ENHANCING THE QUALITY OF PLANNING OF SOFTWARE DEVELOPMENT PROJECTS

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A thesis submitted for the degree of Doctor of Philosophy of

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STATEMENT OF ORIGINALITY

I certify that the thesis entitled *Enhancing the Quality of Planning of Software Development Projects* submitted for the degree of Doctor of Philosophy of the Australian National University is an original work, which is the result of my own independent intellectual effort. Where reference is made to the work of others, due acknowledgment is given.

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PREFACE

When I was 10 years old, in 1978, my English teacher asked me to leave the classroom. As I was a very active child, I expected to be reprimanded. However, she asked me to answer an interview for the school's magazine, and among other questions, she asked what I would like to be in the future. Without hesitation, I answered that I would like to be an engineer.

Five years later, I was persuaded to study the *vestibular*, a very competitive exam that allows students with higher marks to enter university. One month before the exam, my mother, in a tremendous financial effort, gave me my first computer, which had a Z80 processor and 2 KB of RAM! I was fascinated and stopped studying for the exam in order to start developing computer programs and small electronic devices to modify the new computer. Fortunately, I still achieved good exam marks and entered the electronic engineer and computer science courses at university.

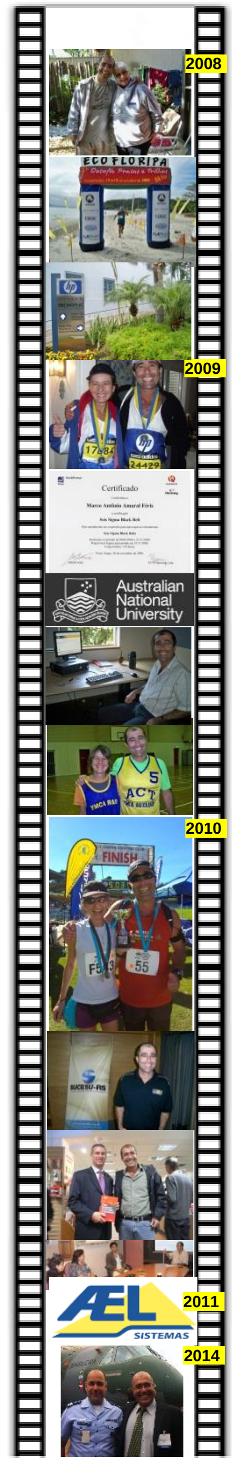
This was a difficult period, practically without free time, but it provided the basis for me to work in large organisations, in different countries, with complex projects for software, hardware and manufacturing.

In 1988, I started working at Altus, an organisation that develops, manufactures, integrates and deploys systems that automate other industries. I had the opportunity to develop and manage several projects there, including systems for the automation of the IBM site, an oil platform and a steel-making house. At the end of the 1990s, I obtained a graduate certification in Business Management at FGV, which is recognised for tradition and quality and is always among those placed first in evaluations by the Brazilian Ministry of Education.

In 2000, I had the opportunity to work in the manufacture of Dell, which involved launching servers, notebooks, desktops, peripherals and software in the Latin American market. Later, I moved to the information and technology (IT) area where, among other projects, I was responsible for the development, testing and support of Dell's online stores for Latin America, which was considered one of the most important projects for Dell in 2006. Moreover, I obtained a Six Sigma Green Belt certification.

In 2009, I then started working at HP as a research and development (R&D) manager, where I was responsible for developing prototype candidates into worldwide products. In addition, I obtained a Six Sigma Black Belt certification.

The year of 2009 was critical, as my wife and I decided to leave a very structured life and a consolidated carrier, so I could undertake a doctorate at one of the most important universities in the world, and supported by one of the most respected academics in the field of project management. This was not an easy decision, as it involved a loss of prestige (from an R&D manager to a student), lack of financial support (we both left good jobs), distance (Australia and Brazil are on the opposite sides in the world) and family (my mother was very sick and passed away when I was far from home). However, we decided to go and face this tremendous challenge. In Australia, I had the opportunity to learn a lot, improve my English skills, teach classes at two universities, define and establish the project management process, and coach other project managers.



For medical reasons, we decided to return home in the second half of 2011, and after I expressed an interest to my former colleagues, I received a job offer to work at AEL to be a program manager responsible for the development of several high-tech avionics and defence systems for the KC-390, the new military aircraft that Embraer is developing. This is what I am doing in parallel with this research. I cannot complain about monotony.

ABSTRACT

As business competition gets tougher, there is much pressure on software development projects to become more productive and efficient. Previous research has shown that quality planning is a key factor in enhancing the success of software development projects. The research method selected for this study was design science research (DSR), and the design science research process (DSRP) model was adopted to conduct the study. This research describes the design and development of the quality of planning (QPLAN) tool and the quality of planning evaluation model (QPEM), which are two innovative artefacts that evaluate the quality of project planning and introduce best planning practices, such as providing references from historical data, suggesting how to manage in an appropriate way and including lessons learnt in the software development process. In particular, the QPEM is based on cognitive maps that represent the project manager's know-how, project manager's characteristics and technological expertise, as well as top management support, enterprise environmental factors and the quality of methods and tools in a form that corresponds closely with humans' perceptions. Data were collected from 66 projects undertaken in 12 organisations from eight types of industries in six countries. The results show that the QPLAN tool has been significantly contributing to enhancing the success rate of projects.

Keywords: Quality, Planning, Software, Development, Project Success, Design Science Research

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GLOSSARY

Term	Description
QPEM	QPEM stands for Quality of Planning Evaluation Model. This model evaluates the quality of planning of software development projects.
QPM	QPM stands for Quality of Planning by Manager. This is a measure from the PMPQ model (Zwikael and Sadeh, 2007, p760). The QPEM model uses it to evaluate the quality of planning through a top–down approach.
QCM	QCM stands for Quality of planning through Cognitive Maps. This is a measure from the QPEM model that evaluates the quality of planning of software development projects from the evaluation of 55 factors, organised in 21 cognitive maps that affect project planning.
QIPlan	QIPlan stands for Planning Quality Index. This index is calculated by QPEM to represent the quality of project planning of software development projects. It is the average of QPM and QCM, and it ranges from 0.0 (lowest) to 1.0 (highest).
QPLAN	QPLAN stands for Quality of PLANning. It is a tool that enhances success rate of software development projects by evaluating the quality of planning of software development projects and by introducing best planning practices regardless of the project management approach adopted by the organisation (Chapter 5).

