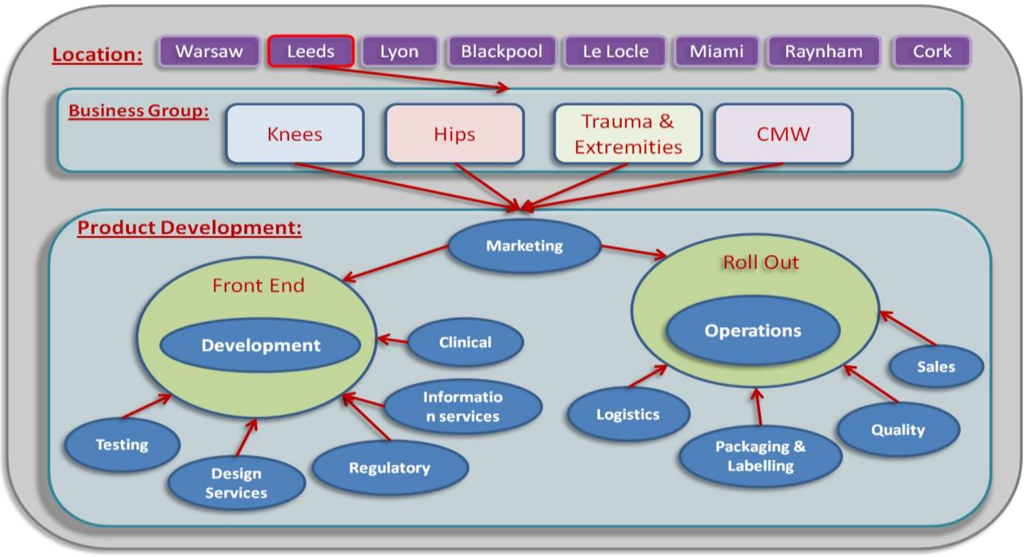

Figure 12 – DePuy business structure

Therefore, in DePuy Leeds there are two areas where resourcing becomes an issue; firstly, within the constrained business group development resource pool and secondly when considering the sharing of supporting functional resources across business groups. For example, when considering the resourcing of a new project, there needs to be an analysis of the project resource requirements in relation to skill sets and volume of resources required, which can then be compared to the skill sets, human issues, such as career paths, and volume of resources available, within the constrained resource pool, as illustrated in Figure 13. Once this knowledge is gathered, managers can make a trade-off between what is required and what is available to them, making decisions such as training staff to obtain skill sets, taking on contractors, and swapping resources between projects.

It is also important to mention that this decision-making process is not a one-off occurrence at the start of a project, but is a constant monitoring process. This is due to the fact that projects evolve over time and the scope of the development project may change, altering the skill sets or resource requirements. Managers will also have to consider the interrelation between projects, for example the introduction of a large highly volatile project may adversely affect the resourcing of smaller projects. This may be due to the fact that smaller less important projects could be easily targeted for their resources by larger more important projects.

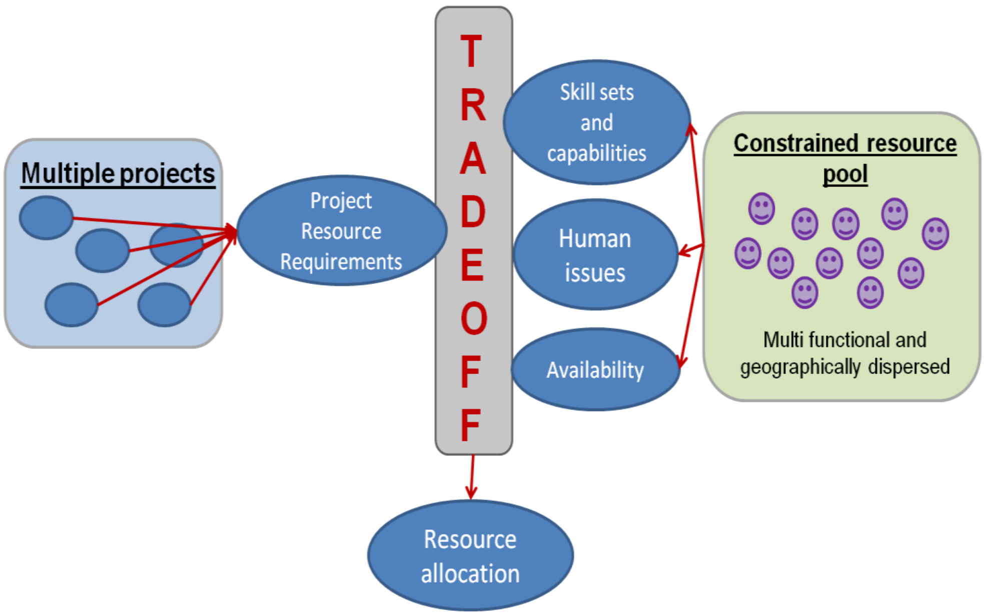

Figure 13 – DePuy's resource allocation process

In an effort to allocate resources to projects and manage the potential for any resourcing issues, DePuy adopt a "project core team" approach to resourcing projects. This involves the creation of a team that will be responsible for the tasks involved in that project. Each team will have a project manager who will be responsible for allocating tasks and ensuring that the project is on course. The team will consist of resources from functions thought to have the correct skill sets to carry out the tasks required. A graphical representation of this can be found in Figure 14. As the project matures and time elapses, the project core team will fluctuate, as managers make the complex resource decisions and trade-offs required to maintain the portfolio of projects. For example, individuals may be taken off the team to be allocated elsewhere and replaced with another resource with a similar skill set. It may also be the case that certain functions are incorporated at different times i.e. the testing function may not be involved until later in the process when testing final designs are more pertinent.

Although there may be fluctuation, the project core team remains a constant entity with the sole responsibility of maintaining the development of that project, which provides structure to the project work carried out within DePuy and makes projects more robust against the dynamic context of the working environment.

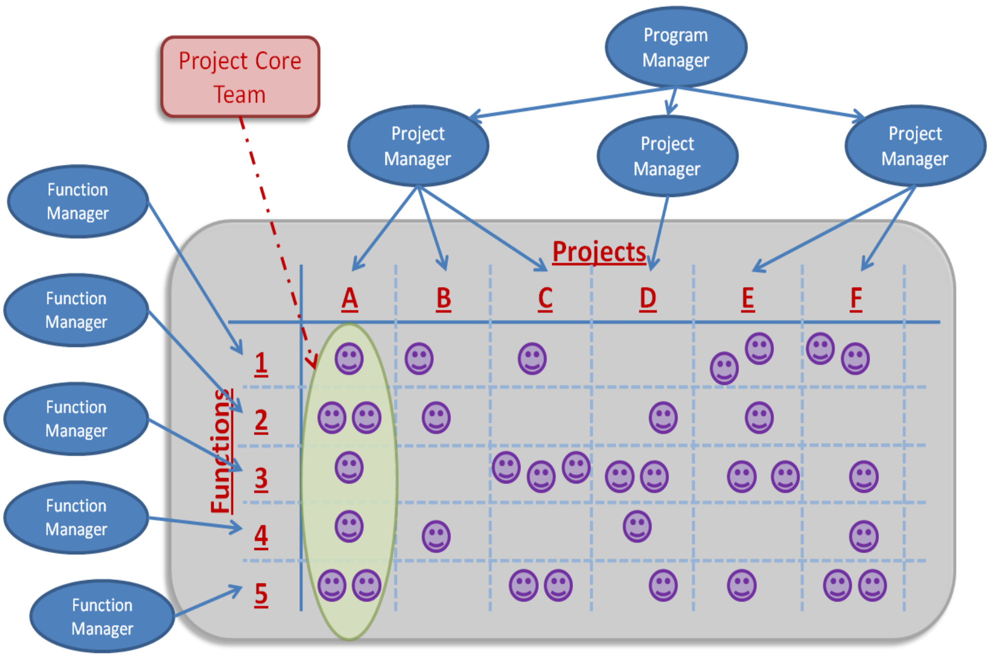

Figure 14 - DePuy's matrix resource management structure

This highlights the need for management to understand the amount of resource each project has been allocated, in order for them to make the high-level resource based decisions and trade-offs which maintain the portfolio of projects. This is an issue that DePuy encountered and endeavoured to overcome through the development and application of the resource review process. Although DePuy manage a monthly project portfolio review, stating the progress of projects over a time line, there is a disconnect with resource allocation. The resource review aimed to gain this information about the allocation of resources to projects, as well as provide information for resource managers to utilise in their decision-making efforts.

The resource review was supported through the use of a simple spreadsheet that listed each business entity's projects on separate pages, and stated the amount of resource each function had allocated to each project. The spreadsheet also highlighted the available resource a function had, creating the ability to analyse if the function was under or over resourced by comparing the resource need and availability. Resource allocations were taken over a two-year planning horizon, gathering high level estimates for each quarter. A version of the resource review spreadsheet was sent out to a representative for each function, commonly the functional managers, to gather the required information. The information gathered from each function was then consolidated into one spreadsheet giving a view of the entire resource allocations over the businesses within DePuy. This spreadsheet was then utilised to analyse the current resource allocation and highlight if there were any areas of concern that required attention. The outcomes of the analysis were then discussed at a portfolio level where a decision could be made to improve the resource allocation and avoid potential problems. A graphical representation of this process can be found in Figure 15.

In light of the information presented to the portfolio decision, they may choose to make changes to a number of variables, such as reducing the number of projects a business is carrying out, increasing the contractors available in a supporting function, approving the allocation of a number of full time staff.

Overall, this approach has worked well for DePuy and has enabled them to consider resources in ways they were never before able to. However, the process of gathering the information required for the resource review is time consuming, often taking up to three months. Once the information is gathered, there are further complexities experienced when manipulating the information to allow significant questions to be answered, such as you would expect when manually manipulating a large set of data within a spreadsheet. This has meant that most of the time in the process revolves around the gathering and preparation of information rather than meaningful discussion and scenario analysis. The knock-on effect of this is that by the time decisions are made there is a potential situation that the information utilised to make the decisions in the first place may be out of date.

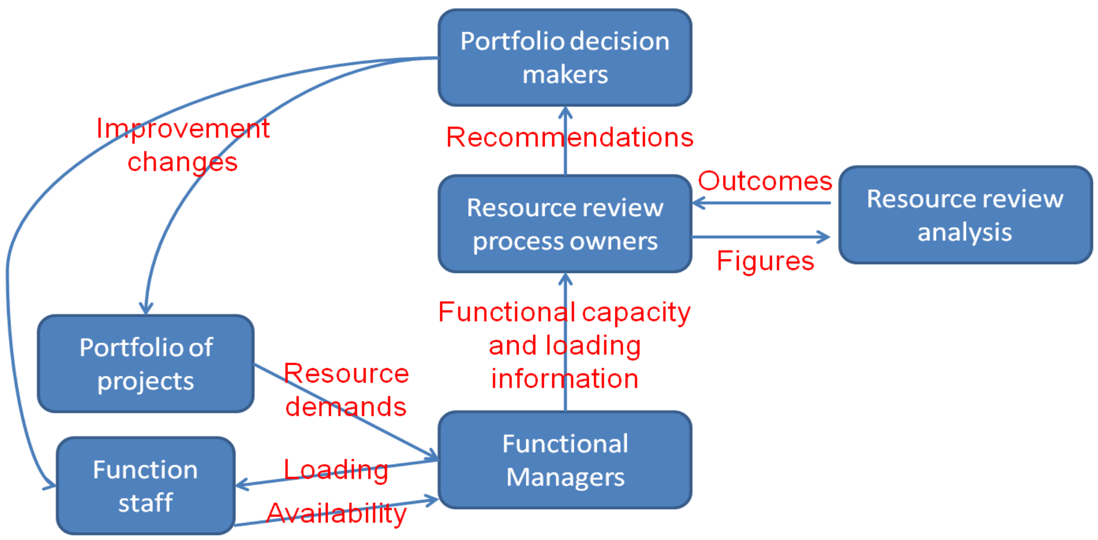

Figure 15 - Resource review process

DePuy were frustrated with this situation and were considering other technologies and systems that could enable a quicker and more reliable gathering and manipulation of resource data. Their first thought was to implement a portfolio management tool, which encountered difficulties due to budgetary constraints. Difficulties were also experienced due to Johnson and Johnson's strict management of software utilisation, which aims to standardise the software tools and packages used within their businesses, meaning that only Johnson and Johnson's approved tools and software can be used. The process of getting a tool or software approved can be long without a guarantee of it being approved at the end of it. Therefore, more careful thought and planning was required in relation to the approach and activities DePuy carried out to improve their current resource management activities.

Summary

DePuy are a complex company who deal with multiple businesses, with multiple projects, that all require resourcing from a constrained pool of resources. They experience difficulties when resourcing projects at two levels; firstly, when constrained ring fenced resources for a business's development function are stretched, and secondly when supporting functions who operate over a number of businesses are over loaded. DePuy utilise a project core team approach to allocating resources to projects that provides needed structure and consistency. A resource review process that utilises a spreadsheet, which can be laborious and time consuming, reducing the ability to discuss complex scenarios and manipulate variables to assess the effects, monitors the resource allocated to the projects. DePuy have been constrained to the software applications they can utilise to manage this problem and have been researching possible ways forward to combat these complications.

5.1.2 Knowledge audit

With the as-is resource management situation established, there is a need to identify an area of focus and reduce the scope of the problem area. This was achieved through a five-step workshop attended by the resource review process owners. The intention of the workshop was to discuss the problem area and establish a focus that would benefit DePuy. Figure 16 describes the five steps of the workshop, highlighting the inputs and outcomes achieved.

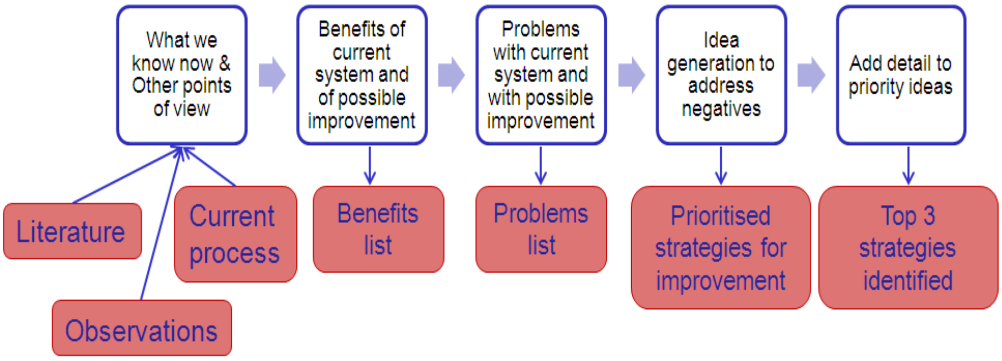

Figure 16 – Knowledge audit process

Firstly, the accumulation of knowledge regarding the businesses current state and literature in the field was discussed at a high level, this gave the session context and understanding of what the problem area was. The process then moved on to discuss the potential benefits that could be delivered through a change in the business regarding resource management. Then a review of the current issues within the business was developed, this illustrated the opportunities that DePuy had within its current resource management system. Based on the first three stages strategies for improvement were discussed and prioritised, that aided in the final step of selecting the top strategies for consideration.

Two resource managers attended the workshop with an interest in the problem area, as resource management impacted their daily work and they also had responsibilities under the resource review process enacted within DePuy. The two managers had been involved in previous knowledge gathering exercises and were found to be the most appropriate individuals to carry out this exercise with.

Outcomes from knowledge audit

The workshop started by discussing the knowledge gathered regarding the as-is resource management situation within DePuy. This acted as an opening conversation to remind those present of the research problem area and to update on any new information found. From this general discussion, the workshop progressed on to list all the positive aspects of the current systems in place and the possible benefits that could be achieved if it were to be improved. This enabled those present to focus on the positive aspects and to see why potential changes could improve the resource management situation. After the positive aspects had been listed the workshop progressed on to talk about the negative aspects, listing all the challenges and barriers that had been experienced, as well the potential drawbacks that could be faced through changing the current process. Once this step was completed, the next step was to suggest ways in which the negative aspects identified could be resolved/addressed within DePuy, as this step involved creativity and concentration it was allowed more time than the other stages of the process. After the list of possible ideas to address negative aspects was completed, the items on the list were prioritised to highlight the measures with the highest importance and possible impact to DePuy. This process led to the final step where the top three strategies identified were given more detail and discussed further. Only three strategies were prioritised in an effort to manage complexity and to establish the areas that would be focused.

The outcomes from each of these stages can be found in Table 12 where the positives, negatives, and ideas to address the negatives are listed. Table 12 also highlights the main outcome that was found through the application of the process i.e. the identification of the main ideas to address DePuy's issues as well as key considerations that need to be addressed to ensure success. The main outcomes sought from the exercise were:

1. The resource review needs to be done more often, or made less time consuming, and linked to the current project plan;

2. The resource review spreadsheet could utilise a more involved user interface i.e. sliders, buttons, macros etc., that would make the job of manipulating data much easier, to inform decision making;

3. The value of doing the process needs to be highlighted to ensure buy-in.

It was also highlighted that one of the key considerations that needs to managed is the impact that IT may have, it was therefore suggested that a meeting needs to be set up with DePuy's IT specialist to discuss this issue. The aim of doing this was to establish if there would be any constraints in applying any specialised IT software, as had been previously experienced.

Overall, the main outcome from this exercise was to determine a focus for the project and the reduction in the scope, which was directed towards the function and abilities of the resource review. This would involve considering how the resource review spreadsheet could be integrated more effectively to the evolving project plan and how more functions within the spreadsheet could enable better data manipulation.

5.1.3 Verification and Validation

In order to ensure that the process had been followed accurately and desirable outputs had been delivered, it was essential to carry out verification and validation prior to carrying on to the next stage in the methodology. Although this had been carried out by the researcher throughout the process a more formal approach was required to ensure the business were also assured.

In this stage of the methodology, the verification and validation took the form of a formal end of stage review attended by key stakeholders and business representatives. The assessment focused on reviewing the outputs that had been created and suggestions for the next stage. Through discussion, it was ascertained that DePuy believed the review was carried out successfully and delivered a variety of results that were both expected and enlightening. The knowledge audit also delivered them with a number of options that the business had been considering in a format they could easily understand. The main result from this informal assessment was that the business was happy to proceed and to pursue the line of research regarding the resource review process and the functions that are required to support it.

5.1.4 Summary

The aim of this Section was to generate and document business related knowledge regarding the context within which the research has been based. The Section was split into two stages; contextual understanding through company review, and knowledge audit. The first stage, contextual understanding, described the process the researcher took towards developing knowledge regarding DePuy's current business context, in relation to resource management working practices. The next stage, knowledge audit, utilised the previous stage's information, and utilised managerial input to develop a more focused aim, reducing the potential scope of the project.

Benefits	Problems / Concerns	Ideas to address negatives
Understanding what is happening from a resource point of view - powerful	Overall refresh timescale	Simplify Spread Sheet, allow easier user updates
Portfolio decisions can be made based on resource availability	Aggregate Project Plan is more dynamic than ability to refresh	Do more often / link to live APP 1
Posssible to add in human factors - will understand how these affect output	Resource review process is manual (copy / paste etc)	Crystal Reports??
Quicker & more repeatable - able to respond quicker	Spreadsheets mask errors	Validate / protection / unit testing
Recognized as the company cross funtional model with buy in	Static	Add dynamic simulation / refresh button / iterative calulations
Used by functional managers for future headcount planning	Scenario planning limited & need to be created each time	User interfacte with sliders / buttons / macros 2
Linked to Aggregate Project Plan - demand vs capacity	Difficult to play with	User interfacte with sliders / buttons / macros
Easily understood - increases visibility / credibility	Difficult to give update access to other people & maintain integrity	Improve resource input assumptions & ability to create these inputs
Excel - accessible	Data manipulation is time consuming	Easier data sorting / manipulation etc
Understand functional interactions - create visibility	Less reliable - creates suspician	Selling job to show validity
Quicker what if sceanrio planning	Issues trusting credibility	Show value 3
Right first time - less rework	Human factors would cause issue	Have as an option - on or off - talk to HR - linked to 1 & 2
Quick analysis	Bespoke software - J&J issue	Talk to IT - what packages are available? Key Constraint
Drives alignment across business over what we can or can't do	Bespoke software - lack of familiarity	Design for ease of use so people unaware they are using it
Creates cross functional business buy in on resourced projects	Access / licence costs, rights etc	Calculate total cost scenarios
Allows scrutiny on resource heavy projects vs payback / NPV etc.....	Ability to maintain long term	Training / manual / rationale / handbook / handover plan / remove complexity
Allows prioritisation of projects & cut off point	Familiarity with creating / changing models	Make it intuitive / flexible
	Specialised	Deskill it
	Creating scenarios - how do you start from scratch	Create interface / pilot some of these
	Validation	Refernce other software validation approaches
	Who supports system?	Vendor / process owner / gain internal IT buy in
	Who pays for it?	R&D
	Cost of software / licence?	Calculate total cost scenarios
	Forced down J&J IT approved systems - limits choice	Understand what this means & options available
	No IT support can be an issue	Understand IT architecture & direction in this field
	Adding workload to functional managers	Musn't add workload
	Other company IT priorities	Understand IT architecture & direction in this field
	Vendor longevity	Understand IT architecture & direction in this field
	Ability to sell it to senior management cost vs benefit - business case	Determine true business benefits & show how it helps meet strategic imperitives
	Probably cross Op Co / Franchise required	Understand IT architecture & direction in this field

Table 12 – Knowledge audit outcomes

5.1.4.1 *Limitations in application*

One of the main limitations experienced in the implementation of this methodology stage was the availability of key knowledge holders within the business. As those who held information were general at a managerial level, their time was seen to be precious and hard to attain. This required a degree of upfront planning and senior leadership buy in order to achieve an appropriate level of managerial input. Without this help, information that would have been influential in the system development may not have been elicited, possibly affecting the quality of the system produced.

One other limitation that was encountered was that those discussing the possibilities of improvement within the business may not have suggested or prioritised initiatives that would negatively impact their own personal position within the business, thus bringing in biases to the decision-making process. A degree of review was essential to ensure that the initiatives highlighted were in line with the business objective, this helped develop a common understanding of what was required. There is however, a potential limitation on the outputs from the review based on this fact.

5.2 Envisage the future

In this stage of the methodology, the host business will be encouraged to develop a view of their ideal future situation, or 'to-be' state, in relation to the problem area and key opportunities identified in the previous stage. This ideal vision will be influenced by the businesses strategic vision, current best practice in the field, technological advancements, as well as the considerations from the company context identified in the previous stage. This stage of the methodology will be accomplished in three main activities, firstly the identification of the long-term goal, secondly the identification of the logical incremental steps towards achieving that goal, and finally the development of a time-based implementation plan.

5.2.1 Identify the long-term goal

To identify DePuy's long term goal in relation to resource management, it was important to establish at a high level what the company aspired to achieve. Therefore, one of the main activities that were carried out in this stage of the methodology application was to discuss resource management approaches with DePuy, both in relation to what is done in their own organisation and what has been achieved elsewhere. Through these discussions on industrial best practices, key knowledge holders in DePuy were able to build a vision of what was available to them and what they personally felt would make the most difference in their business.

An activity that contributed to DePuy's future vision was meeting and discussing resource management approaches with the cosmetics department of Johnson and Johnson, a sister company of DePuy. The cosmetics arm of Johnson and Johnson were widely considered as resource management best practice leaders and were well known in the business for their attitude towards resource management. From this discussion, DePuy were able to understand in a greater level of detail the complexities and level of effort that would be required when implementing a resource management system in their business. Due to the very different business structure of the cosmetics business, DePuy were not able to implement the system their sister company had developed, but were able to develop their own vision from the aspirations and achievements that a fellow Johnson and Johnson's company had achieved.

DePuy also contributed to their future vision through a review of available technologies that could deliver a service to DePuy; among these were ERP and simulation systems. Although this process did not highlight a system that DePuy could actively take on at this stage, due to IT strategy constraints, it did give DePuy the awareness of what could be achieved and what DePuy could realistically expect from such a system.

The outcome from these activities was that DePuy focused on the requirements for a high-level portfolio management tool that could clearly show what projects were being worked on, what stage they were in, and crucially what resources that project was consuming. DePuy were motivated by the idea that they would be able to see the resource allocation and utilisation across the portfolio of projects at a high level, something that they currently have little visibility of. Another driving force for this type of tool was that all information for resource allocation and project specific information would be stored in a central repository, giving management an easy accessed and digestible overview of project specific information.

5.2.2 *Identify the building blocks to achieve the goal*

With an established understanding of their long-term future goal, the next stage in the methodology was to establish what incremental steps were required to achieve that goal. The aim was to decompose the improvement plan into manageable discrete packages of work, which would complement each other to achieve the desired "TO-BE" state, articulated in the long-term goal. This would enable DePuy to manage the work required as a portfolio where resources could be allocated accordingly.

The improvement steps that DePuy identified were as follows;

1. **Single project management** – Apply a standard approach to resource allocation and management within all individual projects to promote consistency.
2. **Resource estimations vs capacity** – Develop the ability to compare what is required against what is available, accurately and consistently, to allow the development of a realistic plan.
3. **Portfolio scenario analysis** – Utilise scenario analysis to enable managers to test resourcing arrangements so that they can make more informed and timely decisions.
4. **Portfolio optimisation** – Utilise optimisation software to allocate resources and balance the portfolio of projects to maximise output, while minimising waste.
5. **Portfolio simulation** – Apply the principles of simulation to create a model of the resource allocation process which can be utilised to predict future events and the impact of decisions on the system.
6. **Comparing actual used resources against estimated** – Develop the ability to effectively record and compare the actual usage of resource on a project, and compare this with what was initially proposed.
7. **Integrated portfolio management tool** – Put in place a tool that enables management to have visibility of and control over the allocation and management of resources and incorporates analysis tools that will enable management to make more effective and efficient decisions.

The above list of actions proposed by DePuy highlights the required steps that they feel need to be achieved to improve their current "AS-IS" process, in order to achieve their desired "to-be" state. All of these building blocks will have their individual complexities and goals and should therefore be managed as separate deliverables that develop the improvement plan as a whole.

It is essential at this stage of the methodology to avoid developing any particular solutions, rather, the steps should be focused around the desired output or technology use that is required. This will ensure that the company involved does not conduct solution development too early and avoid fixation, which could restrict their ability to fully consider all options open to them in the later design stages of the process. Therefore, DePuy kept their stages to improvement simple and relatively high level, one building on the other sequentially in a logical order.

5.2.3 Map stages onto the time line

With the improvement plan broken down into blocks, these blocks were placed on a time scale, to show when each block would be completed in relation to one another. To achieve this, it was essential that a roadmap was developed that illustrates the journey for improvement. What is important to consider at this stage is the method that would be utilised to visualise the roadmap, as this should be appropriate not only for the task that is being carried out but also the context within which it is being utilised. Within DePuy, plans were in general developed on a short, mid and long-term basis, with more detailed planning done at the project level. This approach was utilised in the development of DePuy's improvement roadmap, illustrated in Figure 17.

What can also be seen from the improvement roadmap shown in Figure 17 is that the development stages have also been evaluated on their potential impact on the company. This measure was particularly important to DePuy as it gave them an indication of which development stage would be most beneficial and therefore should be given more support and management guidance, therefore enabling DePuy to achieve a degree of managing by exception. Whilst a development stage could be highlighted as high impact, it could also be low in resource requirements, highlighting that there is not a linear relationship between impact and resource requirements. Due to this reason, there is an outstanding requirement to look at each block of work individually and ascertain its resource requirements, as this was a constraining factor for DePuy. In other contexts, certain constraining factors may have more of an impact such as money, time, available technology etc.

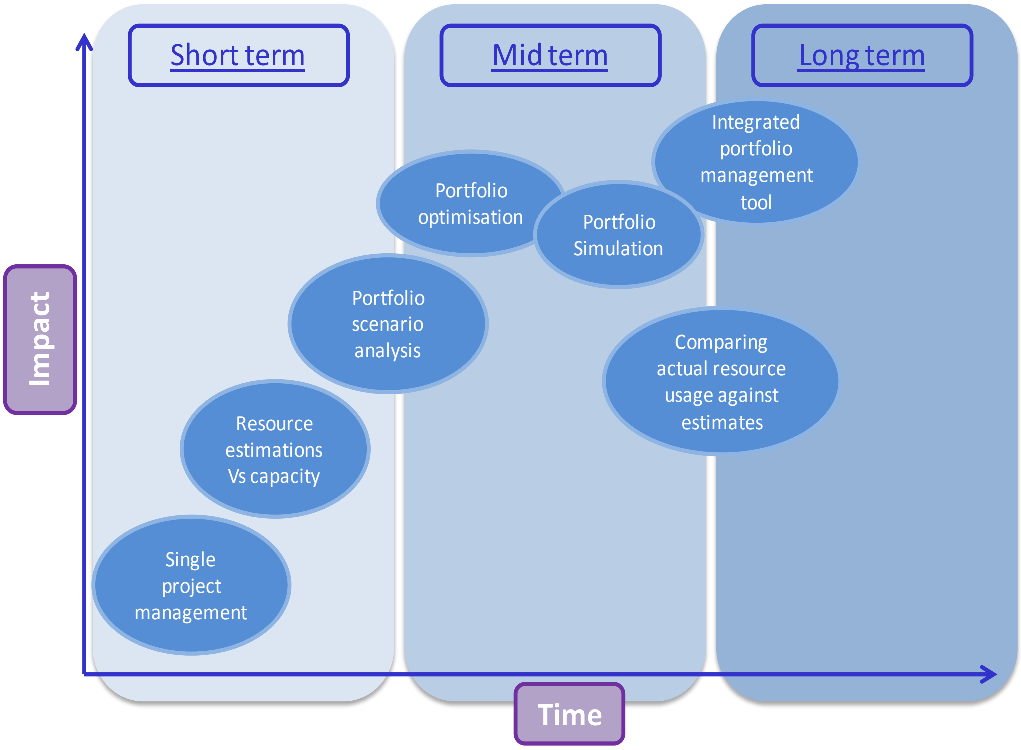

Figure 17 – DePuy's improvement roadmap

As this roadmap is intended as a high-level plan for the progression of improvement within a company, these issues were considered to be too complex and changeable to be shown here, however, it essential that they are considered at a level at which the company finds most appropriate.