Chapter 1: Introduction

This chapter lays the groundwork for this thesis. It begins by showing that, despite the significance of computer software for the world economy, project development has had a low success rate for the last two decades. Section 1.2 deals with the main focus of this research, which is the planning of software development projects. Section 1.3 identifies the knowledge gaps in the project management literature, which indicate a lack of effective evaluation models and tools for determining the quality of planning for software development. Section 1.4 outlines the research questions that aim to decrease this gap, while Section 1.5 presents the research objectives that aim to answer the research questions. Section 1.6 outlines the research method adopted to conduct this applied research: design science research (DSR). Section 1.7 outlines the contributions made by this research. The structure of this thesis is presented in Section 1.8, and Section 1.9 concludes the chapter.

1.1 Introduction

The information technology (IT) industry, covering the segments of data centre systems, enterprise software, devices, IT and telecom services, was predicted to spend US$3.8 trillion in 2015, a 2.4 per cent increase from 2014 (Gartner, 2015). IT spending has grown 13.77 per cent in the last five years, and the trend is set to continue this way in the coming years. This constant and positive trend allows business executives to make critical decisions based on the IT industry, refine strategies and prioritise investments.

Software organisations are taking over large slices of the economy from other sectors (Krishnan et al., 2000). For example, Google is the largest direct-marketing platform, and Netflix is the largest video service by number of subscribers (Andreessen, 2011). In the automotive industry, cars have been launched on the market with software to control their engines and safety features, entertain passengers, and guide drivers to their destination. In the oil and gas industry, software has been used for the automation and control of operations that are essential for exploration and refining efforts. The defence industry has planes that do not have human pilots and missiles that achieve their targets guided by software. In some cases, software organisations have become leaders in traditional industries; for instance, Amazon is the world's largest bookseller. More than one decade ago, Borders handed over its online business to Amazon because it thought that online book sales were unimportant (Andreessen, 2011).

Despite the significant influence of software around the world, the low success rate of software development projects has plagued the IT industry for years (Krishnan et al., 2000). In 2000, only 28 per cent of software projects were considered successful; that is, they were completed on time and on budget, and they offered all features and functions as initially specified. However, 23 per cent failed, and of the remaining fraction, costs were higher than original estimates, they were completed behind schedule, or they offered fewer features or functions than originally specified (Glass, 2005). For customers, unsuccessful projects may lead to a lack of productivity or loss of business, and the implications are equally problematic for organisations (Moløkken-Østvold and Jørgensen, 2005). In 2013, the results were slightly better, but the success rate was still low; only 39 per cent of projects were completed successfully (Obeidat and North, 2014), leading to estimated annual losses for the United States (US) and European Union (EU) markets of around US$100 billion each (Symons, 2010).

1.2 Planning for Enhancing Project Success

As business competition gets tougher, there is much pressure on software development projects to become more productive and efficient. Many factors affect the success rate of software development projects, including high level of complexity (Wohlin and Andrews, 2005), level of project management knowledge, project manager's characteristics and level of technical expertise, level of top management support, effective communication, enterprise environment factors, and quality of methods and tools used (Bechor et al., 2010). To complicate matters further, it is usually not obvious how these factors interact (Obiajunwa, 2012; Wohlin and Andrews, 2001).

To overcome these difficulties, researchers have aimed to enhance the success rate of projects. Many researchers have focused in the planning, which is a critical phase of software development projects (Sudhakar, 2012; Conforto and Amaral, 2010; Gornik, 2007). Among other advantages, the planning allows one to obtain a better understanding of project requirements (Goldstein et al., 2010; Gornik, 2007) and business context (Flynn and Arce, 1997), reduce the inherent uncertainty of the project at this stage and provide a basis for the next project phase (Zwikael, 2009b).

The planning involves the establishment of a more formalised set of plans to accomplish the project’s goals (Shepperd and Cartwright, 2001), including an estimation of time, resources and costs, and identification of the critical path (Dawson and Owens, 2008; Dvir and Lechler, 2004), risks (Tesch et al., 2007) and alternative solutions (Alblas and Wortmann, 2012; Bannerman, 2008). This is the phase before the funder makes the major investment, and costs of changes are typically low. However, in this phase, the level of uncertainty regarding planning is at its peak (Howell et al., 2010; Bakker et al., 2010), it is difficult to set realistic limits and goals for projects because of limits set by the available information (Bakker et al., 2010), risks are usually under-analysed and under-managed (Bannerman, 2008; Willcocks and Griffiths, 1994), and when attempting to understand the business context, there can be a lack of awareness of the major relationships between business objectives and project´s goals (Flynn and Arce, 1997). Planning is characterised by the opportunities and risks that may lead to the project’s success or failure; for instance, definition of requirements (Gornik, 2007), estimations of time and cost (Dvir and Lechler, 2004; Napier et al., 2009), and identification (Tesch et al., 2007) and mitigation of the project’s risks (Gornik, 2007).

This work follows the research stream that focuses in the planning for enhancing the success rate of projects. It aims to better understand the effect of planning on software development projects in order to identify opportunities to enhance the quality of project planning and thereby increase the success rate of projects.

1.3 Knowledge Gaps

Given that quality of planning has a demonstrated causal relationship with project success (Zwikael and Globerson, 2004), the project management literature and the software industry offer a myriad of models, methods and tools for evaluating the quality of project planning. Significant examples are the project management planning quality (PMPQ) model (Zwikael and Globerson, 2004); checklists are used for measuring phase completion and readiness (e.g., planning phase exit milestone), guiding reviews (e.g. error prevention), and ensuring adherence to procedures (e.g. quality assurance of software engineering) (Houston, 2004); metrics are considered a vital part of the software industry because of their contribution to improved quality and productivity through the efficient use of the feedback mechanism, based on rationale that one cannot improve something without first measuring it (Gopal et al., 2002); and tools, such as SEER-SEM, a planning tool for software projects (Lagerström et al., 2012).