5.2.4 Verification and Validation

In order to ensure that the future vision was develop in the correct manner and delivered the expected outcomes at a high quality, a formal review was conducted with the business. The review focused on the appropriateness of the outcomes and raised questions as to the achievability of the suggestions that were made.

The review was carried out in an informal manner, with key representatives from the business. Each deliverable was assessed individually i.e. long term goal, building blocks and the time-based plan. From this review, a number of suggestions were made for delivering the plan and ideas were discussed as to how the next stage could be managed to ensure that scope was managed effectively. Overall, it was ascertained that the deliverables from this stage in the methodology were of a standard acceptable by DePuy and had incorporated their vision for the future well. DePuy were happy to move on to the next stage of defining a particular project to work on, with the knowledge that it would be in keeping with the wider vision of the business.

5.2.5 Summary

In this Section, the application of the second stage of the methodology was described. The aim of this stage was to achieve an understanding of the desired 'to-be' state and an outline of the plan DePuy wanted to put in place to achieve it. It was established that DePuy required a high-level portfolio management tool that gave managers visibility and control over resource management in real time. The next stage of the methodology then identified a number of blocks of work that would be completed to achieve this goal in DePuy, which were then developed into a road map highlighting timescales and potential impact. The outcomes from this stage have not only enabled DePuy to consider and discuss potential for change but also to put in place a preliminary plan for improvement and establish a vision for the future that was previously unknown.

5.2.5.1 ***Limitations in application***

A limitation experienced with application in this stage of the methodology was ensuring that influential high level management were involved in the vision statement development. These managers would become the sponsor of the projects it would develop and needed to be part of the process to both direct it in the way and provide resources to achieve the goals set. Establishing this connection and buy in took an amount of time to develop in the business, without this commitment the system development may not have been given the backing it deserved and could easily have been dropped.

Due to the fact that DePuy had not carried out this type of future planning the process was new and took a degree of familiarisation with those involved prior to it being fully accepted as the way forward. It was clear that capability uplift, regarding system development, was also occurring at the same time as system development. This may have impacted in the overall quality of the outputs generated and re-work that had to be done.

5.3 Pinpoint leverage

This stage of the methodology is aimed at determining which improvement will be taken into active work by DePuy. It may be the case that more than one block of work will be taken into active work at the same time, in this case it is suggested that each block should be taken through this stage individually but managed as a whole.

In the case of DePuy, due to resource and time constraints, only one development stage could be taken on in this improvement effort. Therefore, this Section will describe the process of determining and documenting the scope, overall aim, and objectives of that block of work.

5.3.1 Scope definition

The first action in this stage of the methodology is to identify which development stage from the roadmap will be taken forward in this improvement cycle. To achieve this, key knowledge holders and management were engaged in discussions regarding what development stage would be realistic and would give the greatest impact. From these discussions, it was established that DePuy would like to progress the portfolio scenario analysis block, as work had already been started in the areas of single project management and comparing required resource and capacity. DePuy therefore decided that it was in the best interest of the company to move forward with scenario analysis, which would incorporate learning from the previous stages.

With this clear understanding of what development stages in the roadmap will be taking into work, a definition of what that block of work will achieve is now required. This will define the scope of the work to be achieved, and just as importantly what is considered to be out of scope. In the development of the scope, issues such as level of detail required in the analysis, the need to manage uncertainty, and human factors need to be considered. The way in which the scope is developed and displayed must be in accordance with what is seen to be the most appropriate for the business context. Within DePuy, it was established that scope for this project should be a high-level statement of requirement i.e. what the system should achieve. The more in-depth analysis of the requirements would be taken into account in later stages.

Through group discussion with resource managers, and incremental development and verification, a definition of the scope of the project to be carried out was achieved. The remainder of this Section will detail what was agreed and will describe how this will limit the scope and what is expected to be delivered. The following paragraphs are the output from this discussion and illustrate the scope that will be enacted and managed throughout the improvement.

> *"The system will be utilised at a high level of abstraction therefore the level of detail that will be expected will be low, it will focus on breadth rather than depth in relation to information. This will mean that all projects in work will need to be base-lined in relation to a number of high level metrics, such as expected duration, expected resource use as well as resource assigned. The system will not be expected to individually name actual resources and their skill set, this area of management will be dealt with externally to this system. The system will be expected to visualise the information in a user-friendly way, lending itself to ease of use.*
>
> *A key design constraint that has been identified is the use of IT systems, for this reason the system shall utilise only IT systems that are freely available for use in DePuy at the point of design. There is no scope in the project to bring in any IT solutions at this stage. Although this is considered a constraint utilising familiar IT systems with this system may be an advantage when considering acceptance and adoption.*
>
> *The system will use the input of the managerial staff utilising the system. The manipulation of the data to generate the scenarios will also rely exclusively on the managerial staff. This will mean that the system will only act as a facilitation tool and will not offer solutions. Therefore, the system itself will require only the functionality to visualise and manipulate data in any manner that managerial staff will require to develop scenarios of their choosing."*

5.3.2 Aim and objectives

Now that the scope has been defined and clearly described in relation to what will be expected and what is clearly out of scope, the overall aims and objectives can be defined. The overall aim of the work is a brief statement that summarises the key development that is described in the scope. The aim will enable those developing the system to clearly understand why each task is being carried out and how it relates to the aim. This ultimately offers a focus and achieves a holistic approach to the development of a system.

The overall aim in relation to the development of the scenario analysis system is:

> *"The design, development and delivery of a scenario analysis system which will enable managers to visualise the effects of resource management decisions on the entire portfolio as a whole."*

The next level of detail that is required when considering a clear focus is the definition of a set of objectives in relation to the achieving the aim. These objectives will cover all key tasks that require to be carried out to successfully deliver the system. At this stage, the key tasks will be at a high level and will follow closely the tasks that have been highlighted in the next stage of the methodology i.e. Develop a solution. The aim of detailing the objective in this manner is to identify what DePuy will personally have to achieve in each objective and what tasks may be required to be carried out.

The objectives for the scenario analysis system were set as follows:

1. **Requirements elicitation** – Utilise a number of elicitation techniques to gather a balanced view of what the system is required to achieve. Make allowances for the elicitation of embedded or unknown requirements and the opportunity for change in the requirement with increasing knowledge.
2. **Requirements documentation** – Collect and display all information from elicitation tasks to clearly establish a specification for the system that will define the functional and non-functional requirements.
3. **System development** – Utilise evolutionary prototypes, alongside user testing, to develop a system that meets the requirements that have been set. Fully test the system and make changes when required to ensure all requirements are met.

4. **Validation and Verification** – Ensure that that the right system has been built and that it has been built right.

5.3.3 Verification and Validation

To ensure that the project identified in this stage of the methodology was accurate the scope, aim and objectives were critically scrutinised by the business. The business carefully assessed the deliverables against the future business goals to ensure that the project was in line with the deliverables developed in stage two of the methodology. In this informal discussion, the business assessed if the project scope was correctly constructed and incorporated expected deliverables. The business also assessed if the project would be deliverable in the time scales that had been set, with the resources that had been made available. Discussion also ascertained what steps would need to be taken to ensure that the project would be successful in the later stages of the methodology application.

From this review, it was established that the business was happy to proceed providing that engagement was made with the "Expert" users of the system that was to be developed. It was agreed that this user group would be utilised to inform the requirements elicitation and system development.

5.3.4 Summary

With a clear scope, aim, and objectives set for the scenario analysis system, the work has been given a focus and a reference point from which decisions can be assessed against. This will ensure that tasks will line up against achieving a particular objective within the scope set. This holistic approach to the management of a project at a high-level will ensure that all subsequent tasks will have an overarching constraint placed on them, meaning that only work seen to be value adding will be carried out.

5.3.4.1 ***Limitations in application***

A limitation experienced in this stage of the methodology application was that managers in DePuy were unclear as to what they could achieve, and were therefore reticent and unsure as to how to develop a scope for the system to be developed. The novelty of the system development within the business and the capability gap experienced affected the ability of the senior management to agree on a way forward. However, through group discussion and facilitation by the researcher a consensus was achieved that ensured the business had agreed a way forward. This was caveated with the understanding that the scope and objectives are subject to change as more is learnt about the requirements. This concept was well understood by those in the business who deal with change readily.

5.4 Develop a solution

The aim of this stage of the methodology is to undertake tasks that will effectively and efficiently fulfil the objectives set in the previous stage, while working within the scope that has been established. The tasks that will be undertaken must be established as appropriate for the context within which the system is being developed. Justification for the use of certain methods and approaches will be given throughout this Section.

5.4.1 Requirements elicitation and documentation

The next stage in the process is to develop a better understanding of the requirements DePuy have in relation to the area of focus i.e. resource scenario analysis. To develop this understanding, it was decided that the appropriate method to utilise in this context was to consult the individual responsible for the management and development of the current resource review process, as highlighted from verification and validation discussions in Section 5.3.3. This status of "Expert" was allocated due to the perceived knowledge and experience that this individual had, as well as the fact that it had been that individual's sole responsibility and no other individual could provide the insights required. Therefore, the requirements elicited came from a single source, also reducing the possibility for confusion or conflicting opinions.

5.4.2 Requirements elicitation

The first stage of the requirement elicitation process was to conduct interviews with the Expert. The aim of these interviews was to establish the fundamental requirements, as well as to un-cover and explore requirements not fully or explicitly understood. This was achieved through structuring the interview around the creation and completion of a mind map. The final completed mind map can be seen in Figure 18;

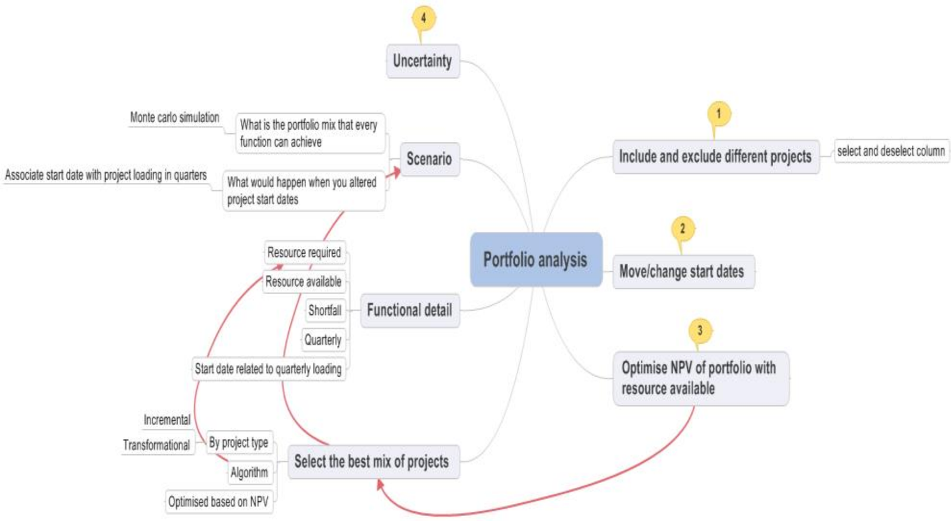

Figure 18 – Semi-structure requirements elicitation mind map

The mind map initially only had two categories included; Scenario and Detail, these were used to focus on what detail should be included and what scenarios could be played out. The details which were found to be essential were:

- Analysis was required for each business group, where each function was required to be represented.
- Information was to be presented at a high level i.e. quarterly over a planning horizon of two years.
- All information regarding resource allocation to projects to be included, the same for resource availability.
- Shortfall should be highlighted by the deduction of the availability in a quarter from the resource requirement in a quarter.
- The assumption in place is that the project starts in the quarter the resource figures commence, no more detail than this is required.

When considering the variety of scenarios, the Expert would to be able to create when considering the current resource review process, two main scenarios were elicited;

1. Achieving the best mix of projects that every function could adequately resource.
2. The ability to assess the impact of altering the start dates of projects.

The first scenario relates to the overall aim of doing the resource review in real time, which has currently eluded DePuy, the perfectly balanced resource profile over all businesses and functions. This scenario is very broad and could be achieved in a number of different ways; discussions were then focused on considering scenarios that could enable this scenario to become reality. This led on to the elicitation of the second scenario; the ability to manipulate the start dates of projects. The Expert believes that this increased flexibility would give an added ability to make more informed decisions when considering the balancing of resources.

The discussion was then opened up to ask about what functions would facilitate the realisation of the scenarios elicited. The outcome from this was the explicit recognition of five functions of interest i.e. select the best mix of projects; optimise the Net Present Value (NPV) of a portfolio of projects based on the resources available; move or change start dates of projects; the ability to include and exclude projects; and finally the inclusion of uncertainty. Once these functions had been discussed and placed on the mind map, they were then prioritised to highlight their respective importance. Select the best mix of projects was not given a rank due to its ambiguity and the fact it could be fulfilled through the other functions highlighted, therefore this aspect was taken out of the prioritisation.

The ranking of the functions discussed were as follows;

1. Include and exclude projects.
2. Move or change start dates.
3. Ability to optimise NPV of a portfolio in relation to the resource available.
4. Include appreciation of uncertainty.

To gain an appreciation of the constraints that may exist on fulfilling any requirements that had been discussed in this stage, it was decided that a discussion with the IT specialist within DePuy was required, as suggested by the knowledge audit. Through lengthy discussion of possible ways forward, it was decided that designing and implementing a system which utilised software that was not already utilised by DePuy was not an option. This was due to the fact that it would take too long to approve the use of new software and was not viable within the time limit experienced in the project. This fact would also have limited the ability for the managers to use the system in the future, if DePuy decided not to approve the use of the software the system had been developed and implemented in. Therefore, the decision was made to base the system within software easily accessed and utilised by managers within

DePuy that would encourage buy-in and minimise the learning curve required. The only software option that fulfilled this was Microsoft Excel, which is used throughout DePuy in relation to the management of resources and projects, and is the software currently used to manage the resource review process. This fact meant that the development of the system would have to be constrained to the development of a system within the Excel software and further focused and reduced the scope of the project.

5.4.3 Requirements documentation

With this understanding of the detail, scenarios, particular functions and IT constraints it was then decided that a clear set of requirements that reflect the understanding generated were required. The documented requirements would give the clarity and structure to the understanding already established, and could then be utilised in later stages for validation and assessment purposes.

A systematic textual analysis of the contextual understanding, knowledge audit and the requirements elicitation exercises was undertaken. This involved a line by line analysis of all stated and implied requirements, utilising the Holistic Requirement Model (HRM) as a structure, shown in Figure 19. The aim of this exercise was to interpret, expand, and clarify expressed and implied requirements, as well as identify missing requirements (Burge 2006).

By using the HRM, as a structure the requirements were sorted into operational, functional and non-functional requirements. The operational requirement describes the main aim of the model, functional requirements describe how to satisfy that aim and non-functional requirements document the constraints from a performance, system and implementation perspective.

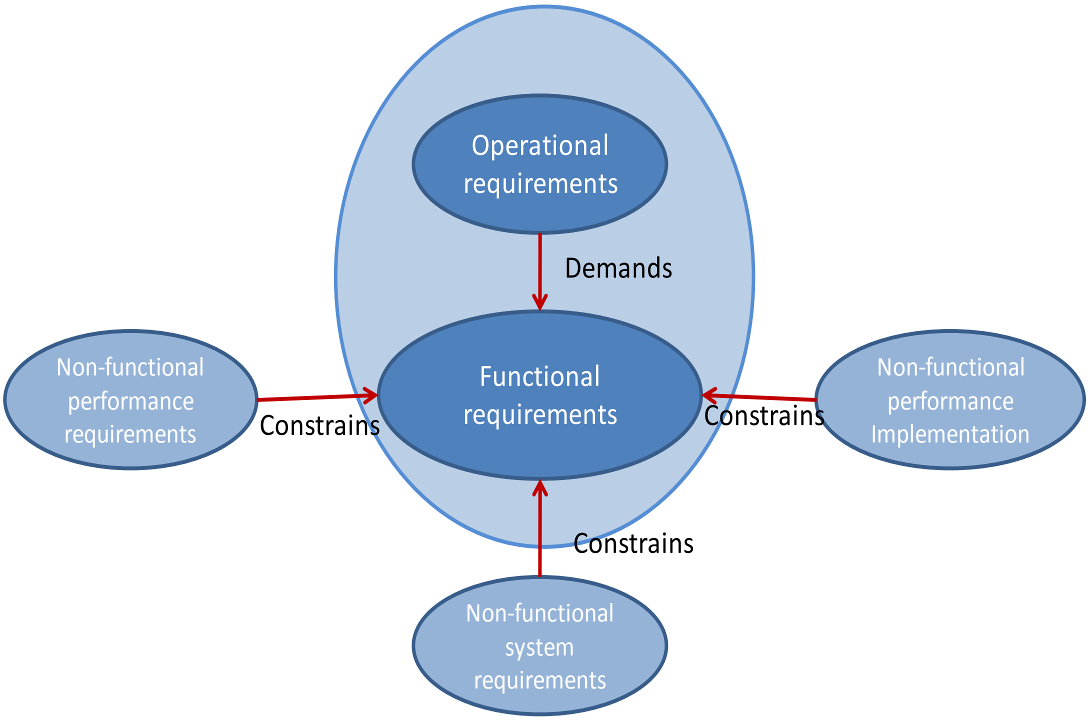

Figure 19 – Holistic requirements model (HRM) (Burge 2006)

The outcome from this was a structured understanding of the requirements of a resource management tool for use by DePuy in their efforts to improve their resource review process. This is highlighted in the operational requirement:

> *"Enable managers to make more informed decisions through the evaluation of potential resourcing scenarios in a timely and reliable manner"*

The structured list of requirements can be found in Table 13, which highlights the operational, functional and non-functional requirements of the system, bearing in mind the constraint of utilising Microsoft excel. The requirements were fully validated by the Expert assigned to be responsible for the project. This was achieved by carefully discussing, and in many cases, altering requirements to ensure they ultimately represent what the Expert had envisaged.

Operational Requirement - What is the main aim of the model?	Description
O1	Enable managers to make more informed decisions through the evaluation of potential resourcing scenarios in a timely and reliable manner

Functional requirements - How to satisfy the operational requirement i.e. what would it have to do, what would it have to show	Description
F1	The tool shall automate the collection of project resource data
F2	The tool shall automate the manipulatation of project resource data
F3	The tool shall utilise a 2 year timeline
F4	The tool shall show all projects listed on the resource refresh spreadsheet
F5	the tool shall include all functions in the resource refresh spreadsheet
F6	The tool shall account for changes in presented data for each business area
F7	The tool shall utilise a Qtr by Qtr level of detail
F8	The tool shall calculate overall resource demand per function per Qtr
F9	The tool shall show resource availability per function per Qtr
F10	The tool shall calculate overall resource shortfall per function per Qtr (available minus demand)
F11	The tool shall present shortfall in a graphical format
F12	The tool shall enable the inclusion and exclusion of selected projects from the portfolio
F13	The tool shall enable the movement of project start dates
F14	The tool shall enable projects to be reset to their original start date after it has been moved
F15	The tool shall detail a projects platform
F16	The tool shall detail a projects current status
F17	The tool shall provide the ability to detail a projects NPV by the user
F18	The tool shall detail the total resource utilised on each individual project
F19	The tool shall detail the ratio of resource utilised to the NPV gained
F20	All totals/ratios will automatically update what any change is made
F21	Each function shall have an individual graph showing the shortfall over the time period
F22	All graphs will automatically update when any changes are made
F23	A view of the overall resourcing picture over all business's will be provided
F24	The overall picture will include all functions

Non-Functional requirements - What are the constraints on the system?	Description
Performance	
NFP1	Accuracy = 100%
NFP2	Timely screen update when enabling functions = under 5 secs
NFP3	Maintain a high level of reliability = MTBF 200 uses
System	
NFS1	Remain under 2Mb in size
NFS2	Easy to use
NFS3	Easily understood outputs
NFS4	Be sympathetic to the style currently used for data analysis
NFS5	Easy to maintain
NFS6	Easy to update
NFS7	Interoperate with other systems
Implementation	
NFI1	Runable on Microsoft Windows XP
NFI2	Compatible with Windows Office 2007, and earlier

Table 13 – System requirements

5.4.4 System development

Due to the complex nature of DePuy's business and their resource allocation process, it was suggested that the system be developed in discrete stages to manage the complexity through the use of prototypes. As DePuy have multiple departments, i.e. hips, knees, etc., all utilising shared resource from functional areas; it was decided to initially focus on one department to develop the system. Once this had been developed fully then the tool could be expanded to include all departments. The initial development focused on the creation of a system solely for use in the hips department, this is what will be discussed in the initial stages of this Section. The development will then move on to discuss how the system was then developed further to include all departments. Upfront conceptual design work was carried out prior to prototyping to gain further understanding of system context and to business buy in, this is documented in attached Appendix C, where SySml models were used to model the resource management function.

5.4.4.1 ***System design documentation***

Utilising Excel in the system development would mean that users would be able to easily engage with the system and utilise the functions that it would provide. Another advantage of using Excel would be that the existing spreadsheet, known as the APP, which manages project specific resource data, can easily be copied and pasted into the system with little interoperability issues.

Due to this opportunity raised the first design decision was made: all information already stored in the resource refresh spread sheets held by the business will be automatically populated in the system. With this understanding a number of use cases were developed, as shown in in Figure 20. Each uses case required to be further understood and developed utilising the functionality available within Excel. Also, the constraints evident with working with a large data set existing within the APP spreadsheet required to be managed. The use cases elicited defined three main functions; enable the automatic population of data from the APP spreadsheet, ability to customise the portfolio, and altering project start dates.

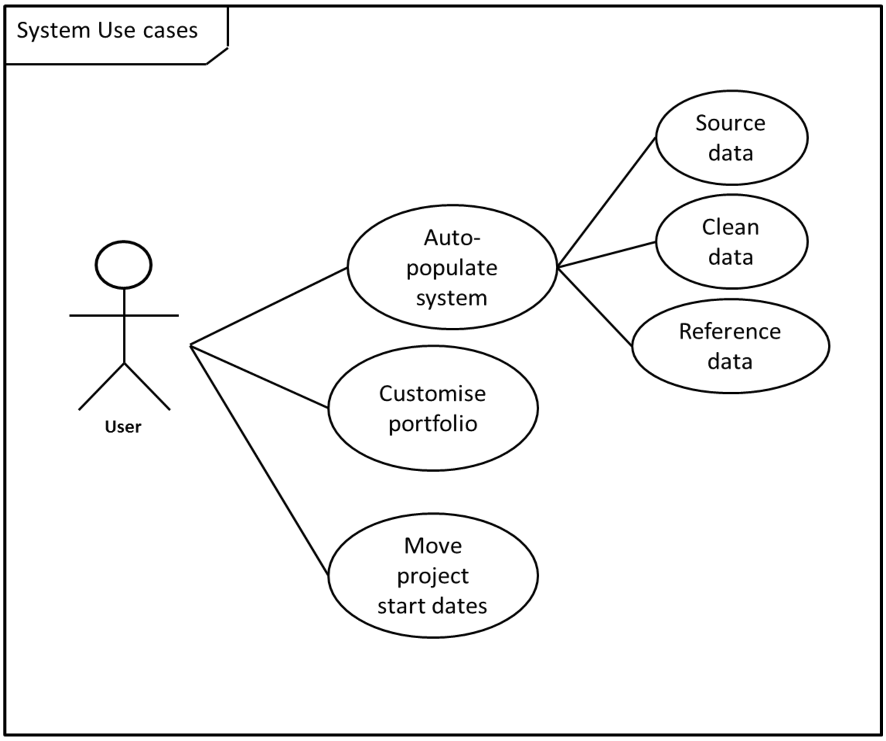

Figure 20 - System Use cases

The first use case that was investigated was the automatic population of the system, the sequence in how this was achieved is shown in Figure 21. This was a relatively easy function to create within Excel through the use of macros, effectively opening up the file then copy and pasting the information required. This lead to the design decision to have three separate excel sheets within the system; one to receive and clean the data, one to hold the clean data, and finally one to manipulate the data. This design decision was made due to the formatting of the resource refresh data within the APP, this required a number of transformations to be made to the data before it could be utilised, for example the elimination of blank lines and cells that meant the data didn't line up. In reaction to this issue a clean-up area in the system was created, which deleted all irrelevant data and formatted it correctly. From this area of the system, the data would be copied to a working area, from which it would be referenced through to the front page where it could then be manipulated. Having the source for data stored in a separate area from the manipulation added a secondary benefit, it meant that when changes were made in the main page the automatically populated data stayed the same and acted as a refresh for when the data needed to be taken back to its original state, which may have been very hard to achieve if the data was only held in one position in the system.

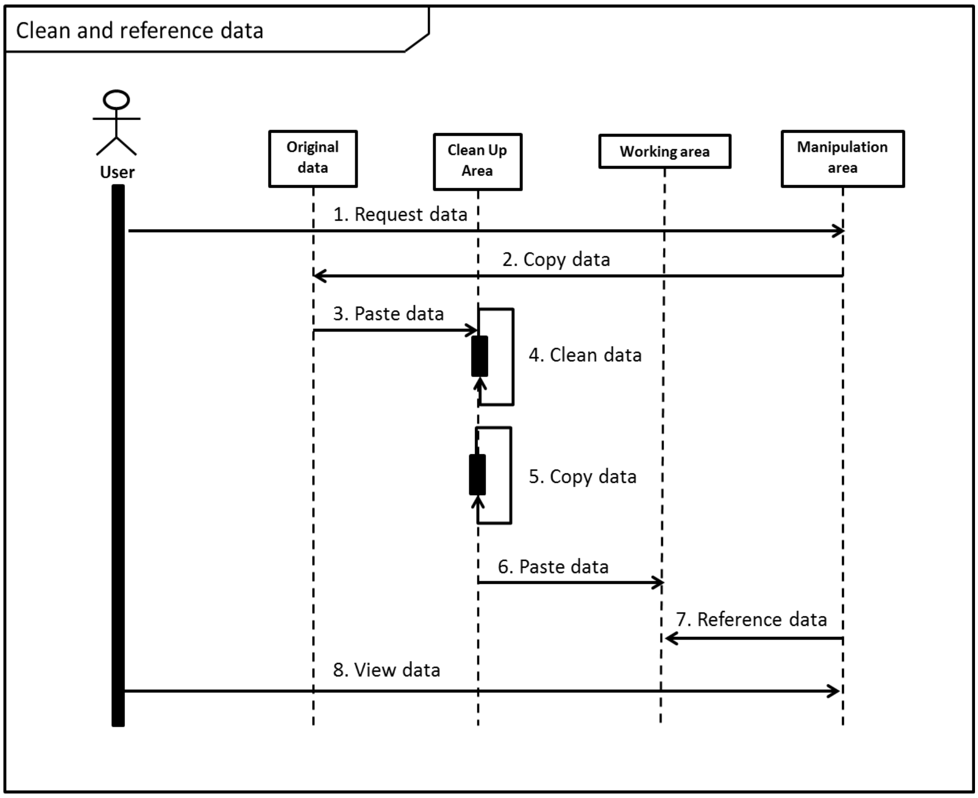

Figure 21 - Source, clean and reference data sequence diagram

The next design decision that was taken on was the layout of the data itself on the user interface. The design was influenced by the functional requirements and aimed to fully meet all that were set. The design was also influenced by the current resource refresh spreadsheet that was being utilised within DePuy to gather resource information on a quarterly basis. As all the information for the system was to be obtained from this source it made sense to mirror its format. Also from a familiarity and functionality stand point the user interface was tried and tested and met the functional requirements that had been elicited. The interface can be seen below in Figure 21. The function of the system will be discussed in more detail through the course of this Section. As can be seen in Figure 22 all project names are stored the left-hand side with a blank cell next to it called "status", this was included to give an opportunity for managers to highlight what stage that project was in i.e. design, testing etc. The next column is where the net present value (NPV) data would be stored, highlighting the difference in value of the projects in the list. The next column shows the accumulated total resource that has been allocated to that project across all functions. This is then utilised to create a ratio between the NPV and the resource allocated. The higher this value, the more that is achieved for each resource allocated, this metric was incorporated to encourage managers to consider the affects that decision making can have on the financial level.

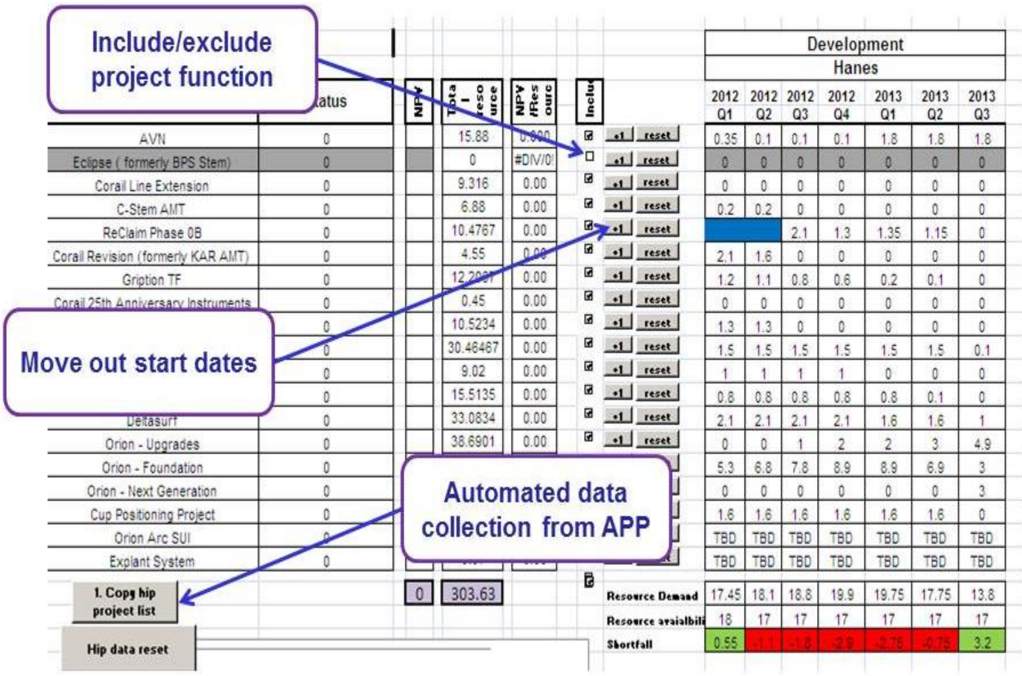

Figure 22 – User interface

To the right of the Figure 22 a functional group is shown, in this case Development, the system had to take into account the matrix structure of the organisation so therefore had multiple business functions to be incorporated. The function data is shown on a two-year timeline split up into quarters, each project has a resource required inserted for each quarter against each project for that specific functional area. At the bottom of each function the resource requirements for each quarter is shown, under the resource required there is a number stating the resource available in that quarter. From this data, a calculation of required resource minus available resource can be undertaken, highlighting any surplus resource or shortfall for each quarter for that function. This approach was copied for all function areas, which were all shown in one spreadsheet page side by side so a user could scroll between each one.

With the overall layout and data inclusion incorporated in the system the next stage was to develop and incorporate the user cases of customise portfolio and move project start dates. The customise portfolio use case was achieved through the design and implementation of a deselect function. This was built into the system through the inclusion of a tick box that allowed the user to remove projects from the portfolio. The activity of portfolio customisation that this function achieves is shown in Figure 23. The function operated by utilising an IF function in the resource data cells in each function quarterly requirements. This function states that if the tick box has been ticked then that cell shall reference the resource data and will produce the number from the source data, but if the tick box is un-ticked then the cell shall be blanked out and shaded grey. Un-ticking the box therefore effectively removes that project from the calculations, updating all relevant calculations in the spreadsheet so that the difference between having the project in and taking it out can be easily calculated.

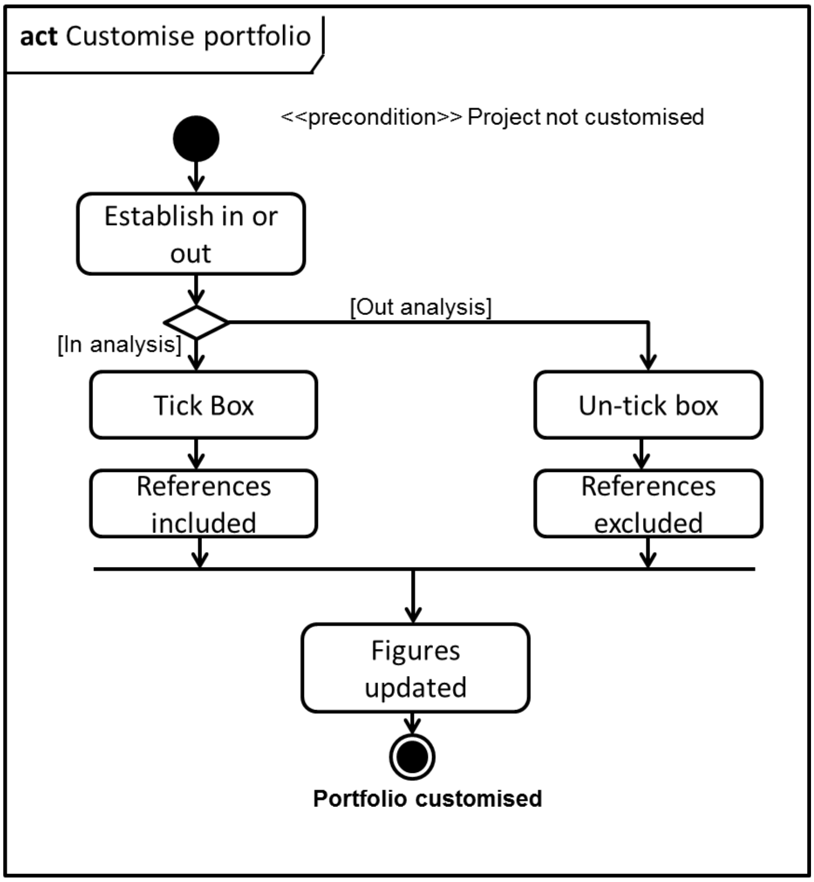

Figure 23 - Customise portfolio activity diagram

The next use case that was implemented within the system was the move project start dates use case. To achieve this use case a macro was used to enable the moving of data related to the start dates of each project, which utilised the copying and pasting of data within the user interface of the system. The sequence of this function is described in the below Figure24. A

+1 button was created, that when pushed would activate the macro associated to the project line the button coordinated with. When the button was pushed, the macro would copy the data in the line, cut it out, and paste it one column along. It would then delete the data that was then hanging over the edge at the other side of the function data box. The macro would then highlight in blue the now blank cell, which would then update all the calculations.

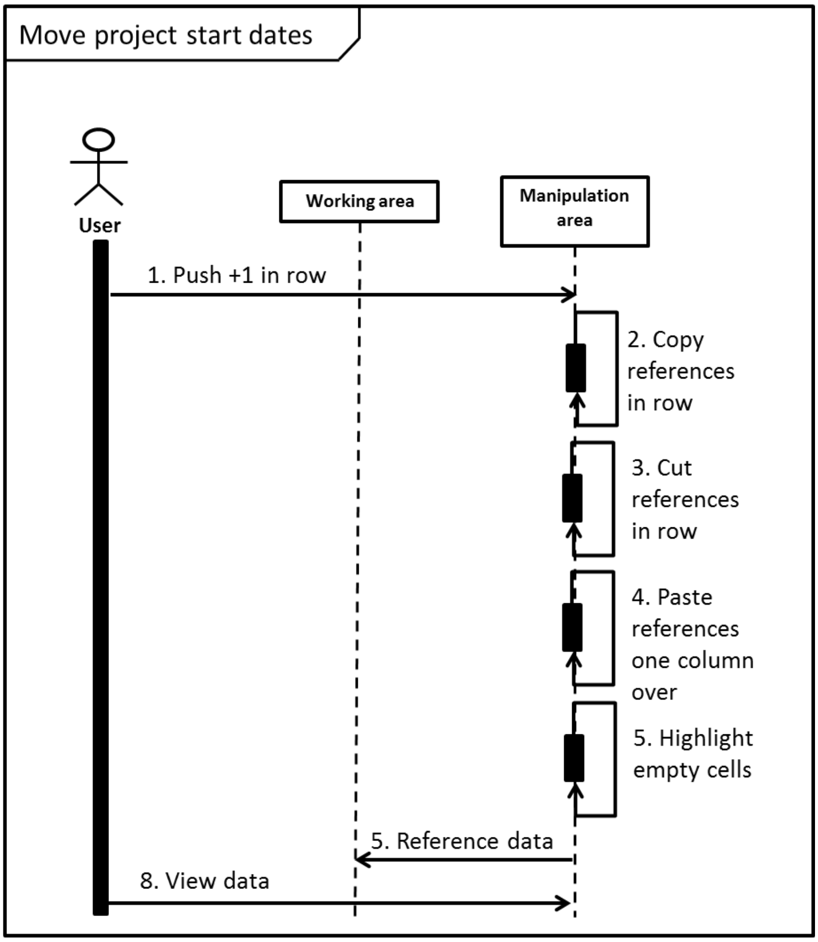

Figure 24 - Move project start dates sequence diagram

If the movement of the start date of the data was not required a reset button was incorporated which cleared all cells in that line and inserted the original formula that referenced the source data. This ensured that all changes made to that project were removed and data has been reset to its original values. The sequence of this function can be seen Figure 25.

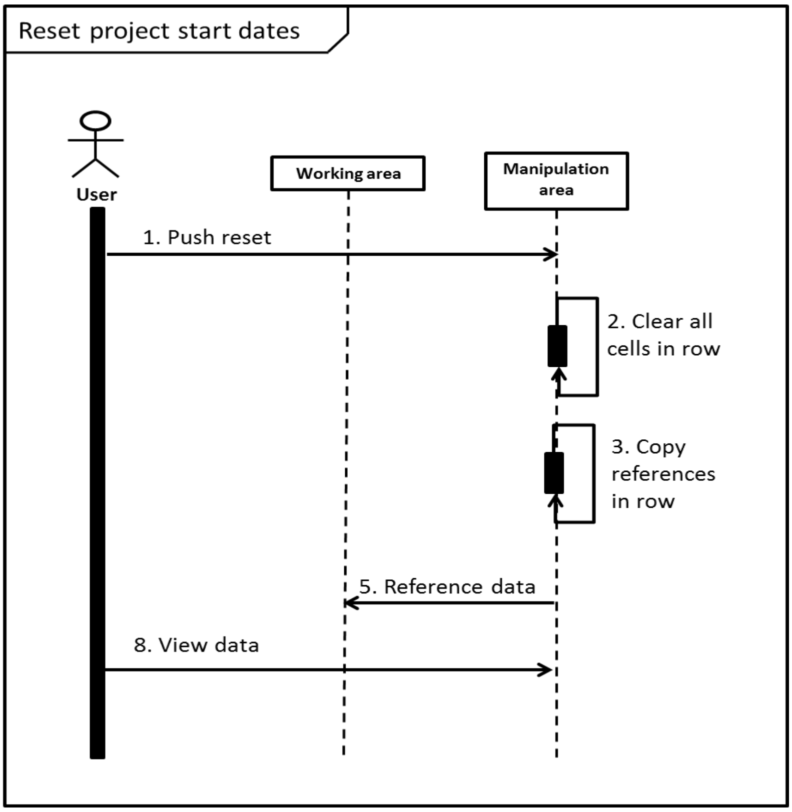

Figure 25 - Reset project start date sequence diagram

To aid in the ease of use of the system a number of other buttons were added to make the function of the system more fluid. Firstly, a copy data button was added which would drag in all data from the source sheet. Then a clear button was added that would blank out all data that had been populated to start from scratch. Another function that was added was the ability to add in projects manually to the data set that may not have been included; this could mean that you insert a potential project that will have an impact to determine how the current resource level will deal with it. This function is therefore essentially in place to aid in the management of uncertainty. It is flexible in its use as the inclusions do not need to be projects they can be events that will have a specific impact to resources, such as maternity leave or illness of a key employee.

Prototype testing – round 1

Once all this functionality had been incorporated and populated utilising the hip department data, the system was then tested for use by the Expert. The aim of this testing was to establish if the work so far had met the requirements set and if it was appropriate for the system to be carried forward to full development, where the functions would be developed further and the system would be improved. This testing was achieved through a user walkthrough of the system utilising sourced data set from an up to date resource refresh. The Expert then utilised the tool to carry out a number of scenarios that he had pre-prepared to establish if it was possible to create them in the tool utilising the functions that had been developed. From this analysis, it was established that the functions worked well and offered the flexibility that was required. However, one drawback that was highlighted was the movement of the screen that occurred when functions were being carried out and the fact that a -1 button for the movement of the start dates did not exist. The Expert gave permission to carry on with development and to develop the system to incorporate all departments, and to investigate designing solutions to the issues highlighted.

Multi-department system development

Due the size of the data set required for each department it was decided that each department should be allocated their own sheet on the spreadsheet, in order that they could be operated and managed independently. This design decision was made to manage the growing complexity of the system and to ensure that the possibility for incorporating errors in the data was minimised. Therefore, the system was enlarged to include the main business functional departments within DePuy; Hips, Knees, Extremities, CMW and Base Business. This was achieved by firstly copying the original Hips sheet and renaming all sheets to their new department. The next step was then to modify and develop the macros and functions for each page, as their original programming was spreadsheet page specific and would need to be changed for each page in turn.

In this stage of development, the design changes suggested in the prototype testing were considered for incorporation to the multi-department system. The first suggestion of minimising the movement experienced when operating functions was a simple fix that meant altering two lines of macro programming on each function that showed a movement on screen. The second suggestion of the incorporation of a -1 button to move back start dates by one quarter was also considered. At first this fix seemed to be quite easy to achieve, mirroring the function of the +1 function by moving data back one quarter. However, since the original data was deleted in the first function this was not achievable. To incorporate this function would have meant that the original +1 function would have to be redesigned and rolled out across the whole system. This issue was raised with the Expert who decided that for the level of effort required to achieve the function it was not an efficient utilisation of resources. Therefore, the -1 function was downgraded to a “would like to have” requirement and a possibility for future additions to the system.

5.4.5 Verification and Validation

As this stage of the methodology focused on the development of a system the verification and validation carried out focused on the system itself, and how it fulfilled the initial requirements that had been set. As well as how it functioned as a system to be utilised in the business context. To ensure that the system was both built correctly and delivered a desirable outcome, prototypes were assessed by the Expert users. Initial assessments had been carried out previously to incrementally develop the prototype, as discussed in Section 5.4.4.1. The final assessment however was carried out in a more formal manner.

From the previous development, a minor change was made to the system to eliminate movement when functions were operated and included all departments. With the function built in the system was then considered to be mature enough to be fully assessed.

The assessment of the system took the form of unit and system tests, as well as user acceptance testing, as discussed and shown in in the attached Appendix E. This involved the Expert user and a number of stakeholder and interested parties. From this assessment, it was established that the system was fit for purpose and would be allowed to progress into implementation within a controlled pilot within the business. From the unit and system testing it was ascertained that all function was built correctly and the system functioned as desired, with very minimal re-work required. From user testing a number of suggestions were made regarding the visualisation of the data and visual cues for the user. It was suggested that familiarisation with the tool and user training would be required to ensure that the system would be utilised appropriately.

To compliment the unit, system and user testing a review was also conducted with the business. This gave the business the chance to discuss and deliberate the system development process and its outcomes, as well as suggest the way forward for the system and the next methodology stage. The main observation from verification and validation discussions at this point in the methodology was that although the system utilised Excel and would potentially be seen to be rather un-refined in comparison to a number of off the shelf products, it offers a low cost and pragmatic solution to a problem DePuy have been facing for a long period of time. When considering DePuy's context, this type of solution fitted well with their current state, as they were able to experience a minimal change that shows abilities they could achieve without a massive amount of expenditure. DePuy were positive they could utilise any learning achieved in the process to push forward in their progression and utilise resources further on in the process where they would be of more use and create more impact that what they may have done at this stage.

One other outcome from the verification and validation discussion was that although the spreadsheet did enable managers to fully consider all scenarios, there was no perceived process for storing or collating the data as an output. It was at this point the decision was made that when changes are made to the system that would require to be saved for later use, the user would have to save a version of the system and give it a name relating to the scenario that had been displayed.

The business was happy with the progress that had been made and the quality and function of the system that had been produced and were therefore happy to proceed to implementing the system within the business context. It was understood that this would be done as a pilot and that further changes would be expected.

5.4.6 Summary

This Section focused on describing the process of applying the "Develop a solution" stage of the overall methodology within DePuy. The main aim of this Section was to design and develop a system that would add value, while meeting all set objectives and the overall aim established.

The outcomes to the objectives set were as follows:

1. **Requirements elicitation** – Expert knowledge holder identified and assigned, they were utilised to obtain requirements through in-depth interview and discussion;
2. **Requirements documentation** – Outcomes from interviews and discussions were summarised and agreed with the Expert and interested parties;
3. **System development** – Spreadsheet system was developed through the use of evolutionary prototypes that were periodically evaluated and updated from feedback;

4. **<u>Validation and Verification</u>** – Final evaluation from the Expert and stakeholders found the system to be effective, and to meet requirements, and to be in scope.

The main contribution that was achieved through the application of this Section of the methodology was that creation of a resource management scenario analysis system for use within DePuy that was accepted for use in their business. Screen shots of the resultant system can be found in the attached Appendix F.

5.4.6.1 *Limitations in application*

Due to novelty of the system development within DePuy it was at first hard to elicit the requirement set from the business. They were very sure as to the impact the system would have but were not clear on how to functionally create this. This resulted in the researcher spending a prolonged period of time with the business to clearly define these. However, as the knowledge holders within the business interacted with prototypes and widened their understanding of what was functionally possible, requirements would evolve and become more certain. There was an increased effort by the research to manage both the original scope and the expectations of the business. This stage of the methodology should further represent the cyclic approach that was taken and build in further change management principles.

One other limitation that was experienced was that system development depended on the skills and ability of the researcher to fully develop the system. Therefore, the functions that were incorporated were done so at the level of skill that was available. If a more experienced developer, or an external contractor, had been involved this may have produced a higher quality output, in terms of appearance and use of specialised development tools.

5.5 Implement in the business

With the system accepted for use within the business the final stage of the methodology was enacted that would see the system implemented within the business context. The first stage of this process was to pilot the system in a controlled manner, so that any evolution or additional requirements could be documented. This information was then used to update the system to its final state that could be then utilised in the business. This Section will discuss the work carried out in each part of the application of the methodology within DePuy and will summarise all the main outcomes from the application of the system. The final part of the Section will discuss the plans that were put in place with DePuy to maintain and control the system and its use within the business.

5.5.1 Pilot prototype

To pilot the system, the decision was made to do a resource refresh prior to any analysis, so that all information that was used was up to date and represented the current state of resources at that point in time. The system could then be used in conjunction with the data received at portfolio level managerial meetings to discuss the results and manipulate the data.

The resource refresh process has previously proved to be time consuming, mainly due to the fact that it relies on the manual collection of resource requirement and availability data of all functions for all projects in all departments. Due to this perceived time delay in acquiring data for use in the pilot of the system it was decided to only utilise hip department data and pilot one section of the tool. DePuy were happy to go ahead with this as the isolated analysis of the hip department could be easily controlled and would minimise disruption to their current process.

Once this data had been collected the resource refresh spreadsheet was officially handed over for use in the scenario analysis tool. The first task was to update the macros that were set up to source data and place it in the analysis tool. These were calibrated and tested to ensure they were working correctly before any analysis was carried out. Once these macros were assured and the associated data verified as being correct by resource managers, the analysis tool was ready for use. The tool was then handed over the Expert that had aided in the development of the system for use in the next resource review meeting that was due to be conducted for the Hip portfolio.

In the Hip portfolio resource management meeting the resource allocations of projects were to be discussed, as well as the potential to introduce new projects into the portfolio in the coming year. The scenario analysis tool was utilised at a portfolio management level to address the issue of resource requirements for the portfolio as a whole, and did not focus on one project in isolation. The outcome from the discussions of the information that was presented to the team was that with the current portfolio, the hip team were consistently under resourced for all projects for the next two years, by 3-5 FTE's. After this initial discussion, the team then utilised the functions of the tool to see how this situation could be remedied, first by moving out start dates of new projects in the portfolio and then by effectively pausing projects already in development. However, due to the size of the problem and the complex relationships between the projects, there was no way that the data could be effectively manipulated to ease the impact of this resource shortfall. The managers were struggling to balance the issue of resource requirements and business requirements. It was evident that projects that had heavy investment could not be paused; ones that could were not heavily resourced so their contribution to lower the impact was minimal. Also, there was a business need to introduce projects that met their strategy and responded to market drivers that were existent at the time, meaning that projects that were due to start could not be held off for long periods of time without risking jeopardising potential profits from the introduction of that product to the market.

Essentially what had been established was that the hips department was under resourced, to the point that they could not sustain the projects they were already assigned, not to mention the projects that were in line to be introduced. This was suspected by the managerial staff but there was previously no way of proving this fact or backing it up with genuine evidence. Although the tool could not be utilised to develop scenarios to enable change to be introduced in the short term, it was the key driver in developing an awareness of the problem that the hips department were facing. Even though the hips department were aware of the resourcing issue, through discussion and an overall understanding of the challenges faced on a day to day firefighting front, the full extent and potential repercussions were not fully understood. This had led the department into a state of constantly resolving issues as they arise, without having the opportunity to consider the root cause of the issues they were experiencing.

As a result, from the analysis of the resource refresh data in the Hip department, an in-depth review of the resourcing issues was commissioned. The aim of this review was to utilise their current state of awareness and diagnoses of problems that were evident and move on to find more strategic and high level solutions that would ease the situation, which could not be accounted for in the analysis tool. Solutions such as the use of temporary staff to boost resource, analysis of projects to establish the cost benefit of not taking them forward and the possibility of dropping projects that were already in development, were considered.

5.5.2 *Document requirements evolution*

From the use of the tool in the Hips department, a number of requirements were discussed that could improve the tool for future use. The first suggestion was the incorporation of graphical outputs that would show the overall health of the department, as the spreadsheet was not seen to be very easy to interoperate quickly. As stated in Section 5.4.3, functional requirements 21 and 22, the initial requirement was to have a graphical output for each function in each department, this was seen to be too confusing and overall unnecessary. The overall graph would give an indication of the resource allocation health for the department as a whole; although at this stage it was not clear how this would be achieved i.e. by project or by function.

The second suggestion was that when multiple departments have data included in the tool an overall view, rolled up into one view of the functions and their resource allocations and requirements, and would be very useful. This view would give function managers the ability to assess their resource requirements across all departments, which the tool did not facilitate in its current form. This was essentially a new requirement that had been discovered through the use of the tool as function managers found that they could only see their resource usage per department, which they did not find useful at a higher level. The restriction here is that this view relies on the inclusion of all data sets for it to be an accurate representation. Also at a functional level, managers will be expected to carry out other resource intensive activities that may not be incorporated in the resource refresh, and therefore not shown in the tool. Therefore, the inclusion of this type of analysis in the tool would have to be managed very carefully to ensure that the data being displayed was accurate and represented the as-is state accurately enough to be of use to functional managers.

The last suggestion was to consider the use of automated optimisation of the portfolio, with respect to financial weightings. Although optimisation had already been discussed as a requirement, this had always been seen as a manual activity where managers would seek the optimal outcome utilising their understanding of the complexities evident that the tool could not incorporate. However, through discussion it was established that an automated optimisation might give managers an idea of what could be achieved. Through discussion this requirement was established to be out of scope for this tool but was an area of expansion that could be looked into in more detail at a later date in another version of the tool.

All other requirements stated in Section 5.4.3 were seen to be valid after the implementation of the pilot, and were therefore not changed or updated in any way. These requirements were to be maintained through the changes to the other requirements discussed in this Section to ensure the integrity of the tool was maintained.

5.5.3 Make required changes

From the understanding gathered from the pilot of the system in the Hip department two main changes were implemented. The first update was carried out was the inclusion of a summarising page that rolled up the entire department data into a very high level functional view. This page did not refer to specific projects and could not be manipulated through the use of macros. Its sole purpose was to state the resource requirement, usage and shortfall for each function across all departments. This was quite easy to implement within the tool as it the programming to achieve this only required to pull through data that already existed within the tool. However, as stated previously, this view of the functions is dependent on the data incorporated; if this was incomplete across any of the departments this could give a false impression at a high level. Also, due to the fact that changes in the individual departments would flow up to the overall view, if any manipulations had been made this would not initially be known, therefore interrogation of the state of the department data would have to be carried out prior to acceptance of the functional view. This would ensure that data that had been manipulated in an isolated sheet that had altered the overall view could be identified.

The second change that was included was the addition of graphical outputs for both individual departments and the functional high level roll up. The graphical output would summarise the resource usage in a chart format that would quickly describe the resource health of the business.

To establish how this would be best established, a number of graphical output options were developed:

- Pie charts stating the project mix for a department
- Bar charts showing resources usage for each function per quarter in a department

- Bar charts showing resource usage as whole for a department, per quarter for a department
- Overall shortfall per quarter for each function broken down by department

These options were developed in prototype format and presented back to the Expert for them to evaluate and to decide which output would provide the most benefit. At a department level, it was established that the most worthwhile output would be the bar chart graphic that showed the overall shortfall per quarter. It was decided that a single bar be used for each quarter that could be split up into multiple functions to show its makeup. This view would enable the manager to see what functions are contributing most to the overall shortfall in each department without the need to interrogate the number in greater depth. At the high level functional viewpoint, the decision was made to use the same approach as the department graphics but to make the shortfall shown as one bar per quarter per function, broken down into departments. This approach would reduce confusion and promote a level of consistency within the tool. The charts were easily developed in the spreadsheet and utilised the programming in Excel to make the graphics.

5.5.4 Apply system

With the changes now implemented within the tool it was now ready to be utilised fully in the business. As the tool was dependent on the collection of resource data the application of the system within DePuy was delayed and only rolled out when this data, was gathered and validated. Once this had been achieved all department resource requirement, usage and shortfall data could be seen in the tool for use in managerial meetings. The tool was utilised in managerial meetings to document scenarios and to encourage more informed discussion and promote an awareness of the resource landscape of DePuy.

An emergent use of the system that had developed throughout its conception and application in DePuy was to test and validate data display and manipulation techniques in a simple and pragmatic format for use in a more sophisticated bespoke portfolio management tool. DePuy were able to use the tool to understand their requirements of such a system, enabling them to become more aware of what would be most appropriate for their needs. The portfolio management system mentioned here had been a long-term goal identified by DePuy in their technology roadmap for improvement. Initially this tool was envisaged as a governance tool that would hold project specific information that would allow managers to upload reports and update performance and progress information. Due to the success of the analysis tool, DePuy were able to utilise the learning from the application of the tool and its functions to make best use of the data that would be held in the portfolio management system. Therefore, the system was designed to gather resource requirements and usage data in a very similar fashion and provide resource outputs on the data that was inputted. This meant that the resource refresh data collection would become redundant and all data would be held centrally in the system and updated regularly by managers.

5.5.5 Maintain and control

To ensure that the tool was utilised and maintained appropriately, training material was documented and passed over to the managerial team in charge of the tool's use. This training document was in the form of a PowerPoint presentation that gave an overview of how the tool was developed and how the functions were programmed. The presentation also went into detail on how to fix common errors that could occur and how to change the programming to incorporate new data sets. Guidance was also put together to advise on the complexities that may be presented when considering the use of the individual department models and the overall rolled up data. The aim of providing this information was to pass on the expert knowledge that the researcher had developed so that DePuy could update and maintain the tool themselves, without the need of the developers.

In addition to the in-depth programming and maintenance information provided to ensure the tool does not breakdown, guidance was given into how to use the tool itself. This guidance discussed the situations that the tool would be most appropriate to be used and most importantly how it should be used. This guidance discussed how data should be imported to the tool, what it should look like when this is done, and what steps you would take to manipulate the data in certain scenarios. The saving of scenarios as examples was also discussed and how these could be compared through the use of the graphical outputs from the tool. As the tool was developed in Excel, all the data and outputs from the system were compatible for use in word format, therefore guidance was given as to how this could be achieved for reporting purposes.

5.5.6 Verification and Validation

To establish if the system development had been successful within DePuy, it was essential to assess the effectiveness of the solution that had been produced. From this verification and validation process an overall view of how successful the development had been could be achieved, with an aim of documenting lessons learned for improvement in latter developments of a similar kind. Although this stage was not highlighted in the methodology it was seen as a requirement for DePuy to carry this out to assess the system performance as a way of validating its development.

To understand the performance of the tool within DePuy, a semi structured interview with the Expert that had aided in the system development and implementation was carried out. This interview focused on five main areas; expectations of the system, benefits realised, issues that had been experienced, lessons to be learned and finally organisational coherence. The outcome from this interview can be found in Figure 26, in the form of a summary of the key points that were discussed.

The first part of the interview was structured to discuss the expectations that were set for the system from DePuy as a customer. This introductory discussion was included to focus the interview and to refresh those involved in relation to the overall scope and aim of the system that was developed. From this part of the interview we established that DePuy had expected a high-level tool that could visualise “what-if” scenarios, such as moving start dates and excluding/including projects, which could operate in real time. It was also established that initially DePuy’s overall aim of doing this was to reduce the time taken in analysis, that originally was an arduous and drawn out affair.

The next part of the interview went on to discuss the benefits that had been realised. It was stated that the system that had been developed and handed over to DePuy had managed to meet 98% of their initial expectations discussed in the first stage of the interview. It was also established that the tool had considerably reduced the time required to analyse data by making the process more efficient. This was mainly achieved due to the fact that all manipulation could be done at the one time and there was no need to take time out to perform analysis and then re-convene to discuss results. This could all be done in the context of the meeting, saving a substantial amount of time and trouble. It was also stated that the process to get to an answer was much more efficient and less confusing, as they were able to use functions and manipulate data in a structured way. This meant that they were able to develop a standard approach to problem solving that previously did not exist.

Although there were considerable benefits realised there were a number of issues that were encountered, the main one being that the system required expert help to maintain and update. This fact meant that the manager required help and assistance to manage the tool and its contents on a regular basis, reducing their ability to progress as quickly as they would have liked. This meant that DePuy struggled to get to the answer they were looking for when faced with technical difficulties.

The interview then went on to discuss the lessons that had been learned through the course of the system development and application in DePuy, which could be utilised in future system development projects. It was identified that the scenario analysis tool may have multiple uses that were at first not realised and therefore not exploited. This mainly focused on the development of the bespoke portfolio management system, referred to as "Bubble". As the scenario analysis tool had influenced the development of the resource management module of this system it has been put forward that both tools be run in parallel in the future to assess the validity of the data in Bubble, as the data input for each tool is considerably different.