However, many of these tools have limitations. The PMPQ model was not designed specifically for software development projects, and it does not evaluate specific factors that affect planning processes, such as level of experience of the organisation with similar projects (Dvir and Lechler, 2004; Willcocks and Griffiths, 1994), staff turnover rate (Wohlin and Andrews, 2001) and whether there are sufficient resources allocated to the project (Fortune and White, 2006). In addition, the PMPQ model does not consider the relationships among these factors, which are significantly correlated with the success rate of projects (Ling et al., 2009).

Checklists depend on expert knowledge of a process to be effective (Houston, 2004). Most metrics used in the software industry are based only on quantitative data, although others factors must be considered in the planning evaluation, such as pressure from marketing to deliver the product in the shortest timeframe (even with lower quality). The SEER-SEM planning tool focuses on the efficiency of the development process to deliver the project's output, and not on the perceived benefits of the project for customers.

This leads to the need for the development of a new approach for evaluating the quality of planning of software development projects. That is, there is a knowledge gap in both the project management literature and the software industry with respect to a lack of effective quality of planning evaluation models and tools for software development projects.

1.4 Research Questions

Motivated by the significance of the software industry around the world and the low success rate of software development projects, the following primary research questions have been formulated to guide this research:

> *RQ1: Does improvement in the quality of planning of software development projects enhance project success rate of these projects?*

> *RQ2: How can the quality of planning of software development projects be better evaluated and improved?*

1.5 Research Objectives

To answer these two research questions, this research has three main objectives, which aim to contribute to the project management literature and the software industry:

1. examine the effect of quality of planning on the success rate of projects in various types of software projects, organisations, industries and countries
2. develop a model that evaluates the quality of project planning of software development projects
3. develop a tool that enhances the success rate of projects by evaluating the quality of planning of software development projects and introducing best practices in the software development planning process.

1.6 Research Method

To address these questions, this research first examines the project management literature that deals with planning of software development projects in order to understand how to gain advantages from planning genuine uncertainty. Second, DSR was selected as the research method, as this research is applied research that aims to solve a real problem (Hevner et al., 2004) in the field of information systems (Baskerville, 2008). The DSRP model, which was developed by Peffers et al. (2006), was used in this study for the development of the model and the tool. This model is consistent with design science processes in prior literature (e.g., Nunamaker et al., 1991; Walls et al., 1992; Hevner et al., 2004); it provides a process for conducting

DSR and a mental model for the research output. The DSRP model has six steps, which are listed below, along with descriptions of how they were applied in this research (see Chapter 3 for more details).

1. Problem identification and motivation: Section 1.1 shows that the software industry is significant for the world economy; however, the low success rate of software development projects has plagued the industry in the last two decades. Section 1.2 shows that, despite researchers' continuous efforts in relation to planning, results have not been effective over time. The proposal of this thesis is to continue focusing on planning, but to aim at improving the understanding of the effect of planning on software development projects in order to identify opportunities that may lead to an increased success rate.
2. Objectives of a solution: Section 1.5 shows that this research aims to: examine the influence of the quality of planning on the success rate of projects; develop QPEM, which is a model that evaluates the quality of project planning of software development projects; and develop the QPLAN tool, which increases the success rate of projects by evaluating the quality of planning and introducing best practices in the software development planning process.
3. Design and development: Chapter 4 describes the design and development of the QPEM model, which is based on a hierarchical structure of cognitive maps for evaluating the quality of planning. Chapter 5 describes the architecture, implementation and features of the QPLAN tool, which is based on evaluating quality of planning through top–down and bottom–up approaches (Jørgensen, 2004), contrasting both evaluation approaches to

identify strengths and weaknesses of planning (Sedoglavich, 2008), identifying project characteristics for defining proper planning (Shenhar and Dvir, 2007) and implementing a mechanism for planning process improvement (Iversen et al., 2004).

4. Demonstration: Chapter 6 demonstrates the utility of the QPLAN tool in 12 organisations in six countries.
5. Evaluation: Chapter 6 tests and evaluates the QPEM and QPLAN tools using a variety of quantitative and qualitative methods. Statistical analysis will be used for testing hypotheses.
6. Communication: Section 3.4.5 describes the communication of this research to academics and practitioners.

1.7 Research Contributions

The findings of this study have several implications for the literature and the industry. The QPEM is an innovative artefact developed to evaluate the quality of planning of software development projects according to the research objectives (Section 1.5). It aims to fill the gap in the project management literature regarding a lack of effective quality of planning evaluation models for software development projects (Section 1.3). QPEM's architecture design integrates the following concepts and knowledge from the project management and computer science literature: the use of two measures with top–down and bottom–up approaches for enhancing the accuracy of planning (Jørgensen, 2004), the PMPQ model (Zwikael and Globerson, 2004), a broad range of relevant planning factors that affect the success rate of projects

(Appendix B), and the use of cognitive maps for mapping the relations between them. The combination of these concepts and knowledge creates a novel approach for quality planning evaluation and extends the PMPQ model.

QPLAN is an innovative artefact developed to increase the success rate of software projects according to the research objectives (Section 1.5). It aims to fill the gap in the software industry of effective quality planning evaluation tools for software development projects (Section 1.3). QPLAN's architecture design integrates the following concepts and knowledge from the project management, computer science and international business literature: identifying critical success processes (Zwikael and Globerson, 2006) at the project level and identifying critical success factors (Pinto and Slevin, 1987; Fortune and White, 2006; Mendoza et al., 2007) at the organisation level. They create a novel approach for quality planning evaluation when combined. In addition, QPLAN introduces the following best practices into the software development planning process, regardless of the project management approach adopted by the organisation: identifying a project's characteristics in order to define proper planning (Shenhar and Dvir, 2007) and implementing a mechanism for planning process improvement (Iversen et al., 2004), which comprises a lessons-learnt process and a knowledge base for registering the past experiences of the organisation.

1.8 Structure of the Thesis

The subsequent parts of the thesis are organised according to the DSR publication schema proposed by Gregor and Hevner (2013). An overview of each chapter is presented below.

Chapter 2 reviews the relevant literature related to project success and planning, focusing on software projects.

Chapter 3 outlines DSR as the research method adopted in this thesis, as well as the process model (Peffers et al., 2006) selected to conducting the research.