Another lesson that was discussed was the use of automation when gathering information between spreadsheets. As the tool relied on macros to copy and paste resource data it made managers feel that inaccuracies may have been incorporated, due to their perceived lack of control. Also, the macro was programmed and rigid in its approach so data would have to be altered post collection in most cases. It was therefore decided that although it was a function that worked and was useful it may not be suitable for DePuy when considering resources. The final lesson learnt referred to the fact that the year in which the tool was rolled out was a particularly challenging year, with tight budgets, timescales and market fluctuations. Due to this fact issues to do with budget and the management of money in the business made more of an impact that it would normally. This meant that functions that would normally be utilised were not, with particular reference made to the function of moving out start dates. The Expert did state that they used this function, but could not make successful scenarios due to other constraints and would like the function to remain as he could see the impact it could make in future years.

Overall it was stated that the tool that was developed for use in DePuy had a very good understanding of the un-met need that had been in existence. For this reason, it was felt that the tool lined up well with the business and proved to have a high level of organisational coherence. This was illustrated in the acceptance of the system at a high level of the business and its subsequent adoption. Neville Turner stated an estimation of the tool meeting 95% of the set requirements, this was formalised in the below assessment in Table 14.

From this assessment, it can be seen that the majority of the requirements set for the system were met. The requirements that the tool failed were regarding the information that the tool provided for each project i.e. the projects platform and current status. In this context, the platform refers to the business case the project is fulfilling and the status refers to the step in the development process the project was currently in. The tool did not incorporate these items as this data was not stored in any location within the current systems that were utilised. The tool did however leave an empty column for a user to type the status in after the data had been uploaded, if they so wished. To fulfil this requirement, the researcher would have had to updated the data stored by the company and sourced all data again. Due to the time constraints experienced this was not achievable and therefore these requirements were not met.

A number of the requirements are stated as “To Be Considered” (TBC), the reasoning behind this is that the user group felt that they didn’t have enough evidence of the tools use in the business context to make a fair Pass/Fail decision. In discussion, the users did believe there was some evidence to support fulfilment but they did not want to sign off the requirement as complete until they had enough experience in its use.

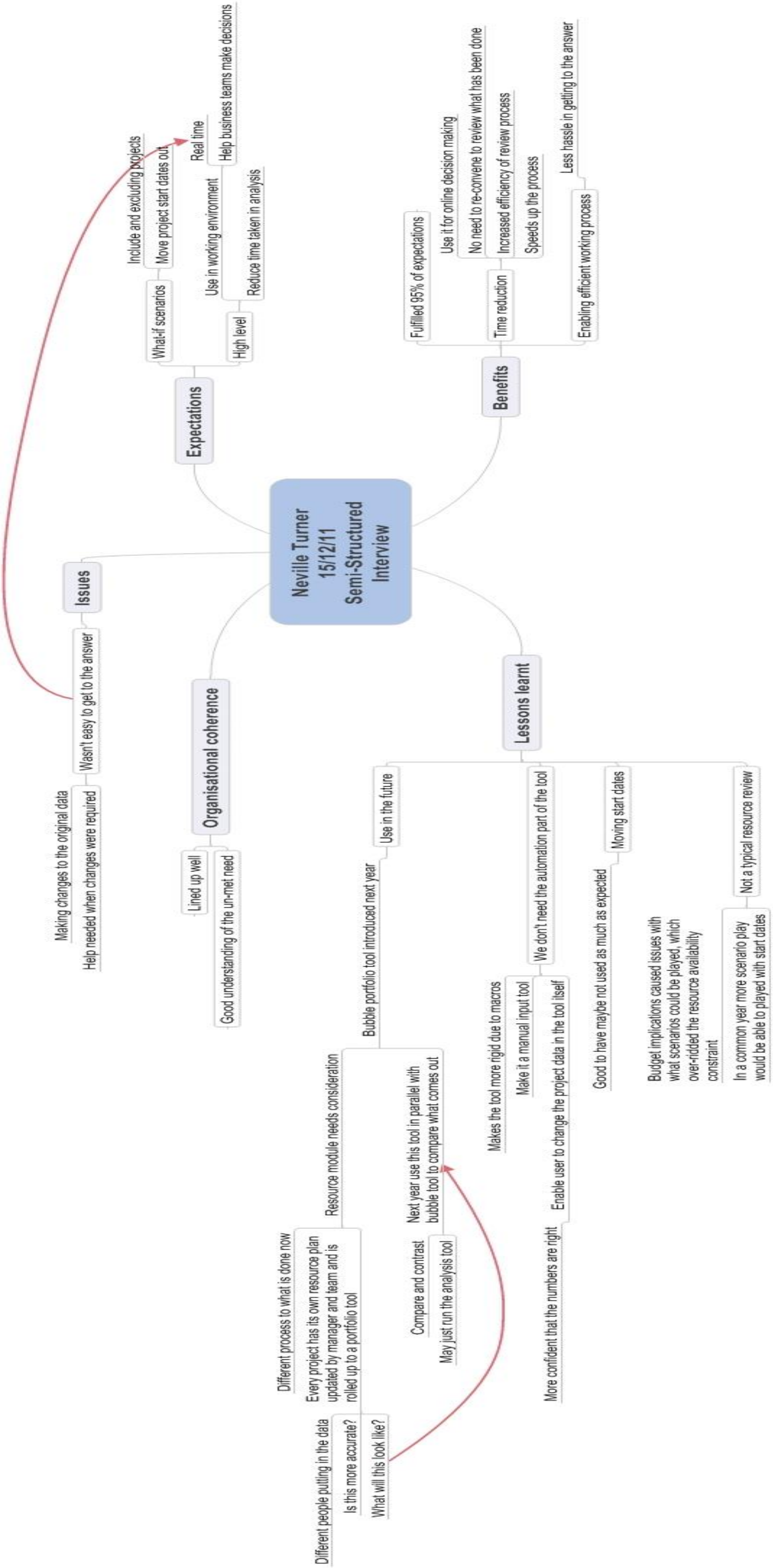

Figure 26 – Resource analysis system evaluation

Operational Requirement - What is the main aim of the model?	Description	Test description	Pass/Fail
O1	Enable managers to make more informed decisions through the evaluation of potential resourcing scenarios in a timely and reliable manner	unit, system, and usability tests	Pass

Functional requirements - How to satisfy the operational requirement i.e. what would it have to do, what would it have to show	Description	Test description	Pass/Fail
F1	The tool shall automate the collection of project resource data	Unit and system tests	Pass
F2	The tool shall automate the manipulatation of project resource data	Unit and system tests	Pass
F3	The tool shall utilise a 2 year timeline	Unit tests	Pass
F4	The tool shall show all projects listed on the resource refresh spreadsheet	Unit tests	Pass
F5	the tool shall include all functions in the resource refresh spreadsheet	Unit tests	Pass
F6	The tool shall account for changes in presented data for each business area	Unit tests	Pass
F7	The tool shall utilise a Qtr by Qtr level of detail	Unit tests	Pass
F8	The tool shall calculate overall resource demand per function per Qtr	Unit and system tests	Pass
F9	The tool shall show resource availability per function per Qtr	Unit and system tests	Pass
F10	The tool shall calculate overall resource shortfall per function per Qtr (available minus demand)	Unit and system tests	Pass
F11	The tool shall present shortfall in a graphical format	Unit and system tests	Pass
F12	The tool shall enable the inclusion and exclusion of selected projects from the portfolio	Unit and system tests	Pass
F13	The tool shall enable the movement of project start dates	Unit and system tests	Pass
F14	The tool shall enable projects to be reset to their original start date after it has been moved	Unit and system tests	Pass
F15	The tool shall detail a projects platform	Unit tests	Fail
F16	The tool shall detail a projects current status	Unit tests	Fail
F17	The tool shall provide the ability to detail a projects NPV by the user	Unit tests	Pass
F18	The tool shall detail the total resource utilised on each individual project	Unit and system tests	Pass
F19	The tool shall detail the ratio of resource utilised to the NPV gained	Unit and system tests	Pass
F20	All totals/ratios will automatically update what any change is made	Unit tests	Pass
F21	Each function shall have an individual graph showing the shortfall over the time period	Unit tests	Pass
F22	All graphs will automatically update when any changes are made	Unit tests	Pass
F23	A view of the overall resourcing picture over all business's will be provided	Unit tests	Pass
F24	The overall picture will include all functions	Unit tests	Pass

Non-Functional requirements - What are the constraints on the system?	Description	Test description	Pass/Fail
Performance			
NFP1	Accuracy = 100%	Unit and system tests	Pass
NFP2	Timely screen update when enabling functions = under 5 secs	System test	Pass
NFP3	Maintain a high level of reliability = MTBF 200 uses	Independent inspection over time	TBC
System			
NFS1	Remain under 2Mb in size	System test	Pass
NFS2	Easy to use	User testing	TBC
NFS3	Easily understood outputs	User testing	TBC
NFS4	Be sympathetic to the style currently used for data analysis	User testing	TBC
NFS5	Easy to maintain	Independent inspection	TBC
NFS6	Easy to update	Independent inspection	TBC
NFS7	Interoperate with other systems	System test	Pass
Implementation			
NFI1	Runable on Microsoft Windows XP	System test	Pass
NFI2	Compatible with Windows Office 2007, and earlier	System test	Pass

Table 14 - Requirements fulfillment assessment

When considering a percentage compliance, as that stated by Neville Turner in his 95% estimation, it is clear that the tool fulfilled a high percentage of its requirements. To achieve an accurate percentage, score each pass requirements was scored 1, fail was scored 0 and TBC was scored 0.5. Utilising this method, it can be ascertained that overall the tool scored 32 out of a possible 36, resulting in an 89% compliance percentage.

To verify this finding the system was further assessed against the original high level requirements that were utilised in Section 4.2.2 to establish if a tool already existed that could perform the functions required. The result of this assessment also states that the tool is 89% compliant with the requirements originally discussed, as shown in Table 15.

The tool scored 9 on all categories, expect for Development, due to the expert skills and knowledge that was required to develop the tool within Excel. Therefore, this Section of the assessment scored the tool 4. This evaluation also shows that the tool developed through the use of the methodology outperforms the tools that were originally considered for use within DePuy. As discussed in Section 4.2.2 no assessed system scored over 60%, the limit for easily implementable was set at 85%. This new assessment highlights further the level of acceptance and fulfilment of the requirements that were set for the tool and its development, as well as its appropriateness for use in DePuy's business context.

The outcomes from this verification and validation exercise was that the system developed for the business fulfilled the elicited need and functioned appropriately. The business was therefore happy to sign off the project primary deliverable as being sound and were happy to maintain its use in the business.

5.5.6.1 *Summary*

This Section discussed the process of applying the system developed within the business context and how this was managed. A pilot was utilised to test and refine the requirements set, that then produced updates to the system prior to launch. The system was then rolled out to users, with a maintenance plan to ensure that the system would not fail in service. A detailed verification and validation exercise was conducted that ascertained that the solution met 89% of its requirements and had developed a high level of business buy-in. Overall the system development within DePuy had been successful in producing a system that the business could adopt, use and sustain.

		Weighting	ERP Score	ERP Resultant
Software limitations	Already Approved for use in DePuy	20%	9	1.8
	Expense	10%	9	0.9
				2.7
Analysis requirements	Reviews all resource allocation to projects	10%	9	0.9
	compares resource available against required	10%	9	0.9
	make customised portfolios	5%	9	0.45
	alter project start dates	5%	9	0.45
	enable live analysis in meeting context	10%	9	0.9
				3.6
Development	Skills required	5%	4	0.2
	Resources required	5%	4	0.2
	Time	10%	4	0.4
				0.8
Usability	Clarity of results	5%	9	0.45
	Accessibility	5%	9	0.45
				0.9
	Outcomes	Score		8
		% Compliant		**88.89%**

Table 15 - System assessment against high level requirements

5.5.6.2 *Limitations in application*

As the system developed was controlled by a small user group, the roll out plan was very easy to develop and complete in this context. Therefore, change management in this case was not a massive issue. However, it is understood that when a system is utilised by a much wider user base this aspect of a systems implementation would become much more complex and require a more in-depth approach.

Also as the system was built utilising excel and a simplified approach to development, the maintenance and upkeep of the system was also basic and easily achievable by those utilising the system. This was seen as a bonus to DePuy as they would not have to rely on an external developer or single person to ensure the system was maintained. However, if a more complex system was to be developed its maintenance would be more complex also. This aspect would need more management and in-depth consideration if a business was implementing a more complex system for use.

5.6 Summary

This Section discussed the implementation of the tailored methodology that was produced through the application of the tailoring process discussed in Section 4. The methodology was utilised in DePuy for the development and implementation of a resource management systems. The methodology was applied in the complex business context of DePuy Orthopaedics who specialise in the development of medical implants. This process was aided through the continued support of managerial staff and experts within the business.

In the context of DePuy the main output from the application of the methodology was the scenario analysis tool itself and its associated benefits that it could realise in their business context. Through the use of the tool, managers were able to take a high-level view of a department's portfolio of projects and the issues it was experiencing to quickly develop a holistic appreciation. The tool also gave managers the ability to manipulate data, utilising their understanding of the complexities experienced, to develop greater understanding and potential solutions to problems that were evident. The tool was utilised successfully within DePuy to analyse resource data and to promote a higher quality of conversation with respect to resource management. The tool was also utilised by DePuy to test and validate their future analysis scenarios for use in their portfolio management tool, a step along in their improvement roadmap. The tool was assessed against both the high level and in-depth system requirements with a result of 89% in both assessments. This assessment also highlighted that the system was more appropriate for DePuy in comparison to other tools, who scored less than 60% in the same assessment. It was also stated by managerial staff that the tool met the expectations that DePuy had and was deemed a success through its acceptance and adoption within DePuy.

5.6.1 Limitations in application and suggestions for further work

Through the process of the application of the tailored methodology within DePuy a number of limitations were experienced that could have potentially impacted the production of a successful system. An overview of these limitations can be found in the below Table 16. Although a number of limitations were experienced through the application of the methodology it was shown in the evaluation that a stool that fulfilled the requirements set was produced. The researcher managed these limitations appropriately throughout the application process so that they made as little impact as possible on the overall quality of the system produced.

Methodology stage	Limitations experienced
Understand your baseline	Availability of key knowledge holders Managerial bias impacting ideas suggested
Envisage the future	Managerial buy-in to process Business capability to carry out vision
Pinpoint leverage	Inability to scope business direction
Develop a solution	Business familiarity with approach Changing business requirements Available skills for development
Implement in the business	Small user group and simple system resulting in reduced complexity

Table 16 - Methodology application limitations summary

To further strengthen the tailored methodology that was produced for DePuy the learning that was produced through its application should be utilised to influence its continual improvement. One key change that could be made is to further strengthen the cyclical nature of the relationship between the requirements set and the prototyping phase of the solution development stage. Only till the implement phase does the idea of requirements change affect the course of the system development, although changes were being made continually throughout the develop a solution phase also. Using this understanding further feedback and change management principles should be built into these stages to ensure that this is better managed in further versions of the methodology.

The other limitations experienced were contextual regarding the access to and capability of the business to address the requirements of the application of the methodology. Although an in-depth assessment of the business was carried out at the beginning of the process, little regard was given to the requirements of the business to successfully utilise the methodology. This aspect could be incorporated upfront as an assessment of the business in relation to their ability to change, this would provide an insight and action that require to be taken that will ensure the process is efficient and effective.

Part three: Validation and Evaluation

6 Discussion

The aim of this research was to create an approach to methodology tailoring for use in complex business contexts, established in Part 1 of the thesis. Part 2 of the thesis focused on the creation of the tailoring approach and its application in a complex business context i.e. DePuy Orthopaedics, it then went on to describe the application of the tailored methodology produced for the development and implementation of a resource management system. In this Section the research outputs, approach, contribution and future work will be discussed. Firstly, the tailored methodology created and applied in Part 2 will be evaluated, to establish validity and to highlight its strengths and weaknesses. The outputs of this evaluation will be utilised to inform an assessment of the validity of the tailoring approach. The Section will then discuss the research methods that were utilised and their associated strengths and weaknesses in the context within which they were applied. The overall contribution to knowledge presented in this thesis will be discussed from both a declarative and procedural perspectives. Finally, the Section will close with a proposal of how identified weaknesses could be addressed through evaluation of the methodology, made evident through the discussion of the previous three subjects i.e. evaluation, research approach and contribution to knowledge.

6.1 Tailoring approach evaluation

The purpose of evaluation is to establish confidence that a system of interest is fit for purpose. Where validation seeks to establish if the right system was built, evaluation seeks to establish if the system was built right (Sargent 2001).

In this research context, validation was achieved through the application of the tailoring approach and subsequent tailored methodology under examination in a business context. This activity proved the tailoring approach was fit for use and satisfied its requirements through its ability to provide positive results. However, there is still a need to further evaluate the tailored methodology to provide assurance that the tailored methodology is valid. This is required as the tailored methodology was both applied and evaluated by those who had utilised and tailored it for use. These individuals may have been biased towards the validity of the tailored methodology due to their vested interest in its success. To ensure that the tailored methodology is in fact valid there is a need for further evaluation.

A well-established and highly effective technique of evaluating systems is to have the system of interest examined by subject matter experts, through a critical assessment. An accumulation of responses from a number of experts will show both the positive and negative aspects and establish how fit the system is for its proposed purpose. Therefore, the aim of carrying out such interviews is to gain an objective and informed critical analysis of the tailored methodology, out with the context within which it was created.

As this evaluation is based on the opinion of experts and not explicit facts demonstrable by evidence, there may be the incorporated of observer bias within the outputs from the evaluation. Opinions can be driven by an individual's personal view and attitude towards the system under evaluation and are therefore vulnerable to the inclusion of bias. There is also a limitation experienced as the experts have a limited understanding of the business context for which the methodology was tailored, limiting their ability to fully comprehend the required functionality of the tailored methodology. This may compromise the accuracy of the results presented, however the evaluation will still provide insight into the strengths and weaknesses of the tailored methodology at a generalised high level. This will subsequently reflect on the appropriateness and ability of the approach taken towards its tailoring.

In order to minimise the impact of observer bias and knowledge of the business context for which the methodology was tailored, the researcher designed and structured the interview process to ensure that as little bias as possible was incorporated. The process aimed to deliver a general assessment of the quality of the methodology to produce IT based resource management systems for use in business contexts. The process taken towards the design and roll out of the evaluation will be discussed in the following Section 6.1.1.

6.1.1 Evaluation process

In this Section, the process for the evaluation interviews is discussed. This includes a discussion of the required interviewee credentials, ethics requirements and the overall evaluation interview plan and set up.

Interviewees and information requirements

The individuals that were sought for the evaluation interviews were industrially based managers who have experience of IT introduction and/or development in a complex business context. Their experience did not have to be directly related to the development and implementation of resource management IT systems but an appreciation of the complexities of carrying out this exercise is required. This will aid the interviewees to take into account the context for which the tailored methodology was developed. Interviewees were also considered if they possessed extensive knowledge of system development methodologies and their application in business contexts. It was desired that interviewees came from a variety of industrial sectors, such as defence, energy, medical and automotive. Having a variety of backgrounds present in the evaluation would further help evaluate the broad applicability of the methodology.

The information that was required from the interviewees was their independent evaluation of the output from the application of the tailoring approach developed within DePuy i.e. the tailored methodology utilised to develop the resource management system, as discussed in Section 4.2.4 and applied in Section 5. As the tailored methodology is the primary deliverable of the tailoring approach, an assessment of the quality of this deliverable produced will provide insight into quality of the approach utilised to develop it.

The evaluation carried out highlighted how the interviewee perceived the tailored methodology to be able to empower a developer/business to deal with the complexities of a resource management IT systems development project. This included discussing each aspect of the methodology and detailing the associated strengths and weaknesses. The main outcome that was sought from the interviewees was whether they considered, based on the evidence presented and their personal experience, that the methodology was fit for use within a complex business context. Based on this outcome the tailoring approach would be assessed to have either failed or succeeded in incorporating elements required to ensure successful system development and implementation.

Ethics - Informed consent

It is important that researchers obtain informed consent from a participant, which can be described as a formal acknowledged agreement between the participant and the researcher which allows the use of the information provided by that participant for the use stated, providing it is based upon a clear appreciation and understanding of the facts, implications, and future consequences of sharing that information. Therefore prior to the interview, participants were provided with an information sheet, detailing the purpose of the interview and any information that was deemed necessary for them to decide whether they would wish to participate. Once this information sheet was read and understood, and the participant was willing to take part, the participants were then invited to meet for an interview. Once the interview was arranged, the participant then decided whether to proceed with the signing of an official informed consent form.

Interview plan

The interview progressed through five main stages, as illustrated in Figure 27. Firstly, the interview was initiated by reiterating the purpose, structure and content of the interview. The interview then proceeded on to the presentation of the tailored methodology under evaluation. This involved the presentation of a set of slides that described the content and operation of the tailored methodology. Once the tailored methodology was presented the interviewee was questioned regarding the tailored methodology, in line with the outcomes sought from the interview.

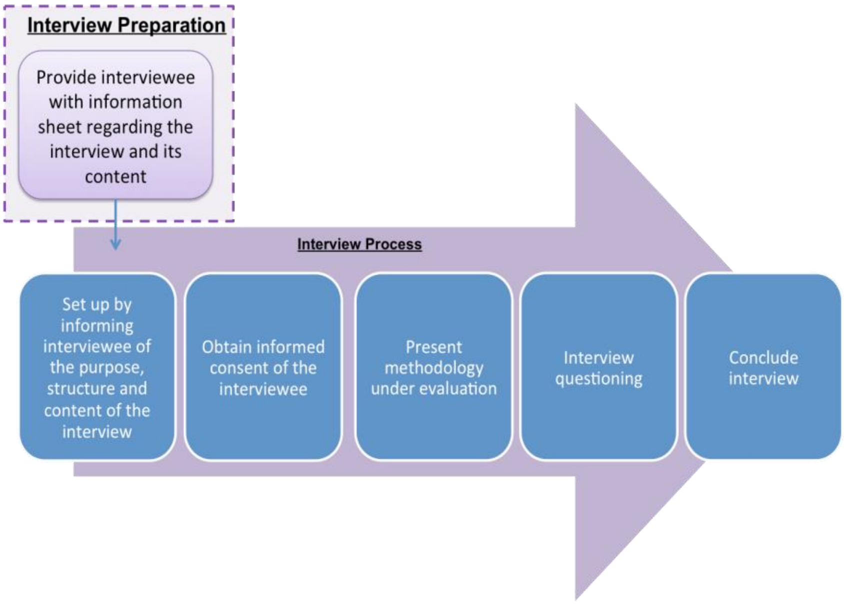

Figure 27 – Interview process

Throughout the presentation of the tailored methodology, the participant was encouraged to ask questions to ensure there were no misinterpretations or gaps. This was also utilised to minimise the impact of observer bias, as the researcher was able to challenge the interviewee regarding the outcomes that were presented.

The contents of the presentation included:

- **Background;** what the research was about and why it was important.
- **How the methodology was developed**; the process of developing the methodology, from identified resource management complexities to a formalised tailored methodology which manages these complexities.
- **The tailored methodology**; the high-level methodology with detail in each stage, highlighting how the tailored methodology managed complexities evident within a business context.
- **Validation**; how the tailored methodology was applied in practice and the outcomes from its application.
- **Evaluation**; The requirement to evaluate the tailored methodology and explain how this would be performed.

In order not to overload the participant, the questioning process was well planned using the following guidelines: do not ask any more than 15 open-ended questions and use probes as and when required (Boyce, Neale et al. 2006).

Sakthivel (1992) stated that;

> *"Research studies suggest that a SDM should have capabilities to develop diverse systems, support various tasks during the systems development cycle, have ease of use, develop information systems within the estimated time and cost, and develop effective systems."(Sakthivel 1992)*

Based on research of SDM's and their requirements Sakthivel (1992) went on to propose a set of 31 requirements for SDM's. The 31 requirements are categorised at a high level into four main groupings of versatility, function, productivity, and effectiveness. Each requirement was given a relative importance, produced through the questioning of 27 practitioners and analysed using AHP. These requirements were used to aid in structuring the questions posed in the interview within this research, in order that the tailored methodology could be analysed against a set of rigorous and well-researched requirements.

The questioning was broken up into the four main requirement sections within which each requirement was analysed. The interviewee was asked to assign a score between 1 and 5, 1 being that the interviewee strongly disagrees with the statement and 5 being that the interviewee strongly agrees with the statement. The interviewee was then invited to reflect on that score and to share their reasoning behind it.

To reduce the amount of questioning involved the scoring will be carried out in the 4 high level groups. Therefore, the interviewee will score all requirements in the groups and will then go on to reflect on the scores as a group. This will also provide structure and a clear aim, ensuring the interview does not expand into areas that may not be practically relevant.

6.1.2 Evaluation outcomes

This Section will discuss how the process described in Section 6.1.1 was enacted and the overall outcomes that were found. The detailed outcomes from the interviewees can be found in the attached Appendix G. Firstly, the Individuals that were approached to carry out the evaluation will be discussed, giving justification for their selection and some background into their experience. The outcomes from the findings will then be discussed covering the four groupings of versatility, function, productivity, and effectiveness.

Interviewee identification

Mr Daniel McKendry

Mr McKendry has worked for BAE Systems for over 16 years in a number of roles related to the management of IT systems and their installation in highly complex systems. Mr McKendry is responsible for the Product Lifecycle Management and the Integrated Bill of Materials of high profile ship building projects within BAE systems. Over his time within BAE Systems Mr. McKendry has gathered a wealth of knowledge regarding the development and implementation of IT systems as well as the difficulties when considering the management of resources. Due to his experience, competence and knowledge of IT systems and their development Mr. McKendry was seen to be an expert in the field. He has also achieved expert status in his management role within BAE Systems where he has gathered many years of experience. For these reasons, it was felt that Mr. McKendry fit the criteria for inclusion well and would provide enlightened and well-judged input to the evaluation process.

Prof. Andrew Daw

Prof. Daw is an experienced Systems Engineer in the engineering community, with over 30 years of experience within the field. Roles of note being 13 years with BAE Systems as a senior systems engineering consultant, he has also been a member and past president of the UK chapter of the International Council on Systems Engineering (INCOSE). Over his many years in the field of Systems Engineering Prof. Daw has experienced a wide range of both successful and failed system developments and has himself developed approaches towards development in reaction to what he has experienced. With his many years of experience, knowledge of the business context and the development of methodologies for use in system development, Prof. Daw was seen to be eligible when considering the evaluation of the methodology.

Versatility

The first scoring group that was covered in the evaluation interview was the perceived versatility of the tailored methodology that had been presented and discussed. The questioning consisted of the proposition of five statements of requirement that were posed one by one to the interviewee.

Interview 1 –Mr McKendry

For the first two points, Mr McKendry agreed that the tailored methodology could be applied to a variety of problems and could produce a variety of answers within a complex business context. However, it was stated that there is a need to further consider and include the experience of the company, and how this could be used in building systems in the future, for example lessons learnt and best practice, as Mr McKendry felt this was not made explicit enough in the early stages of the methodology. For points 1.3 and 1.4 Mr McKendry stated that the tailored methodology may be best applied when considering a simple short term development, if dealing with a larger longer term development there is a need to show data flow and architecture, in particular the business information architecture, which is not catered for in the tailored methodology. For the final point 1.5 Mr McKendry agreed that the tailored methodology has the ability to develop systems utilising different IT systems and technologies but stated that there was a need to consider commercial off the shelf packages in this area, in particular how these interface with other systems. Overall Mr McKendry scored the tailored methodology 64% for versatility illustrating the methodology's ability to be applied to develop a wide range of scenarios and systems. The main concern highlighted in this section was the simplistic nature of the tailored methodology that Mr McKendry felt did not lend itself well to more complex and longer-term projects.

Interview 2 – Prof. Daw

For all five questions posed in this section of the methodology evaluation Prof. Daw scored 4 showing that he agreed with all statements. He stated that he felt the tailored methodology did not constrain developers in a business context in any way and was easy to use, comprehend and to execute. He went on to state that he feels that the tailored methodology was wholly robust and resilient for these reasons and would feel secure utilising it in a business context. Overall the methodology scored 80% in this area highlighting Prof. Daw's acceptance of how versatile the tailored methodology is and the fact that he feels he could utilise it on any system development project to obtain a wide range of solutions.

Function

The function section of the evaluation focused on three main areas; the inclusion of key lifecycle phases; perceived ease of use; and, the inclusion of key considerations in the development of complex systems. The group of statements proposed in this section aim to assess the structure, content and use of the tailored methodology.

Interview 1 - Mr McKendry

When asked whether the tailored methodology presented for evaluation effectively included all key lifecycle phases Mr McKendry stated that he agreed that the investigation and maintenance phases were well catered for and were evident within the tailored methodology. However, he believed that due to the fact that no information architecture was established in the requirements phase, this phase was not included effectively, and therefore scored it a 2. Mr McKendry also scored the development stage a 2 as he believed that a key stage in the process of development was not included i.e. design. It was Mr McKendry's opinion that the tailored methodology jumped straight from understanding requirements to development, without the consideration of design in between. The last stage that was considered was implementation, which was scored at neutral and given a 3.

Mr McKendry stated that he agreed that it had been implemented in the tailored methodology but he felt there was no consideration for the management of change in the implementation phase, and focus was primarily on the system and not the context.

In the ease of use category, the statements regarding good explanation, ease of learning and ease of implementation were all scored 4, Mr McKendry believed that these areas had been well covered and the tailored methodology would be very easily picked up and used. However, the point of flexibility was scored a neutral 3 as Mr McKendry felt the process was very linear and did not account for the feedback that would occur between the stages, in particular between requirements change and the update to the design.