Chapter 4 describes the development of the QPEM, which evaluates the quality of planning of software development projects and fills the gaps found in the project management literature.

Chapter 5 describes the development of the QPLAN tool for the software industry. This tool evaluates the quality of planning and introduces best practices in the software development planning process.

Chapter 6 evaluates QPLAN in terms of functionality, completeness, accuracy, reliability, usability and fit with the organisation's needs.

Chapter 7 concludes by revisiting the research questions, outlining the contributions and limitations of this research, and proposing some directions for future research.

1.9 Chapter Summary

The objective of this chapter was to introduce the thesis and the need for the research work. It started by explaining that, despite the significant effect of software on the world's economy, the low success rate of software project development has plagued the IT industry for many years.

The introduction was followed by the proposed solution for reversing this situation—that is, a focus on planning, which is a critical phase of software development projects (Pinto and Slevin, 1988; Johnson et al., 2001; Belout and Gauvreau, 2004; Zwikael and Globerson, 2004) to identify opportunities that may lead to an increase in the success rate of projects.

The chapter then identified gaps in the current knowledge and the lack of effective quality of planning evaluation models and tools for software development projects.

Likewise, two research questions were raised. The first research question aims to test whether the enhancement in the quality of planning of software development projects enhance success rate of these projects. The second research question assumes that this statement is true, and it aims to identify how the effectiveness of the quality of planning of software development projects can be better evaluated and improved.

To answer these questions, the effect of quality of planning on the success rate of projects must be examined for various types of software projects, organisations, industries and countries. Further, a model must be developed that evaluates the quality of project planning of software development projects, and a tool must be developed that enhances the success rate of software development projects.

Next, DSR was presented as a research method, and the DSRP model was identified for use in conducting the research.

The two research contributions were then outlined: a model that evaluates the quality of planning of software development projects (QPEM), and a tool that enhances the success rate of projects by evaluating the quality of planning and introducing best practices into the software development planning process (QPLAN).

Finally, the layout of the thesis was presented. This chapter provides the basis for the detailed description of the research that follows.

Chapter 2: Literature Review and Theory Development

2.1 Introduction

The previous chapter showed that, despite the significant effect of software on the world's economy, the low success rate of software development has plagued the IT industry for many years. Guided by the two research questions (Section 1.4), this chapter reviews the relevant literature related to project success and planning, from an investigation of 87 articles published in 43 project management, general management and computer science leading journals between 1969 and 2015. Section 2.2 describes the evolution of the project success concept over time and the different points of view of success. It concludes with a recent and more elaborate concept. Section 2.3 presents the characteristics of project planning and how project management approaches deal with it. Section 2.4 discusses the effectiveness of planning on project success and presents a research model and set of hypotheses for testing the effectiveness of quality of planning on project success. Section 2.5 concludes this chapter.

2.2 Project Success

2.2.1 Introduction

Researchers have studied how to successfully manage software projects (Jørgensen and Moløkken-Østvold, 2006) in an industry that is far from slowing down (Shenhar and Dvir, 2007). Researchers tend to see a crisis regarding software development and conclude that their research will improve the success rate of projects (Eveleens and Verhoef, 2010; Glass, 2005). Among others, Krishnan et al. (2000) claimed that the low success rate of software development projects has plagued the IT industry for many years. Moløkken-Østvold and Jørgensen (2005) stated that software development projects have a bad reputation for exceeding their original estimates. Although these findings have been questioned by Eveleens and Verhoef (2010) and Glass (2005, 2006), the fact is that the project success rate is low (Culmsee and Awati, 2012). Symons (2010) found that the estimated annual losses for the US and EU markets were around US$100 billion for each market. This work aims to increase the success rate of these projects.

For theorists, the definition of project success is ambiguous (Rai et al., 2002). For example, a software project where the customer is satisfied with the software's functionalities and performance, but that misses the project's budget or schedule goals by 10 per cent, may not be a successful project. The customer will say that it is a successful project, but the financial manager from the organisation that developed the software may say that it is a failure (Glass, 2005; Schaupp et al., 2009).

The concept of project success has changed over the years. In the mid-1950s, the IT industry was based on centralised mainframe computers that were expensive to buy and costly to operate. At that time, a market for data-processing services was created to supply organisations that did not want to spend large amounts of money (Campbell-Kelly and Garcia-Swartz, 2007), and success depended on the technical quality of the system (Petter et al., 2012). In the mid-1960s, as hardware costs dropped, organisations started buying computers with software to run applications to meet their needs and after-sales services. In the late 1970s, with the advent of low-powered and independent personal computers, the mass-market industry was established, and hardware and software were sold in high volumes at low prices (Campbell-Kelly and Garcia-Swartz, 2007). At this time, success meant producing systems that could contribute to decision-making criteria and reduce costs (Petter et al., 2012). From 1980 to 1990, success was reducing the development life cycle, enhancing the system's performance and obtaining user satisfaction with the systems and quality of the information provided. From 1990 to 2000, success involved the strategic value of IT, team performance, project quality and service quality (Petter et al., 2012). The Internet now connects all types of hardware and software, the industry is internationalised and there are endless opportunities for new businesses that have increased software development to an unprecedented degree (Campbell-Kelly and Garcia-Swartz, 2007). Compared to other eras, the success criteria are broader, and they consider effects on society (Petter et al., 2012).

This section will review the evolution of views and definitions for judging project success accompanying the evolution of the IT industry over time (Petter et al., 2012).

2.2.2 Measuring the Development Performance of a Software Project

The traditional definition of project success was made four decades ago, when Avots (1969, p.78) suggested implicitly that project success is determined based on scope/quality, time and cost: ‘some of the more obvious indications (of project failure) are high costs or schedule overruns, poor-quality products, or, as in the case of sophisticated systems, failure to meet project objectives’. That is, project success is defined as delivering the project on time, within budget and according to specifications. These three success dimensions are also known as the Iron (or Golden) Triangle (Atkinson, 1999; Toor and Ogunlana, 2010; Zwikael and Smyrk, 2011).