In the last section of the function evaluation, the inclusion of key considerations was assessed; this assessment would highlight how the methodology has incorporated considerations found to be highly influential in the development of resource management IT system in business contexts. For the first two considerations, i.e. business requirements and culture, Mr McKendry scored a 4 stating that these issues are clearly dealt with in the upfront stages of the tailored methodology although the inclusion of a business change plan would improve these scores to a 5. The consideration of technology was scored 2 as Mr McKendry believed this required more development in the methodology, in particular the inclusion of a business information architecture that would document and manage the interactions. Complexity was scored 4 as Mr McKendry believed that the tailored methodology as a whole managed complexity effectively throughout. The final two considerations of uncertainty and human factors were scored at neutral as Mr McKendry believed this could be achieved by the tailored methodology but there wasn't enough explicit guidance to definitively state this. He also stated that there was a need to manage uncertainty in relation to information usage and development by other systems which the methodology does not explicitly take account of.

Overall the tailored methodology scored 50% in the area of function; this is mainly due to the fact that Mr McKendry believed that there is a requirement for an information architecture, which impacted a number of the points raised in the assessment. If this issue were to be resolved the scoring in this section would have been much higher. However, as it stands Mr McKendry did believe the tailored methodology to be functionally sound and stated that it incorporated a number of elements effectively and dealt with considerations important in the development of systems in complex business contexts.

Interview 2 – Prof. Daw

When considering the inclusion of lifecycle phases Prof. Daw stated that he felt that mostly all phases assessed in the evaluation were present, primarily agreeing and scoring all statements with a 4. However, after further thought Prof. Daw decided to downgrade statement 2.5, referring to the maintenance stage, to a neutral 3. His reasoning behind this was to highlight that this stage was less obvious than other and was not as well catered for. He felt that it was good to have it referred to and to have it planned for, but the plan itself doesn't not ensure that the system is maintained and therefore controlled in its use.

For the second section of this evaluation of the tailored methodology's function the statements referred to the ease of use of the tailored methodology. Prof. Daw scored all statements in this section as a 4 highlighting that over all the points he felt that the tailored methodology was easy to use. He felt it was very well documented and laid out and would expect it to be easy to learn and to put into practice. He qualified this by stating that this would depend on the level of familiarity that the developer would have with methodologies of this kind and the context and training that had been offered.

In the last section of the evaluation Prof. Daw was asked to consider development considerations and their inclusion in the tailored methodology. The first consideration of business requirements he felt was very well covered and highlighted at the right stage in the right way, scoring it a 4 showing he agreed. The next two considerations of culture and technology were agreed that they were included in the methodology but not at the right level, or in the right places he would have expected. Prof. Daw stated that those using the methodology would require more prompting to gather the information that is required for each of these considerations that is currently offered. For these reasons the considerations of culture and technology were both scored neutral and given a score of 3. The next two considerations that were covered were complexity and uncertainty, that were both scored 2 showing Prof. Daw disagreed they had been incorporate well. Prof. Daw did state that the methodology did do some work towards incorporating them but stated that this is not explicitly dealt with in the tailored methodology; it is something that emerges through its use. In particular, he referenced that the tailored methodology should deal with the identification and management of risk, he went on to state that this is a key activity when considering the management of uncertainty and would expect to carry it out. For the last consideration of human factors, Prof. Daw scored a neutral 3, as he believed that the methodology did go some way to demonstrating that human factors had an influence but did not cover it in enough detail for him to justify scoring it a 4.

Overall Prof. Daw scored the function of the methodology at 69%, highlighting the function of the tool to be sufficient and fit for purpose. The main drawbacks that were highlighted were the non-explicit nature of the management of a number of the key considerations, in particular complexity and uncertainty, Prof. Daw would have liked to have more detail for many of the areas that were assessed. However, he understood that this could not fully be achieved when presenting a high-level view of the tailored methodology and that with further reading and familiarity these areas could become much clearer.

Productivity

In this section of the evaluation the tailored methodology was assessed against its ability to improve the productivity of the development of a system. Therefore, in this section the interviewee was asked questions in relation to how they felt the tailored methodology could achieve certain results through the use and implementation of the tailored methodology. The aim of the use of these statements was to highlight how the tailored methodology adds to the development of systems and how it meets its goals.

Interview 1 - Mr McKendry

The first question related to the use of verification and validation and how its use may have affected productivity, Mr McKendry scored this aspect a 4 in agreement and stated that verification and validation was utilised throughout in the right places which would overall contribute to increased productivity. The second point assessed the use of documentation throughout the tailored methodology; this was scored a neutral 3, as there was no reference made to any design documentation. The next two points of management of system alignment and curtailing costs were both scored a 4 to show Mr McKendry’s agreement that they both were achieved by the tailored methodology and increased productivity. Mr McKendry specified the use of up front problem identification and prototypes were the main driving force behind his scoring in both these elements. The next question refers to the management of time overruns which Mr McKendry scored a neutral 3 as he believed this could be achieved but there was a need for more rigorous management of requirements creep and change in the prototyping phase. The last point in this section discussed how the tailored methodology reduced post implementation problems, Mr McKendry disagreed that the tailored methodology has shown this attribute, as there was no change management plan in place but did state that the system produced may be less problematic in nature.

Overall the tailored methodology scored 67% in this section, the main reasons being the missing documentation that Mr McKendry felt should have been included i.e. a change management plan and design documentation, if these documents had been explicitly referenced the score would have been a lot higher. However, Mr McKendry did agree that the tailored methodology as a whole did contribute towards an increase in productivity and would ensure time and cost over runs were managed, as well as post implementation problems through the alignment of the system to the business context.

Interview 2 – Prof. Daw

For the first three statements discussed in the productivity section of the evaluation Prof. Daw agreed and scored all with a 4. He stated that the tailored methodology utilised verification and validation well and highlighted the use of it at the end of each stage as a gate for progression, he felt this was an especially good idea. He also went on to say that he felt the tailored methodology emphasised the need for good documentation and knowledge management. For these reasons, he felt that the methodology would produce an auditable and repeatable process that promotes alignment through the reduction of potential future uncertainties. When considering the next two statements of curtailing cost and time over-runs, Prof. Daw disagreed that the tailored methodology could achieve this. He stated that these issues are out with the control of the tailored methodology and what should be considered here is the identification of the risks of these things happening and mitigating against the impacts. For this reason, both these statements were scored 2. For the final point regarding the reduction of post implementation problems, Prof. Daw discussed the fact that the tailored methodology provides significant advantages but there is no proof that this could be achieved. This fact linked back into the identification and management of risks that Prof. Daw felt was missing from the tailored methodology. As a result, this statement was scored a neutral 3 as Prof. Daw believed the tailored methodology did a lot to reduce problems but could not be totally assured that this would happen if it were applied.

Overall Prof. Daw scored the tailored methodology 63% in relation to productivity, highlighting the fact the tailored methodology does promote a productive approach to system development but can be improved on. In particular, Prof. Daw believed that there was a need to consider the identification and management of risk when considering time and cost control and in system implementation to reduce the likelihood of problems.

Effectiveness

In this Section, the tailored methodology was assessed against its ability to produce systems of high quality and also assesses the user satisfaction when utilising the methodology. The aim of this section was to assess the perceived quality of produced systems, highlighting the ability of the tailored methodology to produce quality results. This section also focused on the user and their perceived benefits from using the tailored methodology, highlighting their acceptance of the tailored methodology.

Interview 1 - Mr McKendry

For the first three questions of the system quality section of the assessment, Mr McKendry scored 4 and agreed that the tailored methodology develops reliable systems, manages alignment and develops readily acceptable solutions. This scoring was qualified with a statement that the tailored methodology does this very well from an IT standpoint but more needs to be done to involve change management from a business perspective. For this same reason, Mr McKendry then scored the next question a neutral 3, as this statement referred to readily adoptable systems. Mr McKendry stated that although this could be achieved, due to the lack of a change management plan he could not fully agree. Mr McKendry also remained neutral on the final quality question referring to the sustainability of the solutions, with the reason being that there was no mention of an IT architecture for the business that would ensure that all systems were interoperable.

For the assessment of user satisfaction Mr McKendry agreed and scored 4 for three out of the four statements that were posed; these were efficiency, good system management and ensuring success. Mr McKendry stated that the methodology promoted good practice concerning documentation and the development of a vision, through the use of upfront problem solving. On the final question, Mr McKendry scored a neutral 3, this was in relation to the promotion of the use of the system. The reason for the score was that Mr McKendry felt that the tailored methodology alone could not promote the use of the system; this should be achieved through communication with the wider community, although he felt this might be achieved through the use of prototypes.

Overall Mr McKendry scored this section of the assessment at 73%, illustrating that although there are a few areas that Mr McKendry feels need to be added to the tailored methodology on the whole does work to produce quality outputs in a way that satisfies the user of the tailored methodology.

Interview 2 – Prof. Daw

When considering the quality of the systems that the tailored methodology produced Prof. Daw questioned the wording and development of the evaluation script. This resulted in the scoring of four out of the five statements at a neutral 3. He stated that they were all nearly a 4 if the statements had been more speculative in nature. As the questions related to outputs that Prof. Daw could not totally be sure could be produced, he was not happy to give them a score of 4. However, when posed with the statement regarding the management of alignment, he did agree this would be achieved and scored it a 4. Prof Daw elaborated that he felt that the quality of the system that would be developed, utilising the tailored methodology, had many influencing factors other than the methodology itself. For example, a poor-quality system could be produced from a high-quality methodology due to time constraints or inexperience.

Prof. Daw also questioned the structure of the statements in the second section of the evaluation on effectiveness, stating that the statements were not speculative enough for him to agree fully with them. For this reason, he scored three out of the four statements with a neutral 3, stating that if the statement had been changed to highlight the tailored methodology's potential to produce these results he would have scored a 4. The one statement that he did agree with referenced efficiency, Prof. Daw agreed that the tailored methodology was efficient and was not overly detailed, and would therefore promote a pragmatic and efficient approach to system development.

Overall Prof. Daw scored this section of the evaluation at 64%; this score was mainly due to the structure of the statements that had been presented. Prof. Daw was understanding of the meaning behind the statements but could not fully agree when there was no firm evidence to back up his scores. He did however state that the tailored methodology was well developed and believed it would be effective it its application.

6.1.3 Summary of evaluation

This Section of the discussion was focused on the evaluation of the tailored methodology for the development and implementation of resource management systems in complex NPD business contexts, discussed in Section 4.2.4. The evaluation was achieved through a structured interview which followed a defined quantitative approach, aimed at establishing expert's opinions on four high level areas; versatility, function, productivity, and effectiveness. The interview process was designed and strictly managed to minimise the impact of observer bias, as this evaluation is based on the opinions and views of experts.

The approach quantified opinions and perceptions, in order to gather a view of the validity of the tailored methodology under evaluation for use in complex business context for the development of resource management systems. Two industrial experts were interviewed and their views were collected and discussed. The overall scores from each section of the interview can be found in the below Table 17.

From the discussion of the evaluation results with both industrial experts, it was granted that the tailored methodology is valid for the context for which it was developed and therefore fit for use. This conclusion was drawn from the fact that all scores achieved from the evaluation were of a high standard, and would have been higher if the experts had been more familiar with the tailored methodology and the context within which it was tailored and applied. Both experts also commented that they would have been able to score higher if question statements were more speculative in nature allowing them to apply more of their opinion to the outcome.

Evaluation phase	Mr McKendry	Prof. Andrew Daw
Versatility	64%	80%
Function	67%	69%
Productivity	67%	63%
Effectiveness	73%	64%

Table 17 - Summary of Evaluation results

The feedback sought from discussion of the tailored methodology and it merits with the experts was on the whole positive, with the experts stating the tailored methodology would be easy to use and produce quality outputs in complex business contexts. However, the experts did highlight and discuss further a number of opportunities for further development that could be incorporated. A summary of the positives, negatives and suggestions for improvement to the methodology, as discussed by the experts, can be found in the below Table 18.

The negative aspects and suggestions generated in this discussion will be considered for use when further developing the tailored methodology for use in DePuy. A change that will be suggested to DePuy for incorporation will be the inclusion of metrics to accurately measure the baseline and the overall improvement that has been achieved; this will be added into the high-level methodology in the "understand your baseline" stage. The metrics will not be developed by the researcher but the tailored methodology will state they should be developed in reaction to the improvement plan put in place. All other suggestions will be reviewed by DePuy regarding their applicability and value to their system development.

The evaluation process itself was successful and effectively developed a concise quantitative view of the tailored methodology and its merits from systems engineering and management experts. It also produced a number of suggestions for further improvement that will add to the quality of the tailored methodology.

	Positives	Negatives	Suggestions
Danny McKendry	Versatile and does not constrain the user	Overly simplistic in areas	Consider the impact of commercial of the shelf systems
	Easy to use, understand and apply	May only be suited to small developments	Include a information architecture to document interactions
	Development considerations well covered and applied in the methodology	No mention of the design stage	Consider the inclusion of change implementation plan
	Promotes good practice with respect to documentation	No feedback between requirements change and design change	
	Use of prototypes ensures system is developed correctly		
Prof Andrew Daw	Methodology does not constrain the user and is robust and resilient	User needs more prompting to gather certain types of information	Include risk identification and management
	Easy to use, comprehend and execute	Methodology is not explicit enough in a number of areas	Consider the inclusion of how to measure what good looks like through metrics
	Well equipped to aid good knowledge management	Quality of results is dependent on the context, familiarity and experience of the user	The layout of the methodology could be altered to show how the baseline and future are compared to generate a gap anaylsis
	All main stages of the development lifecycle are taken account of	The future is unknown, the methodology should manage uncertainty through documenting and managing risk not eliminating it	
	Good use of verification and validation throughout		

Table 18 – Tailored methodology evaluation positives, negatives, and suggestions

As expert's views have stated that the methodology was fit for purpose in the context described and was also capable of producing systems of high quality, it can be deduced that the approach taken towards its tailoring has also been successful. Indirectly the evaluation carried out substantiates that the tailoring approach has delivered a desirable and valid result. This outcome can be further corroborated by the positive result found through the application of the tailored methodology within DePuy's complex business context. Overall there is extensive and credible evidence presented in both this evaluation and the application of the tailored methodology discussed in Section 5, to state that the tailoring approach discussed in Section 4 is valid and can produce valid outcomes.

6.2 Quality of the research

As discussed in Section 2 of this thesis the research methods were identified that were to be utilised in the different stages of the research process. This design was based on the requirements to produce quality research results that would produce both procedural and declarative knowledge.

Firstly, this Section will discuss the overall quality of the research that was carried out; and will focus on the appropriateness of the research methodology applied. This will also cover the practical limitations experienced when applying the proposed methodology and deviations that may have occurred. The Section will the move on to discuss provide how the research approach was adhered to through the course of the research conducted, as well as give an assessment of the methods that were utilised.

6.2.1 Research methodology evaluation

As discussed in Section 2 the work presented in this thesis utilised a Construction based research methodology. Construction can be described as "the development of a theoretical solution derived from the researchers understanding, practical experience and theory, which is utilised to propose a solution to the problem that is then tested" (Kekäle 2001). This methodology was chosen over the other methodologies assessed as it supported the development of both declarative and procedural knowledge in the research context, which was essential for the research that was to be undertaken. The methodology was utilised to develop a research design that followed the main stages that Construction research suggests, this was then applied within the research context to develop the knowledge that was required.

The purpose of this evaluation is to ascertain if the research methodology chosen for use in this research was correct and provided the researcher with a rigorous and systematic approach. The basis for evaluating research conducted utilising constructive research is discussed by Kasanen and Lukka, et al. (1993). They claim that to ensure quality, the outcomes of constructive research should be (Kasanen, Lukka et al. 1993);

- relevant, simple and easy to use;
- possess practical relevance;
- have practical utility;
- proven to be useful;
- theoretically novel;
- linked to theory; and,
- applicable in other environments, demonstrating the "generalisability" of the research outcome(s)

Therefore, to assess the quality of the research, and therefore the appropriateness of the methodology that was utilised, the outcomes from the research must be assessed against these criteria. The main outcome from the research and the contribution to knowledge is an approach for the development and implementation of systems in complex business contexts through methodology tailoring. This approach and associated outcomes from its application within DePuy will be reviewed to evaluate the quality of the research methodology that was applied. The evaluation will be carried out from the researcher's perspective and will reference outcomes and circumstances that will provide evidence to describe how each criterion for evaluation was either passed or failed. The output from this evaluation can be found in Table 19.

As discussed, the output from the research that was conducted has fulfilled all seven criteria that would ascertain the quality of the research that was carried out. From this outcome, it can be deduced that the Construction methodology that was utilised in this research was appropriate for use and was applied in a manner that ensured quality results were produced.

The main strengths and weaknesses of the Construction research and its application in this research are summarised as follows:

Strengths

- ✓ Promoted a top down, problem centric approach in line with Systems Engineering theory and approaches.
- ✓ Offers the researcher a degree of flexibility when designing and choosing research methods ensuring a pragmatic approach can be adopted.
- ✓ Aids in the identification and framing of the research problem upfront so that the research is solution focused.
- ✓ Ensures the research outputs are readily utilised and found to be practical.

Weaknesses

- Does not adhere to any tool set, being hard or soft, qualitative or quantitative. This may offer flexibility but it does also put more emphasis on the researcher to ensure that the methods utilised are appropriate and designed correctly.

- Requires the researcher to make an innovative leap and design a solution to the problem identified. This may introduce the possibility that the solution could fail if the researchers design was not well established.

Quality Assessment Criteria	Discussion	Proof from research content
Relevant, simple and easy to use	Proven through the process of problem identification where it was determined that there is an explicit need and gap in knowledge Simplicity and ease of use is shown through its application within a business context.	Relevance highlighted in Section 3 Demonstrated in Section 4.
Possess practical relevance	The tailoring approach was applied in DePuy Orthopaedics and was deemed an appropriate through its ability to produce desirable results i.e. the tailored methodology. This fact was backed up through Expert opinions in the field of Systems Engineering.	Application of the tailored methodology discussed in Section 5, evaluated in Section 6.
Has practical utility	The practical aspect of the tailoring approaches relevance was demonstrated through highlighting its need and utilisation in a business context, showing it is relevant and required in a practical setting.	Determination of the need for the approach in Section 3
Proven to be useful	The system that was produced through the application of the tailoring approach was deemed to be successful as the system produced was fully adopted and accepted within DePuy Orthopaedics.	System requirement fulfilment of 89%, as stated in Section 5.5.6
Theoretically novel	The novel nature of the tailoring approach is shown through a thorough analysis of the state of the art that highlights that no other tailoring approach exists	Analysis was carried out and documented in Sections 4 and 5.
Linked to theory	The process for developing the tailoring approach utilised input from a number of areas in both literature and practice.	Detailed and discussed in Section 4
Applicable in other environments	Although the approach has been developed and applied in one context, its evaluation has produced insight towards its validity and applicability in other environments	Detailed and discussed in Sections 4, 5 and 6

Table 19 - Research quality assessment

6.2.2 Discussion of application of the research design

As discussed in Section 2.5, based on the construction research method, the research approach was created to support the development of procedural and declarative knowledge. This research design split into four main stages i.e. Find a relevant problem, research problem, knowledge accumulation and development, and finally validation and evaluation. In each of these stages the researcher described the approach and methods that would be utilised, in line with the research methodology. This sub-section will discuss how this research design was applied in practice and will highlight any deviations and limitations that were experienced.

Find a relevant problem

In this stage of the research design two main methods were prescribed for use in the research design, primarily a literature review in key areas, as well as a company review. As the researcher was led by the company to solve a problem practically relevant to them the literature review focused largely on the problem area of resource management and system development. Only through critical analysis and understating of the root cause was it made clear that the knowledge required was not to be found in the system but in the process for developing the system. Although the company context enabled the researcher to find a relevant problem, it was a struggle to frame this within the company context that the research was being conducted. On reflection, this issue limited the freedom of the research, but conversely created focus for the researcher to generate value. Therefore, this was not a straightforward process of review and document, but a cyclical and iterative approach which took a number of months to secure. There was a risk that an inappropriate are of focus would be developed that either focused too much on novelty or business benefit, without striking a beneficial balance between the two.

Research problem

Once assured that the problem highlighted was in the interests of both the researcher and the business context a more critical review was required to ascertain if the research was novel and also to frame it within the state of the art. A limitation that was experienced in this aspect of the research design was that system development is a wide a varied field of research this proved to be challenging for the researcher to navigate. To remedy this the research was focused on a single aspect of methodology tailoring and the procedural guidance required for businesses. It was ascertained that although current standards exist that manage system development lifecycle model and their tailoring, very little guidance is in place to aid businesses in this tailoring process. After a critical review, it was assured that this was a novel and significant contribution that would also provide DePuy with benefits through its application in their business context.

Knowledge accumulation and development

Within this stage of the research the researcher was required to gather information within the business context, as well as within literature, that would enable them to attempt the creative leap required to develop the procedural knowledge required. This aspect of the research was influenced by the initial activity of interviewing, observing and participating in DePuy's resource management processes. At this stage of the research there was a perceived risk to focus solely on the resource management issues presented and not the contextual influences that were to be derived from this context. However, this was overcome and through careful consideration of the facts presented the researcher was able to derive the required declarative knowledge element regarding the influencing factors on system development within complex businesses. The main deviation experienced in this stage of the research was that that the procedural knowledge was not developed from this declarative knowledge, but utilised it as an input to the process itself. Through the process of searching for knowledge and assessing ways forward the researcher developed and applied an approach that utilised knowledge derived from company review and literature in a creative manner. This was formalised as the procedural knowledge element that is presented within this research as the primary contribution to knowledge. This output was not expected to be created in this way, but benefited the researcher and the research as it provided the knowledge required. This presented the researcher with the issue of substituting the validity of the approach that had been derived, without the ability to reproduce the approach in another business context. This limitation meant that the researcher had to establish validity of the research through an in-depth analysis of the outputs of the knowledge, which impacted the approach taken towards validation and evaluation considerably.

Validation and evaluation

Although the declarative and procedural knowledge had been generated and applied already there was a further requirement to validate that the approach produced desired outcomes. This could only be assured through the application of the output from the procedural knowledge i.e. the tailored methodology. This element would also provide business benefit to DePuy as it would be utilised to develop a system that would address their resource management issues. This process provided the researcher with further insight into system development and provided validation of the tailoring approach as it produced a methodology that in turn produced an accepted, adopted and sustain system. The methodology was then further evaluated by system development experts to provide external input to the validation discussion. The key limitation in this part of the research was the ability to derive validity of the tailoring approach from both the primary and secondary products of its application i.e. the tailored methodology and the system that it produced. However, this was achieved through a coordinated approach and discussion and proved that the tailoring approach was fit for purpose.

Overall the research design was applied thoroughly and utilised the construction approach appropriately. A number of limitations and deviations occurred, primarily the need to balance the need for novel research and business benefit as well as the creative leap being developed through an exploratory approach rather than the application of the declarative knowledge. The research methods were all applied as expected, a review of these methods and their strengths and weaknesses will be provided the following sub-section.

6.2.3 Review of research methods utilised

This sub section will review the research methods that were utilised in the research and will highlight how and where the method was used. This will also offer and appreciation of the strengths and weaknesses of the method and the practical limitations that were experienced in its application.

Interviews

The first method that will be discussed is the use of interviews throughout the research, which were utilised at many stages of the research process for varying reasons. Interviews were first used in the “Find a relevant problem’ phase of the research were the researcher was actively researching the area of resource management and its associated drawbacks within DePuy Orthopaedics. From these interviews the researcher was able to build up a vision of DePuy and their approach to resource management and also develop an idea as to what the problem actually was. The interviews were aimed at key knowledge holders within the business, mainly managers and resource specialists. Interviews were then further used in the "Research the problem" phase of the research that built on the initial interviews, further exploring the problem space in an effort to understand the resource management issues within DePuy in greater depth. Interviews were also utilised in the "Validation and Evaluation" phase of the research, where the outcomes from the research were validated by those who utilised them in the context of DePuy, and evaluated by System Engineering and Managerial experts external to DePuy. Interviews were adopted in the "Methodology Application" phase when developing the scenario analysis tool to gather and develop requirements for the tool and to evaluate prototypes throughout the process.

Strengths

- ✓ Allowed the researcher to develop a deep understanding of the problem being faced in the organisation, in relation to resource management.
- ✓ Enabled the researcher to develop a knowledge base from which further interviews could be designed to gain insight in areas of interest.
- ✓ Allowed the researcher to gather and interrogate a set of requirements that were utilised in the development of a system in the business context.
- ✓ Semi-structured in-depth interviews regarding the success of the outcomes produced by the tailored methodology were able to highlight the validity of the tailored methodology that was applied and understand where further work was required.
- ✓ Structured questionnaire interviews were utilised to evaluate the tailored methodology to ascertain its appropriateness and ability in a number of areas

Weaknesses/limitations

- In early stages of the research, interviews were informal and many of the results were not utilised due to the immaturity of the research at that point in time.
- Choice and number of interviewees were limited to those who were available and had the expert knowledge that was required due to time constraints experienced.

- Inappropriate question structure, when considering the evaluation of the tailored methodology, had an impact on the output that was generated from these interviews.
- In evaluation interviews the output generated relied on the opinions and knowledge and understanding of the expert in relation to the methodology being presented, this could have meant that experts may have misunderstood or projected their own prejudices on to the results.

Limitations

- Inclusion of biases in both the investigative and evaluation interviews may have affected the results achieved, although the design of the interviews attempted to minimise the impact this would have had on research results

Observation

To gain a better understanding of a number of issues highlighted through initial interviews the researcher took part in observation exercises with DePuy Orthopaedics. Observation was carried out in the first two phases of the research process i.e. "Find a relevant problem" and "Research problem"; it was also carried out in the "Methodology application" phase of the research. The observation that was carried out mainly consisted of the researcher being invited to and sitting in on resource management meetings, within which they were not expected to contribute but to develop and understanding of how DePuy carried out resource management and the associated problems. From this understanding further questions were formulated to deepen the researcher's understanding. When considering the application of the methodology the researcher was able to sit in on meetings and situations where the resource management scenario analysis tool was utilised in an effort to understand and develop requirements for the tool.

Strengths

- ✓ The researcher was able to gather knowledge regarding resource management with little change to the environment being observed as possible.
- ✓ Enabled the researcher to further their understanding of points previously discussed in interviews and develop a more rounded appreciation of the context.
- ✓ Allowed the researcher to assess the impact of a solution that was introduced into a meeting environment.

Weaknesses/limitations

- Initially business language was unfamiliar to the researcher.
- Relied on the researcher understanding business related issues, which included acronyms, project specifics, staff names and technologies.
- Tended to be very time and labour intensive and relied on those present to cover issues relevant to the researcher.

<u>Participation</u>

The Construction methodology advocated the use of the researcher's personal experiences and knowledge to develop solutions to perceived problems to produce practical results. Therefore, it was identified that the researcher required gathering personal experience of the issues that were being experienced. The researcher was involved personally in a number of resource management activities within DePuy and was personally responsible for the update of the resource refresh process, which is referred to in a number of places in the contextual understanding stage of the application of the methodology. Due to the fact that the researcher was developing and applying the tailoring approach simultaneously the knowledge gained in this activity was able to influence both the development of the tailoring approach itself and the outcomes from the application of the tailoring approach.

Strengths

- ✓ Researcher was able to understand first-hand the issues that were being experienced and develop their own opinions.
- ✓ Issues that interviewees may have thought not relevant to mention were identified in the personal participation, generating a more rounded appreciation of resource management within DePuy.
- ✓ Experience of the current process within DePuy was utilised in both the development and application of the tailoring approach.

Weaknesses/limitations

- Time consuming and required the researcher to fully apply themselves to the resource refresh process, momentarily removing their focus from the research aims and objectives.

- Researcher applied their own knowledge and experiences to the situation which may have resulted in the documentation of issues and problems that may have been personal to the researcher.
- Relied on the support and backup of senior management within DePuy as the researcher was not a full employee and was trusted with commercially sensitive material.

6.2.4 Summary

In this Section to overall quality of the research was discussed, firstly in relation to the appropriateness and application of the research methodology that was utilised, secondly in relation to the application of the research design, and finally the research methods that were applied. From the assessment of the outcomes from the research it was established that the Construction methodology adopted was appropriate for the context of the research and had been applied in such a way as to produce a quality result that met the requirements of the business. The research quality was assessed against seven criteria that were designed to ascertain the quality of the application and appropriateness of the methodology. The research design and its application was also discussed where it was stated that it had been applied as expected. One main deviation was highlighted as the use of exploratory methods to develop the procedural knowledge. A limitation of the application of the research design was also discussed as the need to both provide novel research outcomes as well as business benefit, this constrained the research and the approach taken. The Section then went on to discuss in detail the main research methods that were utilised in the research and highlighted how these were used. Each method was discussed in relation to their strengths, weaknesses and limitations within the research, highlighting opportunities for future work and improvement if they were to be used again.

7 Conclusion

The overall aim of the research presented in this thesis is to create an approach to system development and implementation in complex business contexts utilising methodology tailoring. The approach will minimise the risk of the resultant system being poorly accepted, adopted, and sustained. The work done in Section 3 of this thesis identified and discussed the problem space, defining the need for the approach and therefore the research focus. The approach was then created and applied in Sections 4 and validated and evaluated in Section 5 & 6. This Section will discuss in detail the contribution to knowledge that was delivered from the outcomes of the research and what future work could be done to further develop the approach. The Section will then conclude with a discussion of the researcher's personal reflections.

7.1 Contribution to knowledge

As discussed in Section 2 of this thesis, there were two main types of knowledge that were envisaged to be created in this research; declarative and procedural. The declarative knowledge was in the form of facts or information derived from research that would influence the creation of the procedural knowledge. The remainder of the Section will discuss each contribution in turn giving an overview of the knowledge that was created.

7.1.1 Contributions to Theory

7.1.1.1 ***Declarative knowledge developed***

Considerations found to influence system development in resource management for NPD context were uncovered through an in-depth critical evaluation of literature discussed in Section 3.2.2. The outcome from the review was the identification of six considerations found to be relevant and influential in the potential adoption and acceptance of systems in a business context. This contribution will guide developers in the development of resource management systems within NPD contexts when contextualising system development methodologies. These considerations are as follows:

- **Business requirements:** What is expected and/or needed, at a functional and non-functional level, by the customer for a system to fulfil its purpose (Nuseibeh and Easterbrook 2000, Nance and Arthur 2006)

- **Culture**: Willingness to change or adopt new ways of working can have an effect on how well a system is adopted (Knoll and Heim 2000, Melao and Pidd 2003, Sheu and Kim 2009)

- **Technology**: Technology that is currently used can be a restrictive factor when considering implementing a system (Jenkins and Chapman 1998, Knoll and Heim 2000)

- **Complexity management**: There is a need for understanding the appropriate scope and level of detail required for analysis of the problem of interest (Flood and Carson 1993, Brooks and Tobias 1996, Chwif, Barretto et al. 2000, Kim and Wilemon 2003)

- **Uncertainty management**: Representing and taking account of the uncertainty present in a business system in a number of different forms and elements that make it hard for managers to plan ahead of time (Brooks and Tobias 1996, Meyer, Loch et al. 2002)

- **Human factors**: Human resources have differing needs, personalities, circumstances, and capabilities/skills which need to be considered in planning efforts which should be highlighted in analysis efforts (Hafeez, Aburawi et al. 2004, Jenkins and Rice 2007)

These considerations highlight, at a high level, what a resource management system development methodology needs to incorporate to ensure that the systems it creates can be accepted, adopted, and sustained within the complex NPD business context in which they are expected to function. These considerations were utilised in Section 4 as an input to the tailoring process for a resource management system to ensure that external literature based input was incorporated in a tailored methodology. These considerations were assessed to establish if they were in fact evident in the context of DePuy and were added to by exploratory results of other contextual influences.

These considerations however, are specific to resource management systems operating in complex business contexts and cannot be taken to be a generalised contribution to system development. As stated in Section 3.2.4 the area of consideration to be made in system development is a widely referenced and researched field. This limits the contribution that this knowledge can realistically achieve and may also question its novelty.

7.1.1.2 *Procedural knowledge developed*

The significant and novel contribution of this research is the procedural knowledge that was produced in the form of an approach to methodology tailoring, backed up with a practical application and case study. This takes the form of a step by step approach that is to be followed when tailoring a system development methodology for use in a complex IT context.

The approach consists of the following steps;

- **Identify contextual factors that influence system development:** Determine what factors from both the business context and literature that will affect the development of a system and develop a synthesised list that will influence methodology tailoring, discussed in Section 4.2.1
    - As stated above in Section 7.1.1.1;
- **Establish if a system already exists that fulfils requirements:** Assess potential systems against high level requirements to establish if a system exists that can be utilised and determine how the outcome will affect the tailored methodology, discussed in Section 4.2.2;
    - This step determines the level of system development required and therefore the focus of the methodology; in the case of DePuy, no system fulfilled the requirements set so a new system was required. In other circumstances, a partial system alteration or full system implantation may be highlighted which would change the requirement for or the focus of the methodology tailored;
- **Select desirable attributes from other methodologies:** Discuss relevant methodologies and the aspects that could be utilised to influence the design of a tailored methodology, discussed in Section 4.2.3;
    - A set of criteria were established that would aid in selecting a set of potential methodologies, these were then assessed against their ability to incorporate the consideration required. From this, an appreciation of the positive attributes of each methodology was highlighted.
- **Formalise detailed tailored methodology:** Utilise learning from prior three stages to tailor a methodology and document its structure and approach, discussed in Section 4.2.4;
    - Positive aspects of the methodologies identified were utilised to tailor make a methodology, the consideration identified were also built into the methodology at this step.

- **Evaluate methodology:** Assess the incorporation of the contextual and methodological influences on the tailored methodology developed, discussed in Section 4.2.5;
    - o To ensure the methodology has achieved a successful level of tailoring it was assessed against the level of inclusion of the considerations highlighted, and explicitly identified how and where this had been achieved;
- **Implement in the business:** Apply methodology in the business context to develop and implement a system, discussed in Sections 4.2.6.
    - o The tailored methodology was applied in DePuy to deliver a new resource management system, which was successfully achieved, as discussed in Section 5.

As the development of an approach to tailoring methodologies required an innovative leap to be achieved, the understanding, knowledge, and experience of the researcher was utilised, as well as current research and approaches common within system development. This was in line with the construction research methodology and was carried out within the complex business context of DePuy Orthopaedics. The development of the procedural knowledge is fully discussed and described in Section 4 of this thesis.

7.1.2 Contributions to practice

Through the development of both the declarative and procedural knowledge, the researcher has contributed to the theory of system development within complex businesses of NPD at DePuy. The researcher has also contributed to the practice of system development and industry through the in-depth description and analysis of the application of the procedural knowledge that was developed. This case study will support other developers when considering system development in complex business contexts by providing insight into the process as well as the tools, techniques, and methods that could be utilised to demonstrate a positive result.

There is also a contribution made to DePuy directly through application of the tailored methodology to develop a resource management system. This system now provides DePuy with the decisions support capability that they did not have prior to the involvement of the researcher. DePuy utilise the system and has considerable reduced the time taken to make resource management decisions and has radically change the way in which the utilise data in the business. There is also potential for that this system could be transferred to other contexts to provide further benefit.

7.1.3 Limitations

Due to the fact that the approach was developed with influences from a business context i.e. DePuy Orthopaedics, this could have led to a bespoke solution being created. Also, as the approach was applied in the same context within which it was created, this factor was not effectively dealt with through application. The generalisability of the procedural knowledge developed was, however, assessed through experts' opinions regarding the tailored methodology developed for use in DePuy. This relied on their experience of the complexities evident within a complex business context and resource management requirements. This may have led to the experts applying their own prejudices and opinions in to the evaluation of the methodology. This fact was considered and was addressed through the use of a structured quantitative approach. However, the experts were not as comfortable with the statements as would have been expected leading to lower scores than would have been anticipated. Overall, the researcher believes that this issue was well managed in the research, but admits that it may limit the level of confidence in the procedural knowledge that has been produced.

Another limitation that may have affected the outputs from the research was the fact that the approach was developed and applied in the business context at the same time, due to the time constraints and demands of the organisation. This meant that, as a part of the approach was developed, it was applied straight away, reducing wasted time, which was a major factor due to the time constraints experienced. However, this meant that learning generated from the application of the methodology did not have an opportunity to be included in the final design for that step of the approach. The learning, however, influenced the stage that was carried out afterwards, meaning that the researcher continually improved their approach throughout the development and application of the approach. This may have introduced an imbalance in the maturity of the approach, with later stages gaining more validity through the gathered understanding of the researcher. However, due to the time constraints involved, this was an issue that was unavoidable.

The final limitation that was experienced was that, due to the construction approach that was utilised in the research, the researcher was encouraged to employ their own judgement and experience to the development of a solution. This fact may have encouraged the inclusion of the researcher's bias and prejudices in the development of the solution. However, as the development of procedural knowledge relies on an innovative leap, this fact was unavoidable. To ensure that the development was structured and well thought out, the process was documented thoroughly describing influences and design decisions. It is believed that this limitation had very little negative impact on the development of the knowledge created in this research, and overall added to the quality of the outcome.

7.2 Further Development

Through discussion and personal reflection on a number of the research outcomes that were developed throughout this research, a number of areas of further development were established. These realisations were developed through discussions with experts in the evaluation of the tailored methodology, through lessons learnt in the application of the approach, and through the application of the research process itself.

As previously discussed, one of the major limitations of the research was the fact that it was applied in the context within which it was developed, and also that it was only applied on one occasion. Therefore, to further prove the validity of the procedural knowledge developed, the approach should be applied and documented once more in a different business context. The application of the approach should be in a context very different from DePuy, but one that still experiences a complex business context, for example the defence or automotive industries. This study would enable the researcher to assess further the validity of the procedural knowledge and to incorporate lessons learned.

7.3 Personal reflections

Having reached the end of this thesis, I can honestly say this has been one of the most enlightening and challenging experience of my life, both personally and professionally. Through the process of identifying and solving a problem, I feel I have added to current knowledge in the arenas of Systems Engineering theory and System Development. Working closely with, and being accepted by DePuy Orthopaedics, has developed me as a person and enabled me to develop an approach with practical application and use. I am very grateful for their patience and acceptance of my work and hope that my work will benefit them in future systems developments.

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Appendix

APPENDIX A – Contextual Interview output

This Appendix provides a summary of the key points derived from 34 interviews carried out by the researcher, over a 3-month period. These interviews were related to the resource management process experienced within the complex business context of DePuy Orthopaedics. The information presented in this Appendix has been anonymised and altered to protect the privacy of both the individuals that were interviewed and DePuy.

1.0 NPD Process issues

- Struggle with understanding *what* is being designed. The scope needs to be defined. Marketing and designers can have different ideas.
- Not enough work done front end to understand what is needed for the market prior to the design phase starting
- Updating and changing scope, define scope early on, manage scope through projects.
- Defining scope – marketing (define product portfolio) – design (ideas in industry)-info space. Technology moves on and scope creeps.
- Define boundaries for design brief, a detailed design brief is required to understand the requirements for its development.
- No preparation time or allowance for over-run and tidy up from previous projects
- Design brief is not thorough enough to fully understand what the project consists
- Involvement of the business leads and management depends on size of project.
- 3 phase model – upfront (business case), meet inputs (design), implement (man hand over). Things are changing in phase one while stuff is happening in phase 3. This can be disruptive.
- Phase one is allowed to drift – people don't put depth of thought in until it is time to sign off.

2.0 Management Structure

- Management structure can often conflict with strategy/ goals
- Conflicting objectives
- Pass it on mentality – functions in teams, individual rather than team focus.
- Not measured as teams, measured by function delivery

- Controls do not exist to allow things to happen in parallel.

3.0 Human Issues / cultural issues

- Attempts to develop an individual's skill set with a mind to future developments are often hard to plan and achieve

- Development is usually achieved through the use of effective feedback

- Not very good at reviewing business objectives

- Prioritising projects can cause issues as politics can often come into play and cause a conflict between profit and priority

- Joint ownership of projects can cause conflict

- People who say "it's not working" don't get listened to.

- Working on the wrong projects is de-motivating.

- Comes down to influence. Who shouts loudest wins.

4.0 PACE - DePuy's project governance and management system

Total spend of R&D proportional to opportunity in various departments (Hips, Knees, Trauma and Extremity, Clinical and Regulatory) To do this it is necessary to understand the size of the market opportunity.

- Review the viability of process, contracted project managers have a conflict of interest to keep unviable projects continuing

- Projects are being sold at stage gate meetings instead of being taken to pieces

- Too much detail in stage gate process when first developed. Trying to get detail out of the process and put it into functions.

- There is an unsaid agreement that PACE adds no value;

    - Longer preparation period needed. Consultants for team working?

    - Smaller project team members change a lot

    - Problems exist even within one function.

    - Sell own projects to review board. Projects should be presented warts and all. Could be seen as a failure as a team, the natural thing to do would be to cover up.

- Revising project plans would help. Question why first guess did not end up like that.

5.0 Headcount

- More resources in house i.e. head count would alleviate issues, but this number is strictly controlled
- Headcount restrictions can cause major issues when planning the delivery of a project
- Due to the limitation on head count there is a Sub- contracting culture developing.

6.0 Resource Management Processes

- No specific resource allocation process
  - Ad hoc
  - Reactive
  - Not well defined
  - Does not track planned versus reality for resource allocation
- Need to balance resources and spend on the project, prevent over-run and over budget
- Many managers believe that they can't plan this type of work, due to the level of uncertainty involved and number of unplanned problems
- There is no detailed planning put in place
- Managers are also engineers on projects, can cause a conflict and no specialism on the management of the actual project, also they seem to be too technically attached to take a holistic view of the project being managed
- The project managers should have a clear job description and detail exactly what they should be doing to manage projects
- A lot is left to individuals to decide what is appropriate as management, no clear guidelines
- A lot of resources are dedicated to changing processes rather than actually doing.
- Don't understand the length of the project after the product has been released to market.
- 10-15 yr. projects that don't disappear, projects add up.
- Project plan not visible – hard to track.
- Firefighting, panic staff buy-in

- Difficult to plan ahead, problems can appear or rush, peaks and troughs.
- Extra resources not always available, specialist areas needing specialised skills, not a bottomless pit of money.
- Mostly firefighting, request extra staff but not approved, not given that resources will be available.
- Things change so quickly, not as easy to react
- Not worth planning as things will change, need to be reactive, more resources around to adjust to change.
- Difficult to take temp staff in a high skill level
- Rigid systems and lengthy recruitment process isn't easily managed.
- Don't bother spending time planning because things change so much.

7.0 Scheduling and Sequencing (General organisation of resources)

- There is a need to improve recording of resources used
- There is a need to show more supporting functions resources such as regulatory, quality, finance etc., as these impact the whole project
- Planning supporting functions need to be more involved in the whole life of the project
- Supporting functions aren't always available –The availability varies a lot depending on the current work load and priority of work.
- Time sheets were used in the past for analysis reasons, but never utilised to their advantage, more simple and understandable sheets would be of benefit
- A clear view of their use and outcome from using time sheets would motivate individuals to use them
- Small bubbles with big time can take resource priority

- Estimation is hard, events can come up easily, unanticipated actions.
- Compress time if over-run by other departments (manufacturing)
- Suggestion – estimations are a finger in the air. Need validation activities. No time studies, only judgement (manufacturing).
- Need to be more prescriptive up front, more specific about how long things take, use project planning properly.

8.0 Ideas

Bottom line is: Understand resources and develop a system for allocation that effectively reduces cycle times and allows more projects to be completed.

Look at what happens now> benchmark > goals

- Look at what's in place now and benchmark against other companies, then set goals to achieve
- Resolution of plan to be effective? Optimum use of resource to plan.
- Improved conflict management between international sites
- Improve management structure so that there is more control
- Project prioritisation needs to be more structured
- Spare resources? Detailed planning less mess.
- Dividend / no. of employees = factor x (find out more about this)
- Would be good to produce concrete figures, need to follow it up.
- Easier version of time sheets needs to demonstrate value.
- Harmonised practice and procedures in every area of the business
- US seem to more people available, look after home country first. How do they do accounting?
- Need to balance NPD with existing products. Currently NPD gets about 60 % of time.

- Need to be able to plan ahead better. Expecting things that don’t turn up and vice versa.

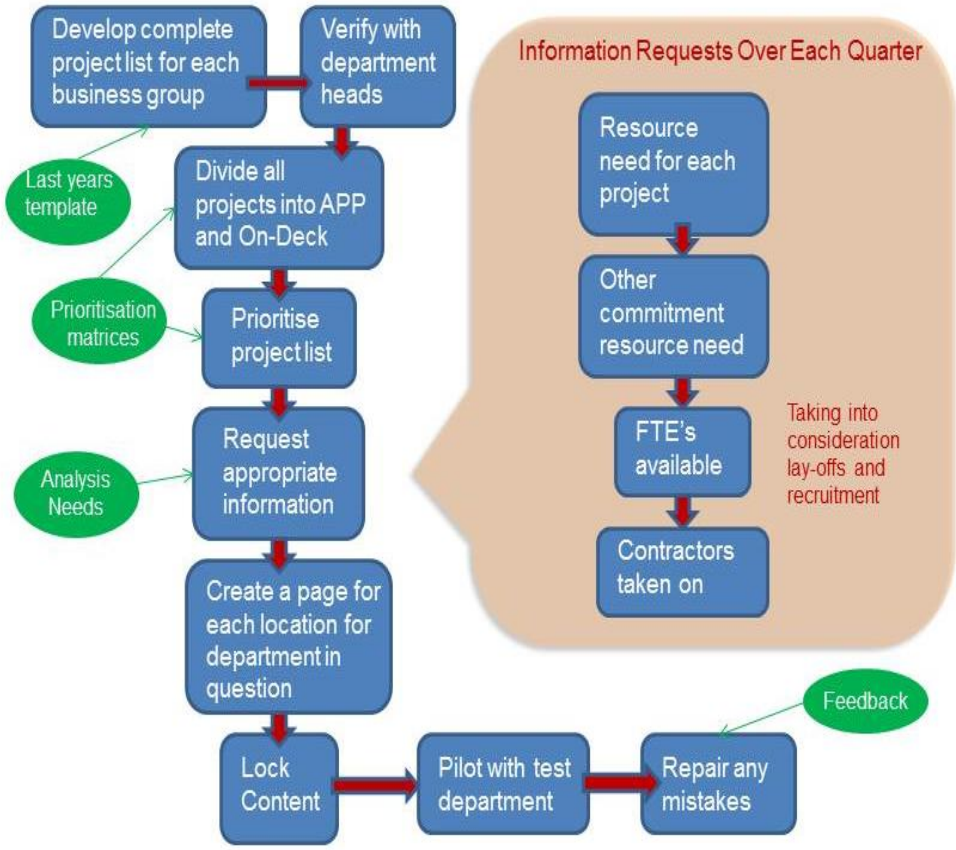
- A resource tracking tool would be good.

9.0 Suggested improvements/ “What if” scenarios

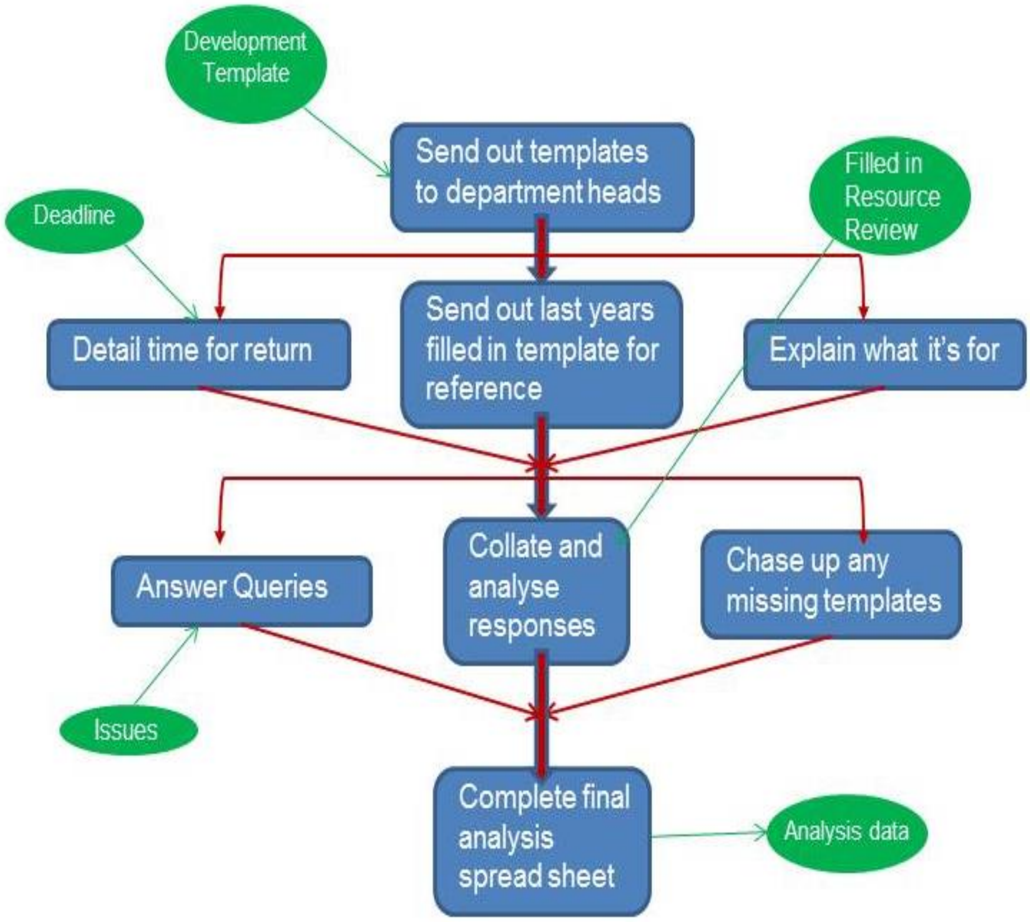
- Characterise each project and define them from each other
- Combine knees and hips. Skills for designers are transferable between hips and knees
- Cut down number of new projects
- Invest early on to aid projects life. over 60 % of department’s time on NPD.
- Centrally allocated resources

APPENDIX B – Resource refresh process maps

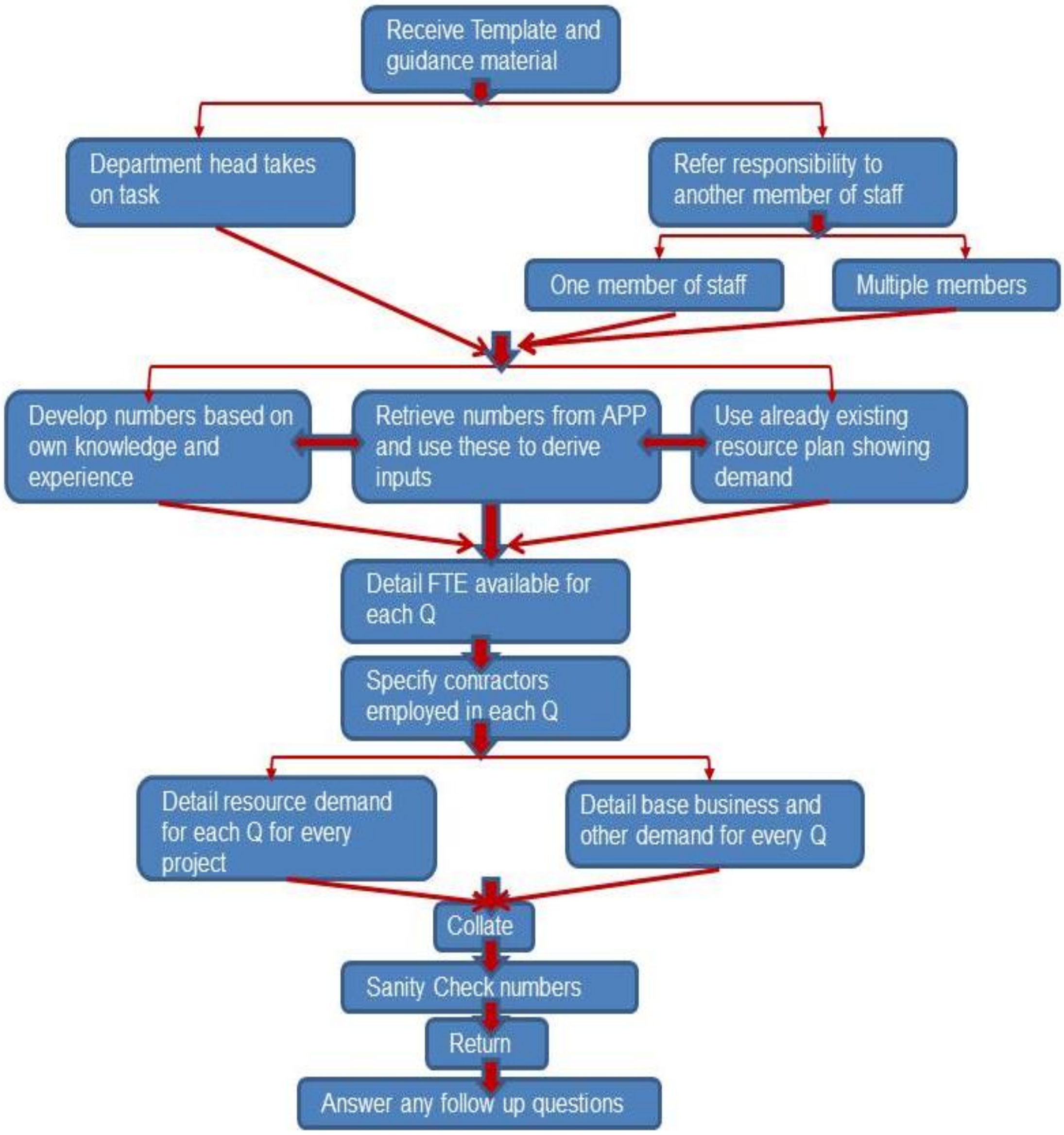
This Appendix provides system diagrams developed by the researcher through the course of their involvement in the resource refresh process within DePuy Orthopaedics. These diagrams summarise the process that the researcher carried out within the business and the outcomes that were delivered through their involvement.



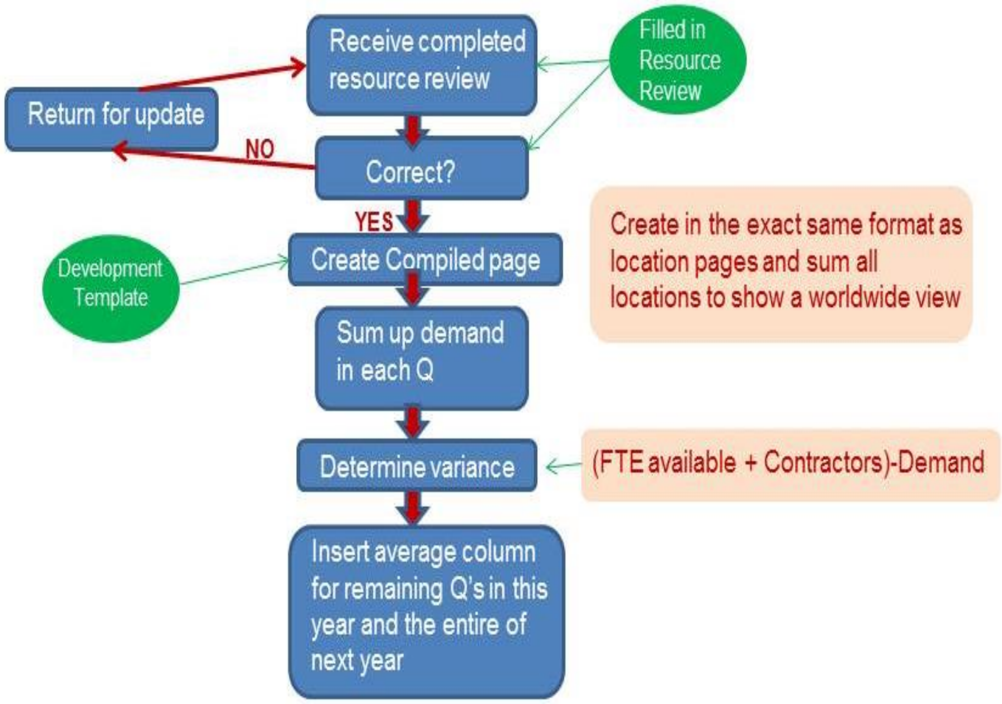
Overall resource refresh process



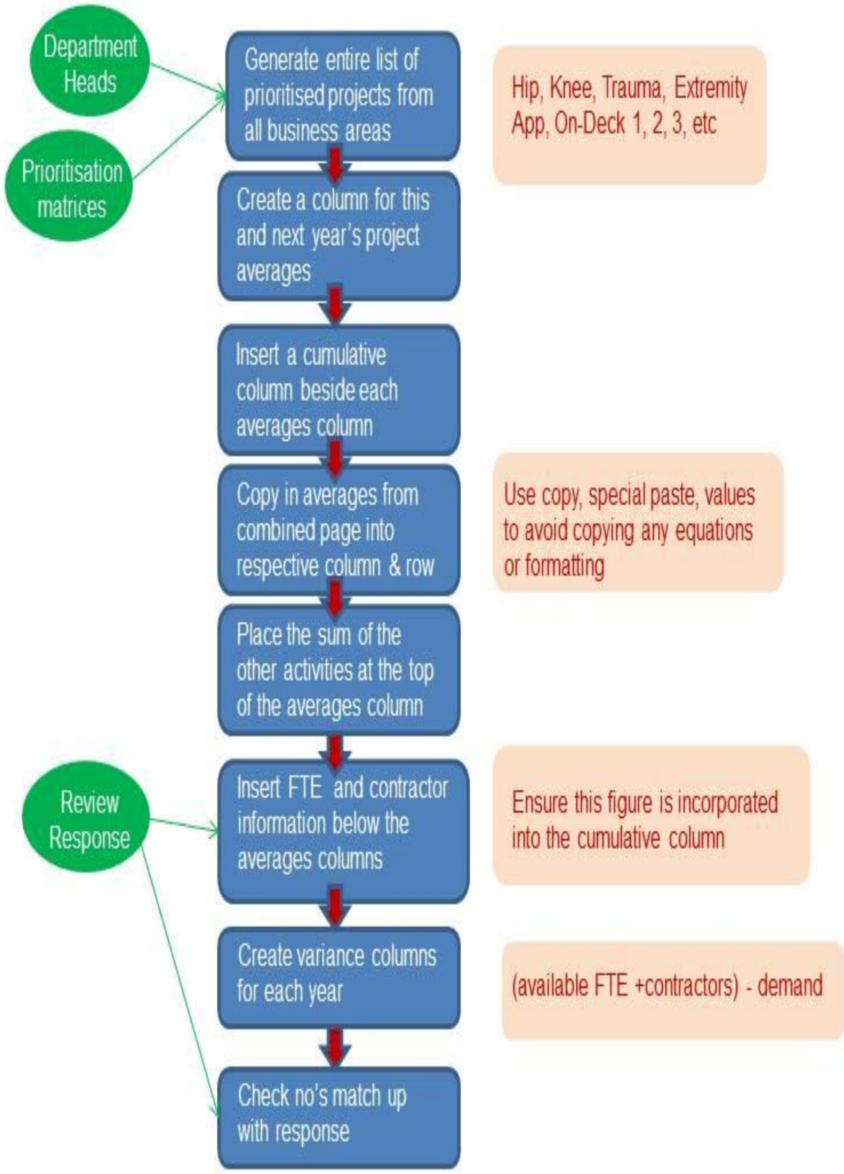
Process for requesting data for the resource refresh