Since Avots’ (1969) original work, researchers have proposed improvements to this definition. Among others, Symons (2010) suggested adding two more dimensions as success criteria: measuring the productivity of software development projects (ratio of software size to effort) and measuring the speed of delivery (ratio of software size to duration). Zwikael and Smyrk (2011) proposed replacing the Iron Triangle with the Steel Tetrahedron, which has an additional dimension for assessing the unplanned effects that the project may produce, such as the degraded performance of a system after a new software release is launched.

The Iron Triangle has also been criticised by other researchers. Dvir and Lechler (2004) argued that it does not investigate the effect of success on project performance during its lifecycle. Scott-Young and Samson (2008) claimed that it ignores important outcomes such as client satisfaction, longer-term business success and the preparation of the organisation for the future. Bakker et al. (2010) stated that this definition does not fit the context of software projects very well because requirements change during the project lifecycle, thereby influencing time and cost plans. Consequently, it is almost impossible to provide adequate estimations (Bakker et al., 2010).

2.2.3 Project Management Success and Project Ownership Success

The evolution of the concept of project success over time has demonstrated the need for new dimensions for testing the benefits that the project aims to provide. This leads to a distinction between two success concepts. According to Zwikael and Smyrk (2011):

- Project management success is for testing the efficiency of the development process to deliver the project’s outputs. The Iron Triangle can be applicable.
- Project ownership success is for testing the project’s outcomes—that is, the perceived benefits of the project for customers, the organisation and society (discussed further below).

2.2.4 Measuring the Benefits of the Software Product Developed

The view of success for measuring the benefits provided by the project has accompanied the evolution of the IT industry over the years (Petter et al., 2012). Pinto and Slevin (1988) included the effect on the customer as a success dimension—that is, assessment of the usefulness of the project, level of satisfaction and effectiveness for the intend users. Pinto and Mantel (1990) used the same concept in other research.

In the software industry, Atkinson (1999), Wohlin and Andrews (2001) considered long-term properties, such as maintainability and evolvability factors, as additional success dimensions. For Bradley (2008), project success was related to organisational effects and deliverables on time and budget. However, Schaupp et al. (2009) stated that it is not possible to define a common list of factors to assess project success for website development, as the factors vary across website types.

Shenhar and Dvir (along with other authors) published a series of studies in this area. In 1998, they refined the definition made by Pinto and Slevin (1988) and added new factors for assessing the effects on the customer, such as social and environmental effects, personal development, professional learning and economic effects (Dvir et al., 1998). In 2001, they included two more dimensions for assessing the benefits for the organisation and the benefits that the project will bring for the future of the organisation, such as marketing opportunities and the creation of new technological and operational infrastructures (Shenhar and Dvir, 2007).

In the information systems (ISs) field, a significant research stream is the work of the DeLone and McLean, who developed a model for measuring success in ISs in 1992 (Petter et al., 2012). Named the D&M IS Success Model, it is dependent on the organisational context (DeLone and McLean, 2003) and aims to synthesise different measures of effectiveness. The model has six interdependent dimensions of IS success:

1. system quality: desirable features (e.g., flexibility, reliability and response time)
2. information quality: desirable characteristics (e.g., relevance, understandability, accuracy and usability)
3. system use: degree and manner in which staff and customers utilise the capabilities of the system
4. user satisfaction: level of satisfaction with the outcomes provided by the system (Petter et al., 2008)
5. effects of the system on individuals
6. effects of the system on the organisation (Petter et al., 2008).

The model was updated in 2003 to support systems developed for e-commerce and address feedback received since its launch (DeLone and McLean, 2003). First, a new success dimension was added to the model—service quality—for measuring factors such as responsiveness, accuracy, reliability, technical competence and empathy of the personnel staff (Pitt et al., 1995). Second, individual impacts and organisation impacts were collapsed into net benefits, which measure the extent to which ISs are contributing to stakeholders' success, such as improved productivity, increased sales, cost reductions, improved profits and job creation (DeLone and McLean, 2003).

Later, Lechler and Dvir (2010) published a more detailed view of project success with four distinct success dimensions. Each one is utilised extensively in the literature:

1. efficiency, for measuring the extent to which time and cost plans have been met (Scott-Young and Samson, 2008; Malach-Pines et al., 2008; Zwikael and Sadeh, 2007; Dvir and Lechler, 2004; Dvir et al., 2003)
2. effectiveness, for measuring the extent of benefits that the project brought to its client (Malach-Pines et al., 2008; Scott-Young and Samson, 2008; Zwikael and Sadeh, 2007; Dvir et al., 2003; Shenhar and Dvir, 2007)
3. customer satisfaction, for measuring the extent of satisfaction with the benefits provided by the project and how it was conducted (Malach-Pines et al., 2008; Scott-Young and Samson, 2008; Zwikael and Sadeh, 2007; Dvir et al., 2003; Shenhar and Dvir, 2007; Atkinson, 1999)
4. business results, for measuring the perceived value of the project (Malach-Pines et al., 2008; Dvir et al., 2003; Shenhar and Dvir, 2007; Atkinson, 1999).

2.2.5 Conclusion

This section reviewed the literature regarding project success. From the traditional project success criteria defined four decades ago until the present day, it showed the evolution of the success concept over time and across different points of view of success. It started by presenting the definition of traditional project success. The success concept was then refined in two different ways: project management success, for measuring the efficiency of the development process, and project ownership success, for measuring the benefits that the project provides to stakeholders. This section concluded by presenting a recent and more detailed concept of project success.

2.3 Project Planning

2.3.1 Introduction

Some practitioners and organisations consider that all projects are similar, and they suggest that success can be achieved by well-defined methods and a common set of tools and techniques for planning and managing their activities. This misconception has contributed to the low success rate of projects (Krishnan et al., 2000).

Software projects have certain characteristics that increase their chance of failure, such as the rapid pace of technological progress, numerous and continuous interactions, pressure from marketing to deliver the product in the shortest timeframe (even with lower quality) and high degree of novelty (Rodriguez-Repiso, et al., 2007b), and the diversity of projects is continuing to grow (Howell et al., 2010).

Given this context, is it possible to claim that a particular project management framework is the most suitable approach for all types of projects? Different project management approaches should be associated with different types of projects (Shenhar et al., 2005) in order to increase the likelihood of achieving success.