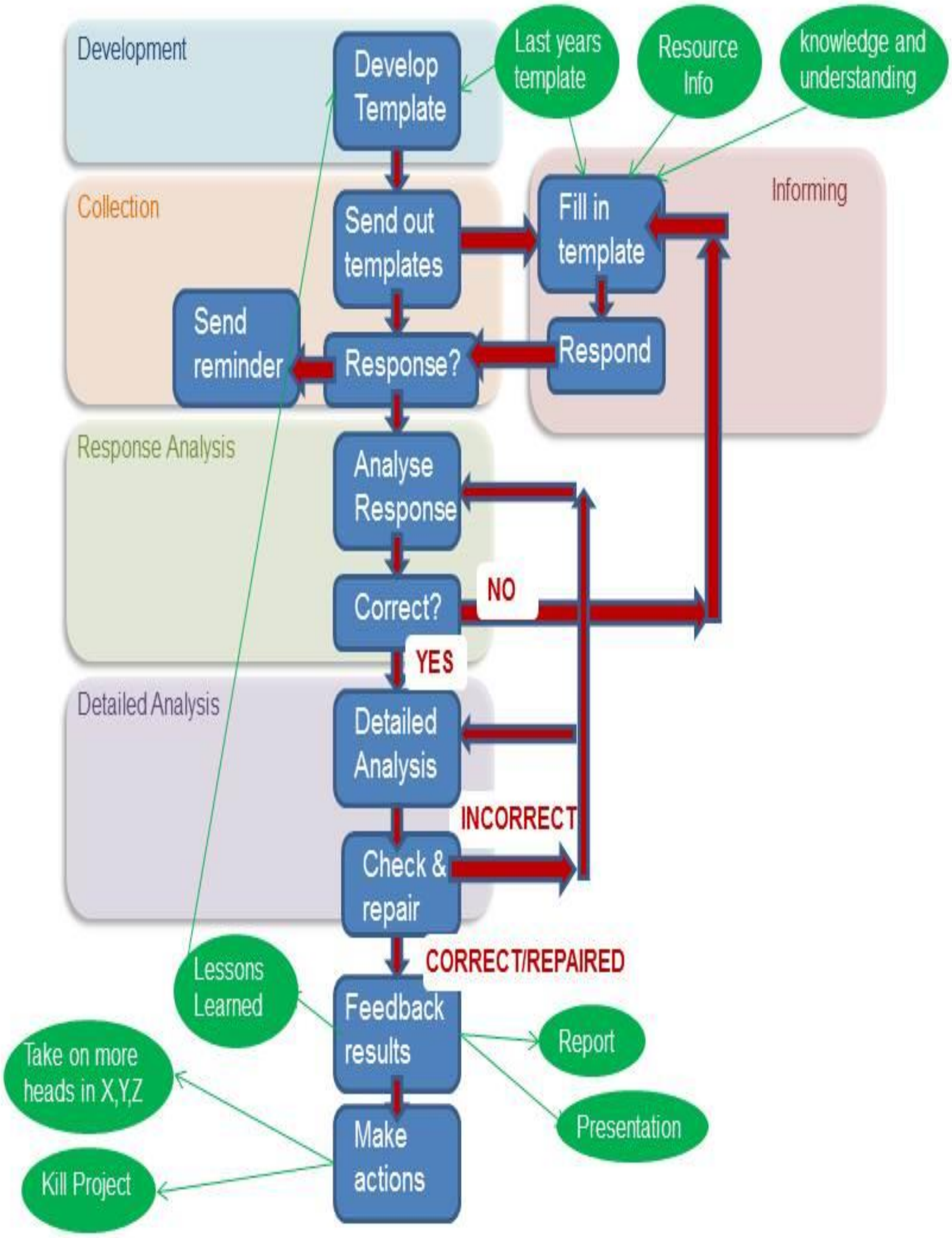
Process carried out by department heads to fill in the APP



Incorporation of received data for analysis process



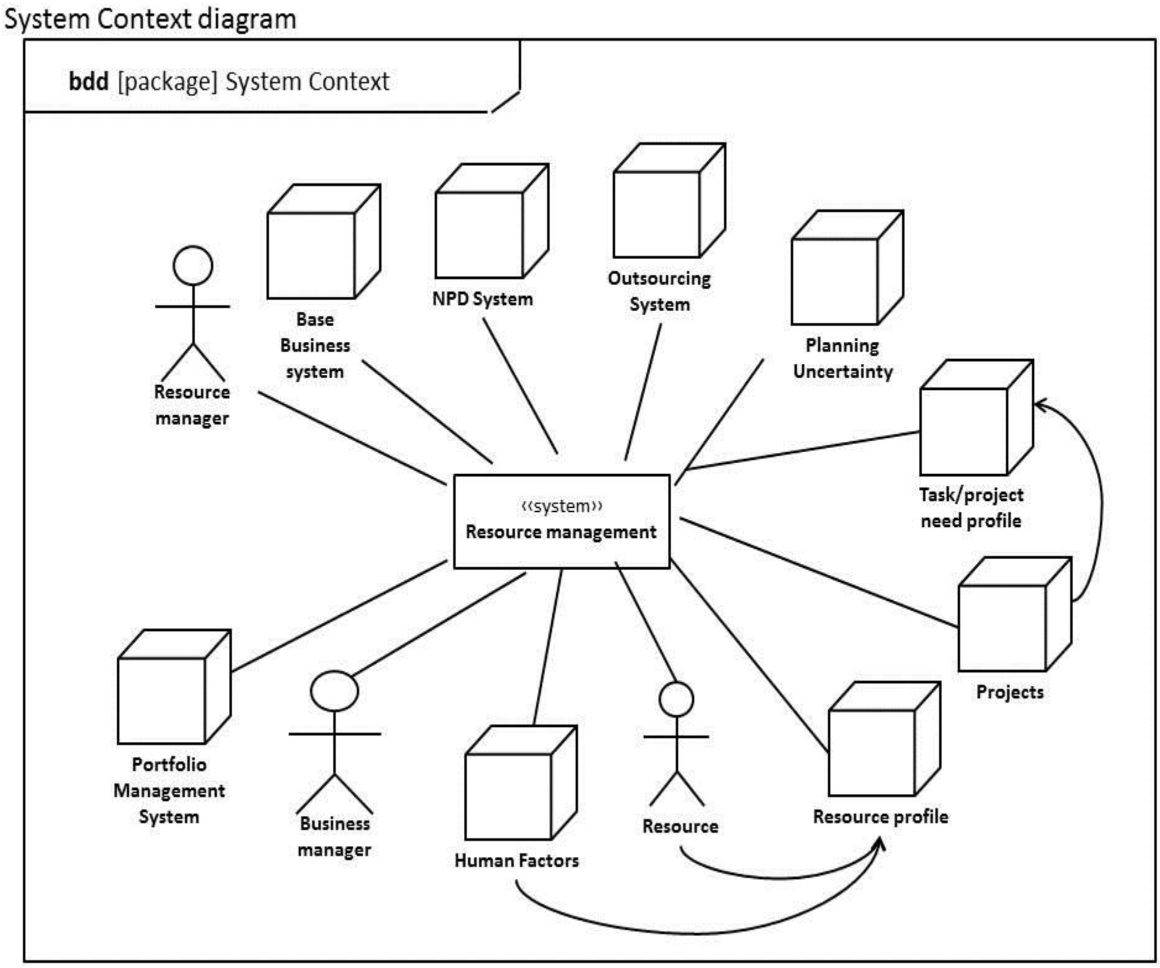
Data analysis process for incorporated data set



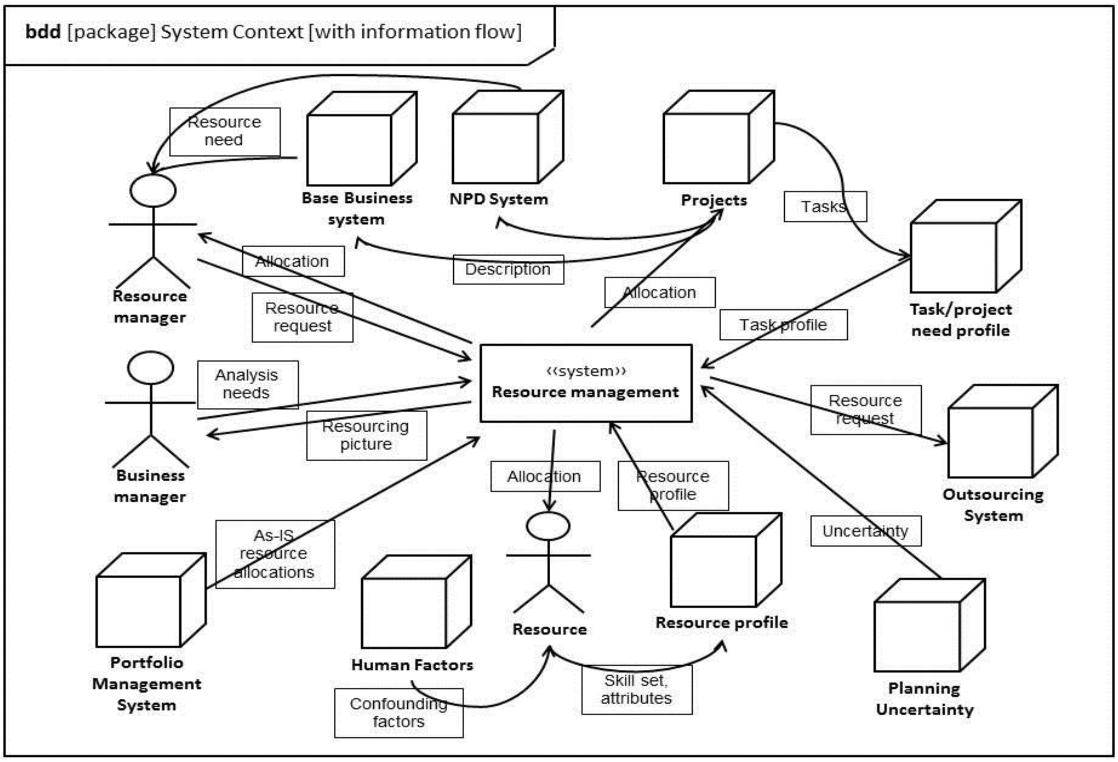
Resource refresh process summary

APPENDIX C – Upfront conceptual design

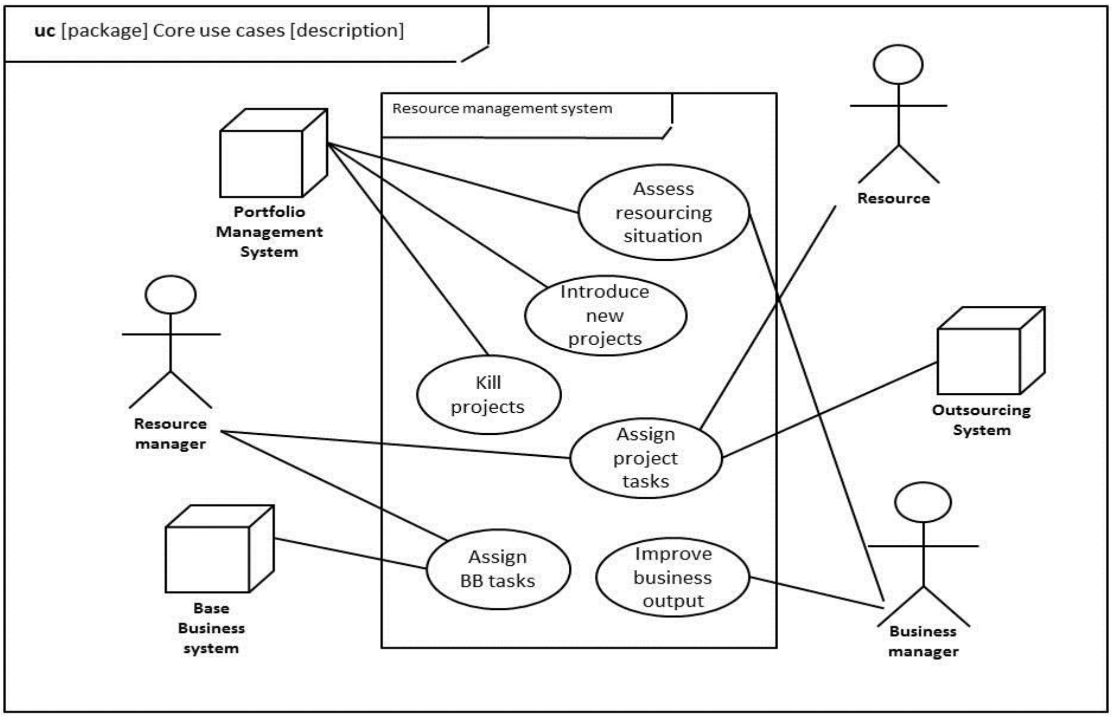
This Appendix provides the system diagrams created with the business to describe the current resource management system in place. This was utilised to understand the functions that are currently being undertaken by the business and was utilised to inform design decision made in system development.



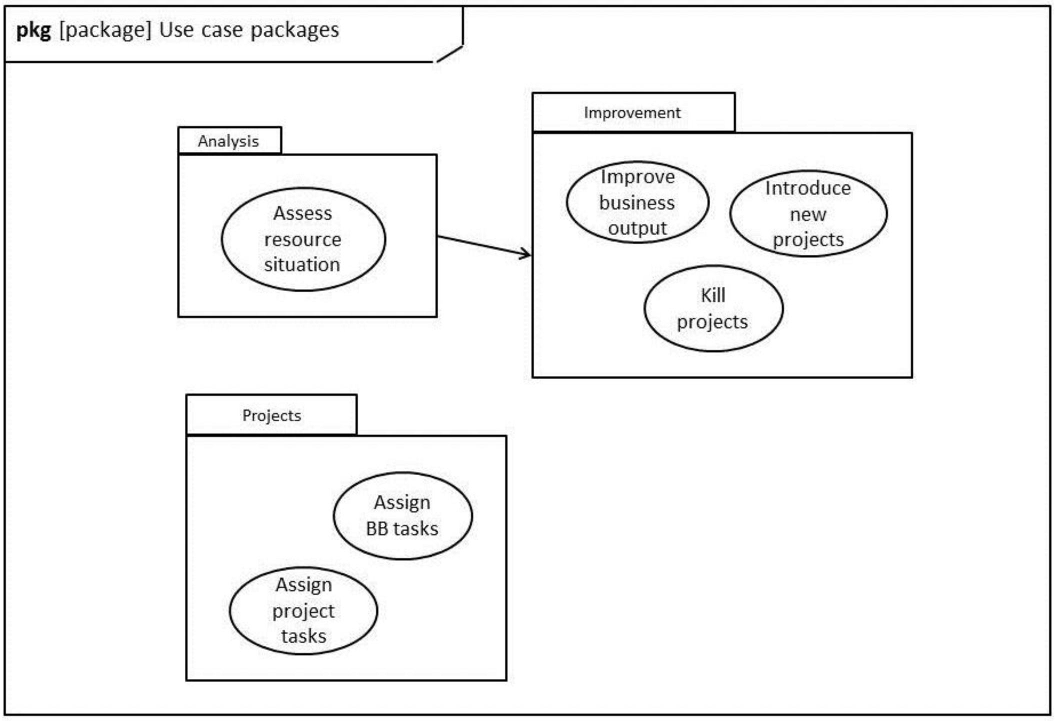
Resource management system context diagram



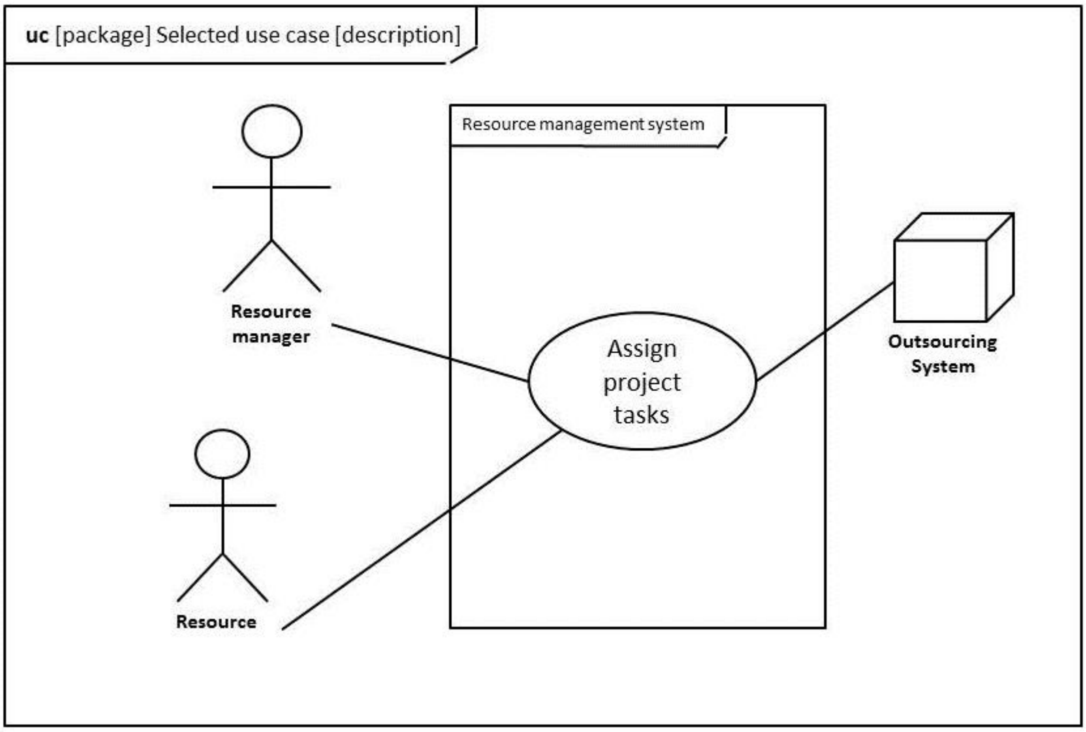
System context diagram with information flow



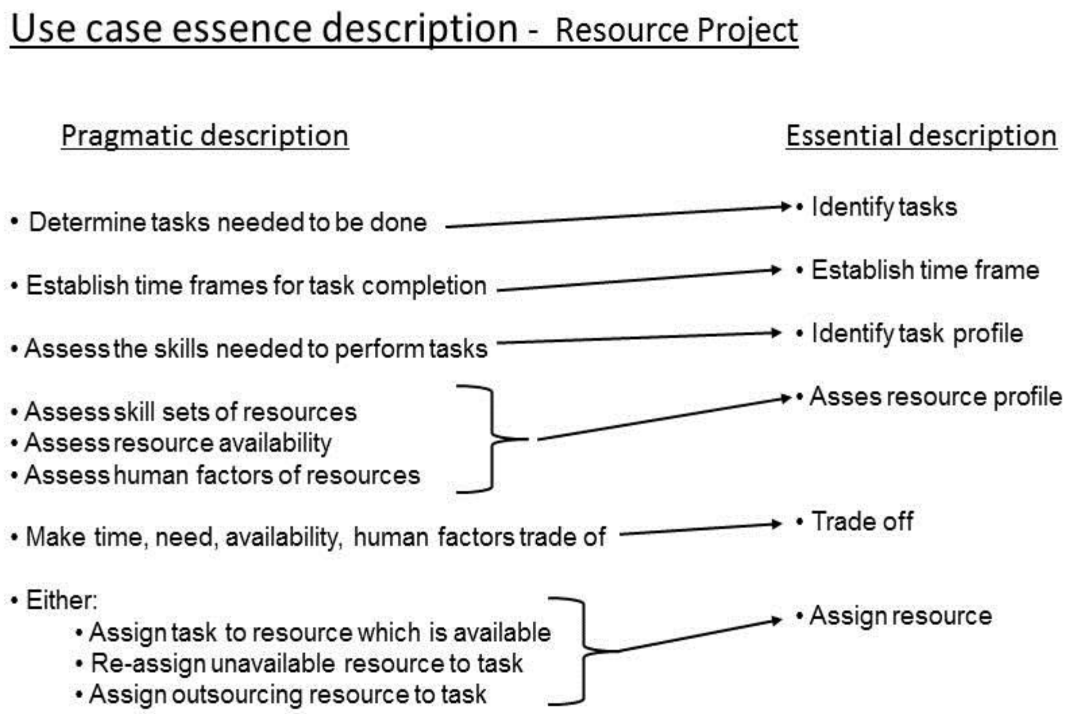
Resource management use cases



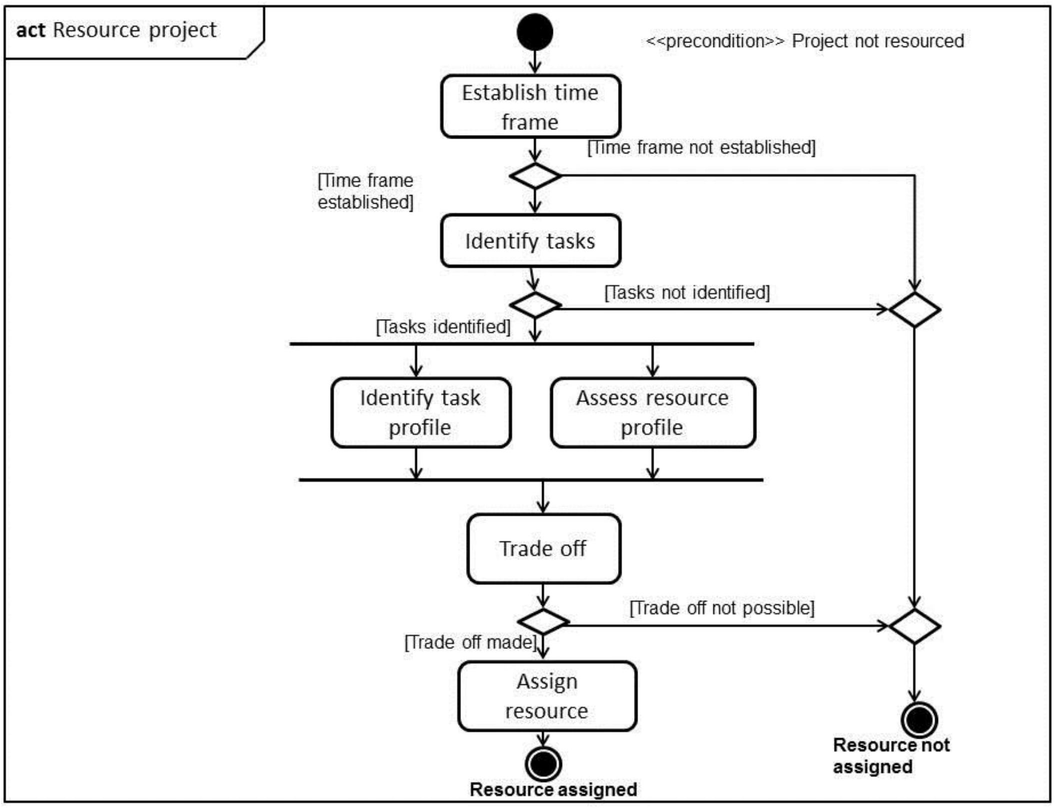
Use case package diagram



Assign project tasks use case



Essential descriptions diagram



Resource project activity diagram

APPENDIX E – Unit, system and user testing

This Appendix will provide the hip prototype and multidepartment porotype unit, system and user testing that was carried out within the business, as part of the validation and verification of the system.

Test ID	Input Parameters	Expected Output	Pass/Fail	Comment/issues
UT1- Check the Resource sheet				
			6.6.11	
UT1.1 Are all Hip projects included	Compare working sheet with main sheet	Same number of projects in same order		
UT1.2 Are all functions included	Consult original APP	All functional areas included		
UT1.3 Is data shown on a 2 year timeline	*	2 year time line for each functional area		
UT1.4 Is data shown at a quarterly level of detail	*	data shown in quarterly breakdown		
UT1.5 Does each project have a reference to their current status	Check status column B10 onwards	Each project will have a reference to their individual status		
UT1.6 Does each project have a reference to their project specific data	Check columns D,F,H,J	colour coded columns refeering to NPV, Risk, Resource and start date should be included		NPV and priority numbers are mixed in column J
UT1.7 Does each project reference the correct resource data on the working sheet	Check each data cell has a refrencing formula inside once populate button has been pressed	Each data cell should reference a cell in the working sheet		
UT1.8 Are functional resource avaiability figures correctly referenced	Cross check working sheet resource number with numbers shown in main sheet	All numbers will be referenced correctly to the right project in the right quarter		There are no operations numbers in this example, looks to be a fault but there are no numbers in source to show in the analysis
UT1.9 Does each project have a include/exclude tick box	reference column K and check if each row has a tick box from row 10 to row 47	Each project row should have a tick box in column K		Tick box size is too small
UT1.10 Are all projects initially included in calculations	Reference column K and check if every tick box is checked	All tick boxes should be checked		
UT1.11 Does each project have a +1 Qtr button	Reference column L and check if each row has a +1 button	Each project row should have a +1 button in column L		
UT1.12 Does each project havd a reset button	Reference column L and check if each row has a reset button	Each project row should have a reset button in column L		
UT1.13 Does the resource demand figure update when projects are excluded	Exclude first project and record if the difference found in demand figure is the same as what was recorded in the first project	Resource demand figure should update when projects are excluded		
UT1.14 Does the resource shortfall figure update when resource demand alters	Change resource demand figure and observe if shortfall updates	Shortfall figure should update when demand changes		
UT1.15 When a tick box is unticked that project row is excluded from calculations, blocked out, and shown to be 0	Untick all tick boxes	Row is blocked out grey and all cells are 0		
UT1.16 When the +1 Qtr button has been pressed does conditional formatting still work in that row	Press +1 and then untick tick box	When the data is moved over the project can still be blocked out		Row 27 +1Q Macro does not exist, Row 31 macro was not assigned
UT1.17 After the project reset button has been pressed does conditional formatting work in that row	Reset row and untick tick box	The project row can still be blocked out after it has been reset		Macros reference cell in upper left corner at end of reset which prooves annoying when focusing on lower parts of the page

Copy hip project list button			**6.6.11**	Due to the fact the working sheet is written over each time the copy button is pressed but not cleared with the reset, the working sheet is always filled with data, this means the when a reset row button is pressed on the blank sheet it can reference data, may be confusing and means the sheet cannot be used for directly inserting data into the sheet as the rest will reference the wrong data
UT2.1 - Does the current APP get opened and the entire Hipp APP get copied and pasted into working sheet	Click Copy button	App copied into working sheet		
UT2.2 - Does the blank rows in the working get deleted	Click Copy button	All blank rows are deleted		
UT2.3 Do the function by Qtr resource availability figures get copied into the working sheet	Click Copy button	Availability figures are pasted in at the top of the working sheet		
UT2.4 Does the project list get copy and pasted into the project column in the main sheet	Click Copy button	Project list can be found in column c		
UT2.5 Does the Project specific data get copied and pasted in the main sheet	Click Copy button	data found in columns D,F,H,J		NPV and priority numbers are mixed in column J
UT2.6 Does the project status get copied and pasted from the working sheet	Click Copy button	Status found in column B		
UT2.7 Do the function by Qtr resource availability figures get copy and pasted into the resource available row	Click Copy button	Figures found in M90 - CM90		
Populate button				
UT2.8 Does the formula which references the resource data from the working sheet get pasted into all approriate cells	Click populate button	Each cell should have a reference formaula such as IF(L10=true, Workingsheet!M6,0)		
Reset button				
UT2.9 Does the project list get deleted	Click reset button	Column C should be blank		
UT2.10 Does the project specific data get deleted	Click reset button	Columns DFHJ should be blank		
UT2.11 Does the Project status data get deleted	Click reset button	Column B should be blank		
UT2.12 Does all formulas and formatting get deleted from the resource data cells	Click reset button	Data cells should be clear from all numbers, references and formatting		Objects pasted in from the working sheet are not deleted and cannot be singled out for deletion using a macro, needs to be manually deleted on every reset
Plus 1 Qtr buttons 1-47				
UT2.13 Does the data move over 1 Quarter each time the button is pushed	Click +1 button in each project row	Data should move over by one cell to the right for that project row		
UT2.14 Does the overhanging data get deleted between the functional groups	Click +1 button in each project row	Columns between functional groups remain clear from figures		
UT2.15 Does the inserted box format red to show movement	Click +1 button in each project row	When +1 is pressed the inserted box is red		
Project reset buttons 1-47				Only works with referenced data, will not be suitable for inputed data from user
UT2.16 Is the original referencing formula and formatting replaced	Click reset button in each row	Original references are restored and all red formatting deleted		Macros reference cell in upper left corner at end of reset which prooves annoying when focusing on lower parts of the page