This section deals with project planning, which is a critical success factor for software development projects (Pinto and Slevin, 1988). It starts by presenting project planning characteristics that have opportunities and risks that may lead to project success. This is followed by a description of several project management approaches that can deal with planning, as an improper managerial approach may be considered one cause (Zwikael and Bar-Yoseph, 2004) of disappointing results in the software industry (Krishnan et al., 2000). Finally, based on rationale that one cannot improve something without first measuring it (Gopal et al., 2002), this section presents three methods for evaluating the quality of planning in software development projects.

2.3.2 Project Planning Characteristics

Planning is the first step under the responsibility of project managers (PMI, 2013). It aims to ensure that the problem domain, architecture solution, requirements analyses and project plans are mature enough for conducting the project through the next phases and achieving the desired goals (Gornik, 2007).

This is the project phase before the funder makes the major investment. Here, the level of effort steadily increases, the level of uncertainty remains high but tends to decrease towards the end of the phase, and the costs of changes are typically low, but costs that influence the final characteristics of the project's product begin to rise (see Figure 2.1).

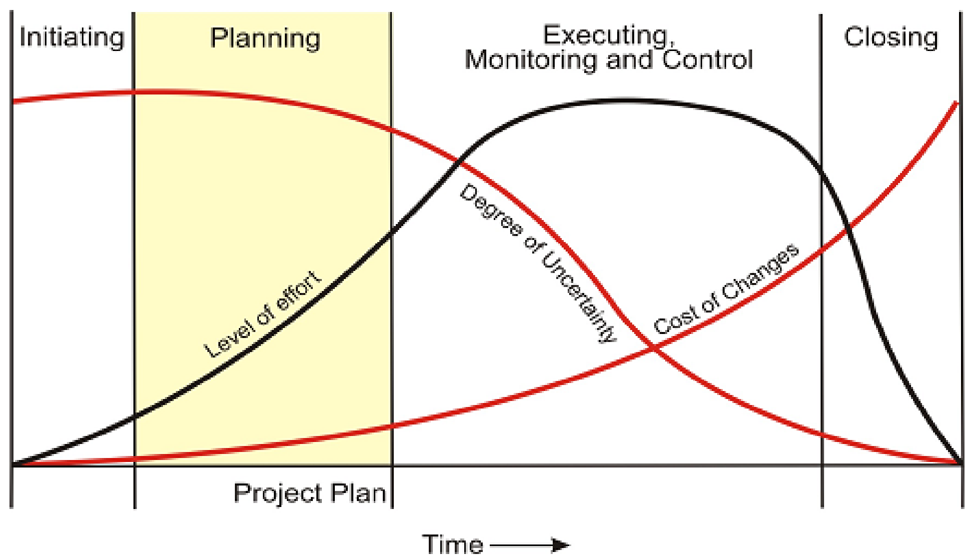

Figure 2.1: Typical project lifecycle
(adapted from PMI, 2013)

During planning, the project management plan (PMP) should be developed by the project manager (Zwikael and Sadeh, 2007; Shepperd and Cartwright, 2001) in order to deal with requirements (Gornik, 2007), time and cost estimations, identification of the critical path (Dvir and Lechler, 2004), alternative solutions

(Alblas and Wortmann, 2012; Bannerman, 2008), and risks (Tesch et al., 2007) and their mitigation (Gornik, 2007).

This is not an easy task. In the planning, a project's uncertainty peaks (Howell et al., 2010; Bakker et al., 2010). It is difficult to set realistic limits and goals because of limited available information (Bakker et al., 2010). Risks are usually under-analysed and under-managed (Willcocks and Griffiths, 1994). When attempting to understand the business context, there is a lack of awareness of the major relationships between goals and aims to sustain the desired outcomes (Flynn and Arce, 1997). Issues are even more severe when some might conclude that planning is not necessarily helpful or even desirable (Dvir et al., 2003). In summary, project planning is characterised by having opportunities and risks that may lead to project success.

2.3.3 Project Management Approaches to Planning

2.3.3.1 Introduction

Project management principles such as managing the project scope, schedule and risks have been promoted for years in books, academic articles, training materials and professional certifications, among other initiatives (Nicholas and Hidding, 2010). Initially, these principles were conceived as the development of a project management plan aimed at achieving pre-determined goals within a specified timeline, which inevitably led to trade-offs between time, cost and quality.

Project management now deals with projects as sets of practices aimed at providing better products to customers through integration considering organisational practices and being effective in terms of resource utilisation (Parast, 2011). Nevertheless, despite continuous efforts, results have not been effective over time (Bakker et al., 2010). These disappointing results call for the need to enhance project management approaches (Zwikael and Bar-Yoseph, 2004; Howell et al., 2010), which are usually variations of the traditional project management approach promulgated by the Project Management Body of Knowledge (PMBOK) (Nicholas and Hidding, 2010).

This section presents several project management approaches and how they deal with planning: the sequential Stage-Gate model, Critical Chain Project Management (CCPM), which is based on the Theory of Constraints (TOC); Agile, which is widely accepted in the IT field (Howell et al., 2010); and Microsoft Solution Framework (MSF), IBM Rational Unified Process (RUP) and Projects IN Controlled Environments version 2 (PRINCE2), from two significant players in the software industry.

2.3.3.2 Stage-Gate Model

Created by Robert Cooper, Stage-Gate is a sequential development process that aims to promote result-oriented thinking by introducing five stages for managing activities, budgets and resources over time, and five gates with acceptance criteria for moving from one phase to the next.

In Stage 2—Build Business Case (planning), the project manager is responsible for analysing the project technically and developing the PMP, which is an input for Gate 3—Go to Development (Cooper et al., 2002).

2.3.3.3 Critical Chain Project Management (CCPM)

Created by Eliyahu Goldratt (Goldratt, 1997), CCPM is based on his TOC. It aims to modify common behaviours of team members by including buffers on the duration of tasks to be safety, which usually leads to delivering fewer features than expected and missing project deadlines (Pinto, 2002). CCPM is focused on the planning and executing phases.

In the planning, CCPM identifies the critical chain, halves the estimations for reducing the embedded safety and creates three types of buffers to accommodate the effects of variation and uncertainty inherent in any type of project: project buffers, to absorb any delays in the longest chain of dependant tasks; feeding buffers, to avoid delays of a subsequent task on the critical chain; and resource buffers, to work on the tasks as planned.

2.3.3.4 Agile

Published by the Agile Alliance in 2001 (Fowler and Highsmith, 2001), Agile is a flexible methodology (Howell et al., 2010) that focuses on the individual rather than processes in order to promote an iterative and incremental way of thinking to address unavoidable changes (Noor et al., 2008).

The planning is made by sprints rather than project phases, and it tends to be tailored by practitioners for their specific needs. For example, Intel Shannon uses two planning stages—one at the start of the project and one at the start of each sprint—with milestones aligned with sprint completions (Fitzgerald et al., 2006).

2.3.3.5 Microsoft Solution Framework (MSF)

Created by Microsoft in 1994, MSF is a milestone-driven approach (Jenkin and Chan, 2010) for the entire project development lifecycle (Microsoft, 2005). It aims to be a flexible approach to accommodate different types and sizes of projects (Microsoft, 2005) through five phases: initiation, planning, developing, stabilising and deploying.

In the planning, the project manager is responsible for planning and designing a solution to meet the project’s needs and expectations, and for delivering the PMP that serves as an input for the stakeholders to decide whether the project should go to the next phase (Jenkin and Chan, 2010).

2.3.3.6 IBM Rational Unified Process (RUP)

The IBM RUP is a development process aimed at ensuring the development of high-quality software that meets the customer's needs within a predictable schedule and budget. RUP has guidelines, templates and tools (Karlsson and Wistrand, 2006) for developing software iteratively, managing requirements, verifying quality, controlling changes and visually modelling the structure and behaviour of architectures and components (Gornik, 2007). RUP has four project phases: inception, elaboration, construction and transition (Dahanayake et al., 2003).

In the elaboration phase (planning), the project manager analyses the problem domain, establishes the software architecture and develops the PMP that serves as an input for the stakeholders to decide whether the project should go to the next phase (Jenkin and Chan, 2010).

2.3.3.7 Projects IN Controlled Environments version 2 (PRINCE2)

Developed by the UK government agency Office of Government Commerce (OGC), PRINCE2 is used widely in both the private and public sectors (Karamitsos et al., 2010). It is a process-oriented framework designed to accommodate different types and sizes of projects through four key elements (Kruger and Rudman, 2013):

1. Seven principles, to determine who should do what, when and why: continued business justification, learn from experience, defined roles and responsibilities, manage by stages, manage by exception, focus on products and tailored to suit the project environment (Tomanek et al., 2014; Kruger and Rudman, 2013; Karamitsos et al., 2010).
2. Seven processes, to define how the jobs get done: starting up a project, directing a project, initiating a project, controlling a stage, managing product, delivery, managing a stage boundary and closing a project (Tomanek et al., 2014; Kruger and Rudman, 2013; Karamitsos et al., 2010).
3. Seven themes, which must be addressed continually throughout the project: business case, organisation, quality, risk, plans, change and progress (Tomanek et al., 2014; Kruger and Rudman, 2013; Karamitsos et al., 2010).
4. Project Environment, the need to tailor PRINCE2 to a specific context (Kruger and Rudman, 2013).

The planning in PRINCE2 is made through the principle *manage by stages*, the themes *plans* and *risk* and the processes *initiating a project*, *managing a stage boundary*, and *starting up a project*. In the planning, the project manager updates the business plan and prepares the project plan with the strategies for managing risks, quality, configuration and communication (Tomanek et al., 2014).

2.3.3.8 Conclusion

The section explored several project management approaches that deal with planning in different ways. Stage-Gate is a sequential approach, while Agile is iterative and MSF and RUP are a mix of both. In terms of best practices, CCPM aims to modify common behaviours of team members by including buffers on tasks duration as a safety time. RUP provides more tools and templates related to the development process, PRINCE2 can be tailored to a specific context, whereas MSF deals with fewer details in a more general way (Santos, 2007). This discussion served for helping project managers to select a proper managerial approach for planning (Zwikael and Bar-Yoseph, 2004), which should be according to the project's characteristics (Shenhar and Dvir, 2007).

2.3.4 Evaluating the Quality of Planning

2.3.4.1 Introduction

This section presents three methods used to evaluate the quality of planning in software development projects based on rationale that one cannot improve something without first measuring it (Gopal et al., 2002). The three methods are the PMPQ model, found in the project management literature, and checklists and metrics, which are widely used by quality management and process improvement systems.

2.3.4.2 PMPQ Model

Zwikael and Globerson (2004) developed the PMPQ model to evaluate the quality of project planning through the evaluation of planning products. The model has been validated and utilised extensively in the literature (e.g., Zwikael and Globerson, 2004, 2006; Masters and Frazier, 2007; Zwikael and Sadeh, 2007; Papke-Shields et al., 2010; Zwikael and Ahn, 2011; Barry and Uys, 2011; Rees-Caldwell and Pennington, 2013; Zwikael et al., 2014).

The overall project planning quality indicator in the model, called the PMPQ index, consists of two subindices: quality of planning by organisation (QPO), which evaluates the organisational support processes, and quality of planning by manager (QPM), which evaluates the project's know-how processes. QPO represents the means that the organisation places at the disposal of the project manager to enable proper project planning, execution and completion. It is a weighted linear combination of the 17 organisational support-related variables related to organisation systems, cultures, styles, structure and project office (Zwikael and Sadeh, 2007).

QPM represents the project manager's know-how—that is, processes for which a project manager is responsible directly or indirectly. This index is measured in an established 16-item scale through a weighted linear combination of the quality of 16 planning products from 16 core planning processes defined in the PMBOK (PMI, 2013).

Table 2.1 shows the 16 core planning processes used by the PMPQ model (Zwikael and Globerson, 2004), organised into nine project management knowledge areas defined by PMBOK (PMI, 2013).