Unit testing for Hip Prototype

Test ID	Input Parameters	Expected Output	Pass/Fail	Comment/issues
ST1- Chech basic functionality of the system				
			6.6.11	
ST1.1 Does the tool operate in a system compatible with Windows XP	Check file properties	Tool should be operatable on Window XP		
ST1.2 Is the tool compatible with Windows Office 2007 and earlier	Check file properties	Tool should be compatible with Office 2007 and earlier		Utilises 2007 office excel
ST1.3 Is the overall file size under 500kb	Check file properties	File size should be under 500kb		File size is 354kb
ST1.4 Is the file in a format which can be utilised by a large proportion of users	Check file format	File format should be supported by a large prioportion of users		standard file format utilised in company
ST1.5 Does the file interoperate with other systems utilised in the system environment	Check operating system and other available systems such as share drives, word processors etc	The file format should have a high level of interoperability with other systems in its working environment		Iteroperable with all office packages
ST1.4 Do functions operate quickly i.e. Under 5 seconds to update	Press all function buttons	Screen should update under 5 secondss		Is dependent on the speed of the machine which is running the programme
ST2- Check the outputs of the system				
ST2.1 Is the resource demand figure calculated correctly	add up demand figures and cross check with output	Demand should equal the sum of the projects resource demands		
ST2.2 Is the resoure shortfall figure calculated correctly	Calculate seperatley and cross check	Shortfall should show the total edmand minus the resource available		
ST2.3 When no projects are included is the resource demand 0	Deselect all projects	When no projects are included all overall demand should show as 0		
ST2.4 When the shortfall is -0.51 and below cell should fill red	provoke shortfall -0.51 and below in all cells	shortfall cell should fill red		
ST2.5 When the shortfall is -0.5 and above cell should fill green	provoke shortfall -0.5 and above in all cells	Shortfall cell should fill green		
ST3 - Compare with current analysis spreadsheet				
ST3.1 Are resource demand figures the same	Campare with APP	Figures should be the same		
ST3.2 Are resource availability figures the same	Campare with APP	Figures should be the same		
ST3.3 Are resource shortfall figures the same	Campare with APP	Figures should be the same		
ST3.4 When the first project is excluded are demand figures the same	Campare with APP	Figures should be the same		
ST3.5 When the first project is excluded are shortfall figures the same	Campare with APP	Figures should be the same		
ST3.6 When the first project is moved over 1 Qtr are the demand figures the same	Campare with APP	Figures should be the same		
ST3.7 When the first project is moved over by 1 Qtr are the shortfall figures the same	Campare with APP	Figures should be the same		

System testing for hip prototype

Test ID	Input Parameters	Expected Output	Pass/Fail	Pass/Fail	Pass/Fail	Pass/Fail	Pass/Fail	Pass/Fail	Pass/Fail
UT1- Check the Resource sheet									
			Hips	**Knees**	**Extremities**	**CMW**	**Trauma**	**Base Business**	**TruMatch**
UT1.1 Are all projects included	Compare working sheet with main sheet	Same number of projects in same order	pass	pass	pass	pass	pass	pass	pass
UT1.2 Are all functions included	Compare working sheet with main sheet	All functional areas included	pass	pass	pass	pass	pass	pass	pass
UT1.3 Is data shown on a 2 year timeline	Compare working sheet with main sheet	2 year time line for each functional area	pass	pass	pass	pass	pass	pass	pass
UT1.4 Is data shown at a quarterly level of detail	Compare working sheet with main sheet	data shown in quarterly breakdown	pass	pass	pass	pass	pass	pass	pass
UT1.5 Does each project have a reference to their current status	Check status column	Each project will have a reference to their individual status	fail	fail	fail	fail	fail	fail	fail
UT1.6 Does each project have a reference to their project specific data	Check first 3 columns	Project name, status and platform should be shown	fail	fail	fail	fail	fail	fail	fail
UT1.7 Does each project reference the correct resource data on the working sheet	Check each data cell has a refrencing formula inside once populate button has been pressed	Each data cell should reference a cell in the working sheet	pass	pass	pass	pass	pass	pass	pass
UT1.8 Are functional resource avaiability figures correctly referenced	Cross check working sheet resource number with numbers shown in main sheet	All numbers will be referenced correctly to the right project in the right quarter	pass	pass	pass	pass	pass	pass	pass
UT1.9 Does each project have a include/exclude tick box	reference column K and check if each row has a tick box from row 10 to row 47	Each project row should have a tick box in column K	pass	pass	pass	pass	pass	pass	pass
UT1.10 Are all projects initially included in calculations	Reference column K and check if every tick box is checked	All tick boxes should be checked	pass	pass	pass	pass	pass	pass	pass
UT1.11 Does each project have a +1 Qtr button	Reference column L and check if each row has a +1 button	Each project row should have a +1 button in column L	pass	pass	pass	pass	pass	pass	pass
UT1.12 Does each project havd a reset button	Reference column L and check if each row has a reset button	Each project row should have a reset button in column L	pass	pass	pass	pass	pass	pass	pass
UT1.13 Does the resource demand figure update when projects are excluded	Exclude first project and record if the difference found in demand figure is the same as what was recorded in the first project	Resource demand figure should update when projects are excluded	pass	pass	pass	pass	pass	pass	pass
UT1.14 Does the resource shortfall figure update when resource demand alters	Change resource demand figure and observe if shortfall updates	Shortfall figure should update when demand changes	pass	pass	pass	pass	pass	pass	pass
UT1.15 When a tick box is unticked that project row is excluded from calculations, blocked out, and shown to be 0	Untick all tick boxes	Row is blocked out grey and all cells are 0	pass	pass	pass	pass	pass	pass	pass
UT1.16 When the +1 Qtr button has been pressed does conditional formatting still work in that row	Press +1 and then untick tick box	When the data is moved over the project can still be blocked out	pass	pass	pass	pass	pass	pass	pass
UT1.17 After the project reset button has been pressed does conditional formatting work in that row	Reset row and untick tick box	The project row can still be blocked out after it has been reset	pass	pass	pass	pass	pass	pass	pass
UT2- Check inputs									
Copy hip project list button			**Hips**	**Knees**	**Extremities**	**CMW**	**Trauma**	**Base Business**	**TruMatch**
UT2.1 - Does the consolidated resource refresh sheet get opened and the resource information get copied and pasted into working sheet	Click Copy button	Resource information copied into working sheet	pass	pass	pass	pass	pass	pass	pass
UT2.2 - Does the blank rows in the working sheet get deleted	Click Copy button	All blank rows are deleted	pass	pass	pass	pass	pass	pass	pass
UT2.3 Do the function by Qtr resource availability figures get copied into the working sheet	Click Copy button	Availability figures are pasted in at the top of the working sheet	pass	pass	pass	pass	pass	pass	pass
UT2.4 Does the project list appear in the project column in the main sheet	Click Copy button	Project list should appear with no gaps in first left hand side column	pass	pass	pass	pass	pass	pass	pass
UT2.5 Does the Project specific data appear in the main sheet	Click Copy button	data found in project name, platform and status columns	fail	fail	fail	fail	fail	fail	fail
UT2.6 Do the function by Qtr resource availability figures appear in the resource available row	Click Copy button	Data found under resource demand figure	pass	pass	pass	pass	pass	pass	pass
Reset button									
UT2.7 Does the project list get deleted	Click reset button	Project column should be blank	pass	pass	pass	pass	pass	pass	pass
UT2.8 Does the project specific data get deleted	Click reset button	Project name, status and platform columns should be blank	pass	pass	pass	pass	pass	pass	pass
UT2.9 Do all resource numbers return to 0	Click reset button	Data cells should be 0 and still have referencing formula inserted	pass	pass	pass	pass	pass	pass	pass
UT2.10 Is the working sheet blank	Click reset button	Working sheet should contain no data from the source	pass	pass	pass	pass	pass	pass	pass
Plus 1 Qtr buttons 1-47									
UT2.11 Does the data move over 1 Quarter each time the button is pushed	Click +1 button in each project row	Data should move over by one cell to the right for that project row	pass	pass	pass	pass	pass	pass	pass
UT2.12 Does the overhanging data get deleted between the functional groups	Click +1 button in each project row	Columns between functional groups remain clear from figures	pass	pass	pass	pass	pass	pass	pass
UT2.13 Does the inserted box format blue to show movement	Click +1 button in each project row	When +1 is pressed the inserted box is blue	pass	pass	pass	pass	pass	pass	pass
Project reset buttons 1-47									
UT2.14 Is the original referencing formula and formatting replaced	Click reset button in each row	Original references are restored and all colour formatting deleted	pass	pass	pass	pass	pass	pass	pass

Multi-department Unit testing

Test ID	Input Parameters	Expected Output	Pass/Fail						
ST1- Chech basic functionality of the system									
ST1.1 Does the tool operate in a system compatible with Windows XP	Check file properties	Tool should be operatable on Window XP	pass						
ST1.2 Is the tool compatible with Windows Office 2007 and earlier	Check file properties	Tool should be compatible with Office 2007 and earlier	pass						
ST1.3 Is the overall file size under 2Mb	Check file properties	File size should be under 2Mb	pass						
ST1.4 Is the file in a format which can be utilised by a large proportion of users	Check file format	File format should be supported by a large prioportion of users	pass						
ST1.5 Does the file interoperate with other systems utilised in the system environment	Check operating system and other available systems such as share drives, word processors etc	The file format should have a high level of interoperability with other systems in its working environment	pass						
ST1.4 Do functions operate quickly i.e. Under 5 seconds to update	Press all function buttons	Screen should update under 5 seconds	pass						
Test ID	**Input Parameters**	**Expected Output**	**Pass/Fail**	**Pass/Fail**	**Pass/Fail**	**Pass/Fail**	**Pass/Fail**	**Pass/Fail**	**Pass/Fail**
ST2- Check the outputs of the system									
			Hips	Knees	Extremities	CMW	Trauma	Base Business	TruMatch
ST2.1 Is the resource demand figure calculated correctly	add up demand figures and cross check with output	Demand should equal the sum of the projects resource demands	pass	pass	pass	pass	pass	pass	pass
ST2.2 Is the resoure shortfall figure calculated correctly	Calculate seperatley and cross check	Shortfall should show the total edmand minus the resource available	pass	pass	pass	pass	pass	pass	pass
ST2.3 When no projects are included is the resource demand 0	Deselect all projects	When no projects are included all overall demand should show as 0	pass	pass	pass	pass	pass	pass	pass
ST2.4 When the shortfall is -0.51 and below cell should fill red	provoke shortfall -0.51 and below in all cells	shortfall cell should fill red	pass	pass	pass	pass	pass	pass	pass
ST2.5 When the shortfall is -0.5 and above cell should fill green	provoke shortfall -0.5 and above in all cells	Shortfall cell should fill green	pass	pass	pass	pass	pass	pass	pass
ST3 - Compare with data source analysis spreadsheet									
			Hips	Knees	Extremities	CMW	Trauma	Base Business	TruMatch
ST3.1 Are resource demand figures the same	Campare with APP	Figures should be the same	pass	pass	pass	pass	pass	pass	pass
ST3.2 Are resource availability figures the same	Campare with APP	Figures should be the same	pass	pass	pass	pass	pass	pass	pass
ST3.3 Are resource shortfall figures the same	Campare with APP	Figures should be the same	pass	pass	pass	pass	pass	pass	pass
ST3.4 When the first project is excluded are demand figures the same	Exclude first project in both analysis and source sheets and compare	Figures in the analysis sheet should show the project row to be zero and the resource demand sum equal to the original sum minus that projects initila contribution	pass	pass	pass	pass	pass	pass	pass
ST3.5 When the first project is excluded are shortfall figures the same	Exclude first project in both analysis and source sheets and compare	Figures in the analysis sheet should show the project row to be zero and the resource shortfall equal to the new sum minus resource avaiability	pass	pass	pass	pass	pass	pass	pass
ST3.6 When the first project is moved over 1 Qtr are the demand figures the same	Move first project over in both analysis and source sheet and compare	Figures in the analysis sheet should shift over one quarter and totals should update due to this movement	pass	pass	pass	pass	pass	pass	pass
ST3.7 When the first project is moved over by 1 Qtr are the shortfall figures the same	Move first project over in both analysis and source sheet and compare	Figures in the analysis sheet should shift over one quarter and totals should update due to this movement	pass	pass	pass	pass	pass	pass	pass

Multi department system testing

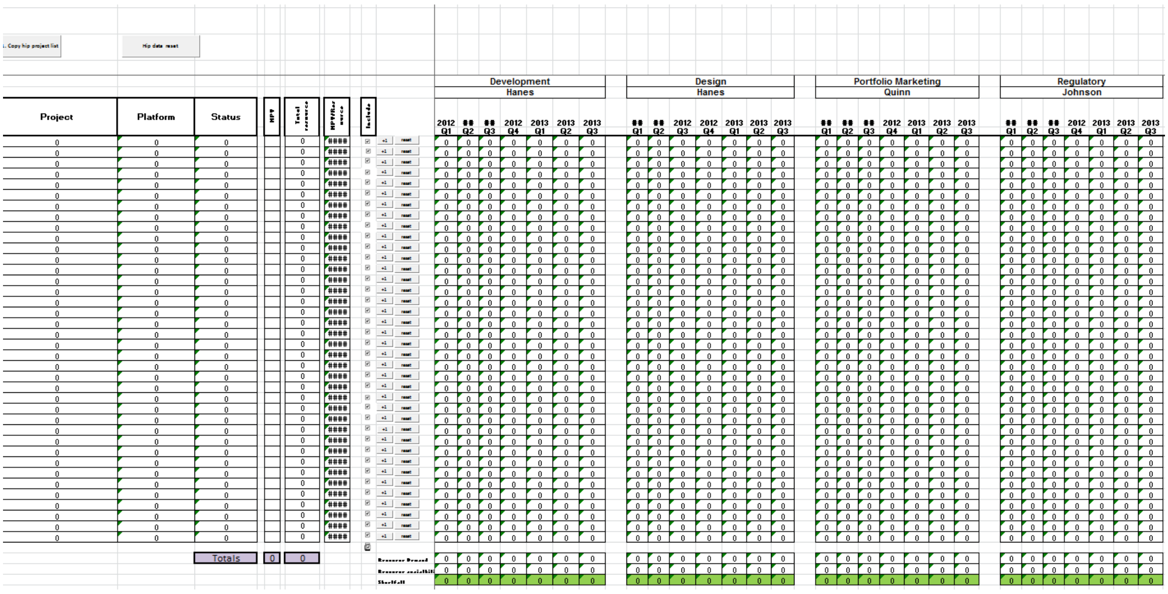
	John McCabe 7.6.11		
Action 1 - Gather project information	**Rating**	**Comment**	**Action Required**
1.1 The user will know what to do?	disagree	Not obvious where to start	Incorporate in training
1.2 The user will see how to do it?	disagree	Direction could be improved	Incorporate in training and more visual cues in the system
1.3 The user will understand from the feedback whether the action was correct or not?	agree	Obvious when projects added	
Action 2 - Populate resource information	**Rating**	**Comment**	**Action Required**
2.1 The user will know what to do?	agree	Obvious how to do this	
2.2 The user will see how to do it?	agree	Obvious how to do this	
2.3 The user will understand from the feedback whether the action was correct or not?	agree	Data addition makes this clear	
Action 3 - Select/de-select project rows to make custom portfolio	**Rating**	**Comment**	**Action Required**
3.1 The user will know what to do?	disagree	Difficult to find	Make more visual and incorporate in training
3.2 The user will see how to do it?	undecided	Not obvious word "Include" means this	Define what functions mean in a key
3.3 The user will understand from the feedback whether the action was correct or not?	agree	Apart from tick in box no other clue - would expect to see something	Some sort of indication in project listing would be useful as well
Action 4 - Move over project resource data quarter by quarter	**Rating**	**Comment**	**Action Required**
4.1 The user will know what to do?	agree	Obvious what the +1 button does	
4.2 The user will see how to do it?	agree	As above	
4.3 The user will understand from the feedback whether the action was correct or not?	agree	Red squares and visual impact is clear	
Action 5 - Reset Project data to original format	**Rating**	**Comment**	**Action Required**
5.1 The user will know what to do?	strongly agree	Obvious	
5.2 The user will see how to do it?	strongly agree	Obvious	
5.3 The user will understand from the feedback whether the action was correct or not?	strongly agree	Very visible	
6 - Overall system use	**Rating**	**Comment**	**Action Required**
6.1 The system is easy to use	undecided	It is once you've been shown, less so if working on own	Detailed training and guidance document may be required to ensure users understand how to utilise all functions
6.2 The outputs are easy to understand	agree	Flow /outcomes easy to see eg move out by 1Q	
6.3 The system design is sympathetic to current analysis methods	agree	Can see how this works	
6.4 I have confidence in the system and it's outputs	undecided	Not sure - need to play with numbers in it	Mopre familiarisation is required with user group

User acceptance testing

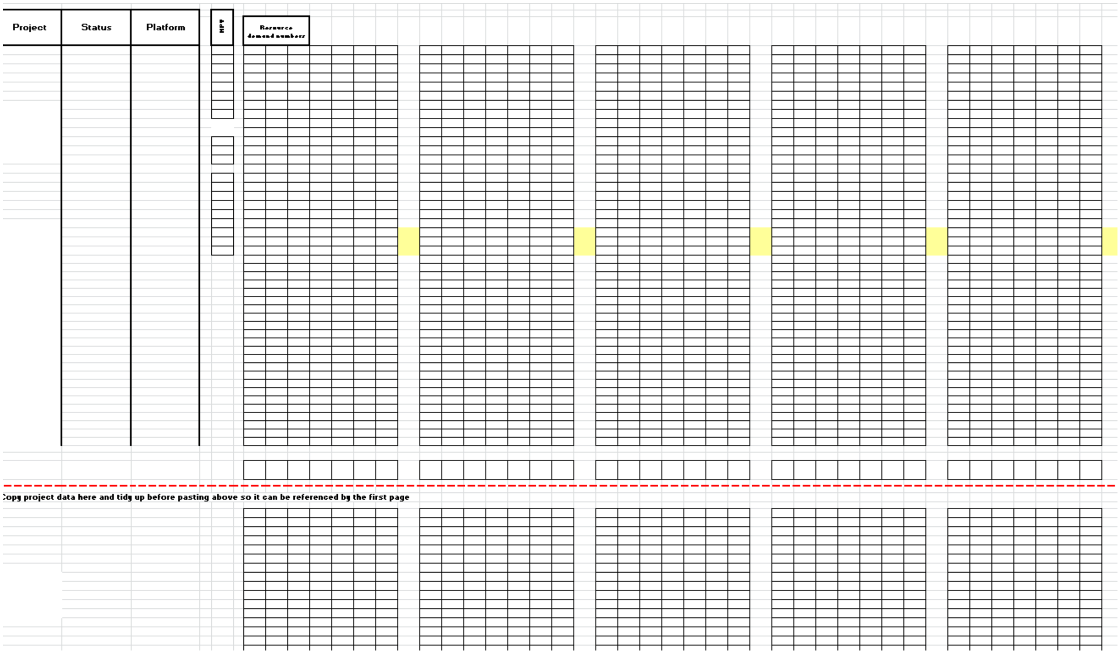
APPENDIX F– Prototype screen shots

This Appendix provides a number of screen shots of the prototype system developed within DePuy Orthopaedics for use in their resource management process.

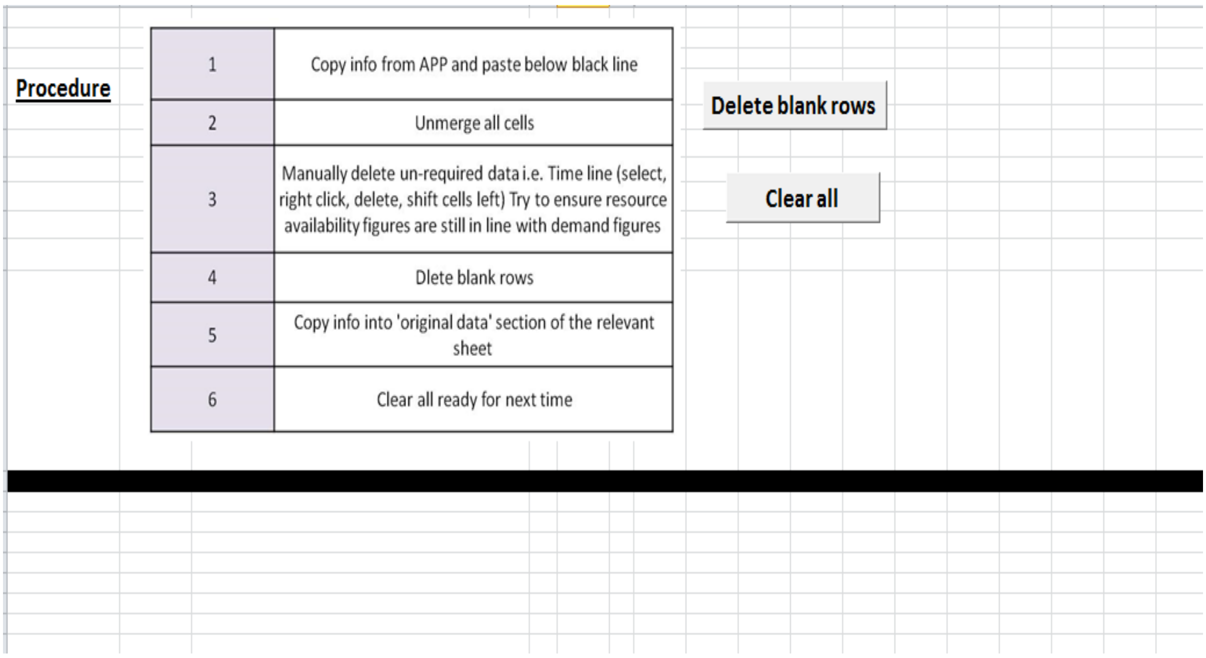
Prototype 1- Hip prototype



Manipulation area and user interface

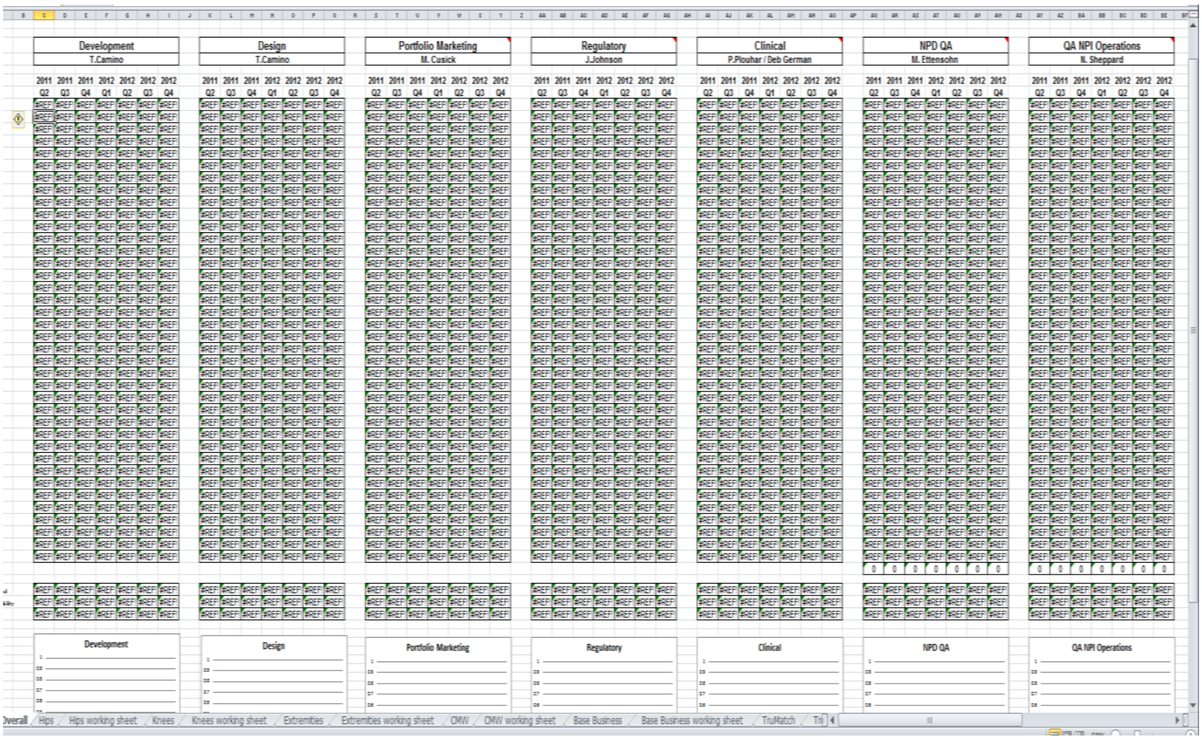


Data working area



Data clean up area and process diagram

Prototype 2 – Multidepartment



Multidepartment roll up

APPENDIX G – Industrial evaluation interviews

This Appendix will provide the interview outcomes from the Expert evaluation interviews carried out within Section 6 of the Thesis. These tables show the scorings assigned and the exact resultants for each section of the evaluation for each interviewee.

Interview 1 – Danny McKendry

	1.Versatility	Strongly disagree 1	Disagree 2	Neutral 3	Agree 4	Strongly agree 5
1.1	Has the ability to be applied to a variety of different problems				4	
1.2	Has the ability to develop a variety of answers				4	
1.3	Has the ability to develop varied systems of different sizes		2			
1.4	Has the ability to develop systems with different usage durations (from short to long term)		2			
1.5	Has the ability to develop systems utilising different IT systems and technologies				4	

Score	Percentage
16	64

	2. Function	Strongly disagree 1	Disagree 2	Neutral 3	Agree 4	Strongly agree 5
	Lifecycle (Does the methodology include the following lifecycle phases found to be required in a development project)					
2.1	Investigation stage				4	
2.2	Requirements stage		2			
2.3	Development stage		2			
2.4	Implementation stage			3		
2.5	Maintenance stage				4	

	Ease of use	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
2.6	Does the methodology posses good explanation and documentation, facilatating ease of use				4	
2.7	Is the methodology easy to learn and understand				4	
2.8	Does the methodology appear to be easy to implement				4	
2.9	Does the methodology appear to be flexible in its use			3		

	Development considerations (Does the methodology manage the interactions of improtant considerations, at the right time and in an appropriate manner)	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
2.1	Business requirements				4	
2.11	Culture (taking into account the interactions which current bussiness culture will have on system development)				4	
2.12	Technology (managing the complex relationship between the current technological state of the business and the required state for potential system solutions)		2			
2.13	Complexity (of both the project and the system developed)				4	
2.14	Uncertainty (of both the uncertainty experienced in the problem space and the use of uncertainty modelling in solution systems)			3		
2.15	Human factors (covers the impact humans have on the system developed as well as how human factors are highlighted in a solution system)			3		

Score	Percentage
50	66.66666667

	3. Productivity	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
		1	2	3	4	5
3.1	Improves productivity of the project using verification and validation				4	
3.2	Improves the development productivity by documenting the process and outcomes accurately and appropriatley			3		
3.3	Improves the development productivity by managing the alignment between systems developed and the business context				4	
3.4	Improves the development productivity by curtailing cost overruns				4	
3.5	Improves the development productivity by curtailing time overruns			3		
3.6	Improves the development productivity by reducing post-implementation problems		2			

Score	Percentage
20	66.66666667

	4. Effectiveness	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
		1	2	3	4	5
	Systems quality					
4.1	Develops reliable systems				4	
4.2	Manages the allignment of the system developed and the business context				4	
4.3	Develops relevant systems which are readily accepted				4	
4.4	Develops relevant systems that are readily adopted			3		
4.5	Develops systems that can be realistically sustained by the business			3		

	User satisfaction					
4.6	Develops systems efficiently				4	
4.7	Promotes the use of the system			3		
4.8	Facilitates good system management				4	
4.9	Ensures the success of the developed system				4	

Score	Percentage
33	73.33333333

Interview 2 - Prof Andrew Daw

	1.Versatility	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
		1	2	3	4	5
1.1	Has the ability to be applied to a variety of different problems				4	
1.2	Has the ability to develop a variety of answers				4	
1.3	Has the ability to develop varied systems of different sizes				4	
1.4	Has the ability to develop systems with different usage durations (from short to long term)				4	
1.5	Has the ability to develop systems utilising different IT systems and technologies				4	

Score	Percentage
20	80

		Strongly disagree	Disagree	Neutral	Agree	Strongly agree
	2. Function	1	2	3	4	5
	Lifecycle (Does the methodology include the following lifecycle phases found to be required in a development project)					
2.1	Investigation stage				4	
2.2	Requirements stage				4	
2.3	Development stage				4	
2.4	Implementation stage				4	
2.5	Maintenance stage			3		

	Ease of use					
2.6	Does the methodology posses good explanation and documentation, facilatating ease of use				4	
2.7	Is the methodology easy to learn and understand				4	
2.8	Does the methodology appear to be easy to implement				4	
2.9	Does the methodology appear to be flexible in its use				4	

	Development considerations (Does the methodology manage the interactions of improtant considerations, at the right time and in an appropriate manner)					
2.1	Business requirements				4	
2.11	Culture (taking into account the interactions which current bussiness culture will have on system development)			3		
2.12	Technology (managing the complex relationship between the current technological state of the business and the required state for potential system solutions)			3		
2.13	Complexity (of both the project and the system developed)		2			
2.14	Uncertainty (of both the uncertainty experienced in the problem space and the use of uncertainty modelling in solution systems)		2			
2.15	Human factors (covers the impact humans have on the system developed as well as how human factors are highlighted in a solution system)			3		

Score	Percentage
52	69.33333333

	3. Productivity	Strongly disagree 1	Disagree 2	Neutral 3	Agree 4	Strongly agree 5
3.1	Improves productivity of the project using verification and validation				4	
3.2	Improves the development productivity by documenting the process and outcomes accurately and appropriatley				4	
3.3	Improves the development productivity by managing the alignment between systems developed and the business context				4	
3.4	Improves the development productivity by curtailing cost overruns		2			
3.5	Improves the development productivity by curtailing time overruns		2			
3.6	Improves the development productivity by reducing post-implementation problems			3		

Score	Percentage
19	63.33333333

	4. Effectiveness	Strongly disagree 1	Disagree 2	Neutral 3	Agree 4	Strongly agree 5
	Systems quality					
4.1	Develops reliable systems			3		
4.2	Manages the allignment of the system developed and the business context				4	
4.3	Develops relevant systems which are readily accepted			3		
4.4	Develops relevant systems that are readily adopted			3		
4.5	Develops systems that can be realistically sustained by the business			3		
	User satisfaction					
4.6	Develops systems efficiently				4	
4.7	Promotes the use of the system			3		
4.8	Facilitates good system management			3		
4.9	Ensures the success of the developed system			3		

Score	Percentage
29	64.44444444