Table 2.1: Sixteen planning processes used by the PMPQ model

Knowledge Areas	Planning Process	Description
Integration	Develop project management plan	Documents actions necessary to define, prepare, integrate and coordinate all subsidiary plans
Scope	Define scope	Development of a detailed description of the project and product
	Create work breakdown structure	Subdivide project deliverables and project work into smaller, more manageable components
Time	Define activities	Identify specific actions to be performed to produce the project deliverables
	Sequence activities	Identify and document relationships among activities
	Estimate activity resources	Estimate type/quantities of material/people/equipment/ supplies required to perform each activity
	Estimate activity durations	Approximate the number of work periods needed to complete each activity
	Develop schedule	Analyse activity sequences, durations, requirements and constraints to create the schedule
Cost	Estimate costs	Develop an approximation of the monetary resources needed to complete project activities
	Determine budget	Aggregate the estimated costs of individual activities to establish an authorised cost baseline
Quality	Plan quality	Identify quality requirements and documenting how the project will demonstrate compliance
Human resources	Develop human resource plan	Identify and document roles, responsibilities and required skills, and report relationships
	Acquire project team	Confirm human resources (HR) availability and obtaining the team necessary to complete project assignments
Communications	Plan communications	Determine project stakeholder information needs and define a communication approach
Risk	Plan risk management	Define how to conduct risk management activities for a project
Procurement	Plan procurements	Document project purchasing decisions and the approach, and identify potential sellers

2.3.4.3 Checklists

Other approaches to assess the quality of planning include checklists. Based on expert knowledge of a process (Houston, 2004), checklists are used for measuring phase completion and readiness (e.g., planning phase exit milestone), guiding reviews (e.g. error prevention), and ensuring adherence to procedures (e.g. quality assurance of software engineering). Checklists are extensively used in organisations that had adopted: the capability maturity model integration (CMMI) model (Barbour, 2001); Six Sigma, which is considered a complementary approach for CMMI because of its characteristic of continuous process improvement (Mahanti and Jiju, 2009); and ISO/IEC standards (Barbour, 2001) dedicated to software, such as ISO/IEC 15939, which defines a measurement process applicable to system and software engineering and management disciplines, and the SQuaRE model, for covering software quality requirements specifications and software quality evaluations.

Checklists provide guidance on crucial questions that need to be asked and a systematic approach to the various stages involved in research design and analysis. Checklists are perhaps the simplest and most productive quality analysis tools. However, the quality of a checklist depends on how it is produced (Houston, 2004). Excessive and uncritical use can be counterproductive (Barbour, 2001).

For software development projects, checklists are used for measuring phase completion and readiness, guiding reviews, and ensuring adherence to procedures, with a low cost. Examples of checklists for software development

a) Checklist for dealing with cryptography (adapted from Microsoft, 2007, p.34):

[ ] Code uses platform-provided cryptography and does not use custom implementations.

[ ] Keys are not held in code.

[ ] Access to persisted keys is restricted.

[ ] Keys are cycled periodically.

[ ] Exported private keys are protected

b) Checklist for dealing with sensitive data (adapted from Microsoft, 2007, p.28):

[ ] Secrets are not stored in code.

[ ] Database connections, passwords, keys or other secrets are not stored in plaintext.

[ ] Sensitive data is not logged in clear text by the application

[ ] The design identifies protection mechanisms for sensitive data that is sent over the network.

[ ] Sensitive data is not stored in persistent cookies.

However, the quality and usefulness of a checklist depends on how it is produced. Checklists are valuable only to the extent that they incorporate expert knowledge of a process, including lessons learnt from past projects (Houston, 2004).

2.3.4.4 Metrics

Metrics are considered a vital part of the software industry because of their contribution to improved quality and productivity, from the belief that once implemented and utilised, they should lead the software organisation towards more disciplined processes through the efficient use of feedback mechanisms.

The rationale to use metrics arises from the notion that one cannot improve something without first measuring it (Gopal et al., 2002). In more detail, from better recognition of issues, practitioners can better manage the software development process and make the necessary changes to increase productivity and quality, thereby reducing cycle times and costs in the long run. Examples of metrics are quality of planning index (QIPlan) and the organisation project quality index (QIPlanOrg, which are described further in Sections 4.2 and 5.2.

However, many companies find metrics a complex matter and difficult to undertake. Less than 10 per cent of the industry classifies metrics programs as positive, and most metrics initiatives do not last beyond the second year. To be successful, the implementation of a metrics program should have the support of the organisation and be easy to use (Gopal et al., 2002). In addition, practitioners should understand that metrics are not the goal, but an important tool that highlights problems and gives ideas as to what can be done (Daskalantonakis, 1992).

2.3.4.5 Conclusion

This section presented three methods for evaluating the quality of planning that may be applied to software development projects: the PMPQ model, which evaluates the quality of project planning through the evaluation of 16 planning products from 16 core planning processes defined in the PMBOK (Zwikael and Sadeh, 2007), and checklists and metrics, which are widely used by quality management and process improvement systems such as ISO/IEC standards, CMMI and Six Sigma.

All three methods have limitations. The PMPQ model was not designed specifically for software development projects, it does not evaluate the specific factors that affect the 16 core planning processes, and it does not consider the relationships among them, which are significantly correlated with project success (Ling et al., 2009). Checklists depend on expert knowledge of a process to be effective (Houston, 2004). Metrics are based only on quantitative data, although there are others factors to consider in the planning evaluation, such as pressure from marketing to deliver the product in the shortest timeframe (even with lower quality). This leads to the need to develop a new approach to assess the quality of project planning software development, and to integrate the best of each approach presented and overcome their limitations. This will be described in Chapter 4 (QPEM Model).

2.3.5 Conclusion

This section investigated the characteristics of project planning, explored several project planning approaches and identified three methods for evaluating the quality of planning. This discussion served to better understand the effect of project planning on software development projects in order to identify opportunities that may lead to an increase in the success rate of projects.

2.4 Effectiveness of Planning in Project Success

2.4.1 Introduction

This section discusses the effectiveness of planning on project success. It starts by discussing the existing debate in the literature, where most researchers argue that planning is a critical factor for enhancing the success rate of projects. However, others claim that its importance is overplayed. This is more pronounced in software projects whose characteristics differ from other engineering projects (Rodriguez-Repiso et al., 2007b). For example, volatility of requirements, intangibility of software products and high level of complexity of the system continuously challenge project managers (Napier et al., 2009). Motivated by this debate, this section will then present a research model and the hypotheses to test it.

2.4.2 Planning Debate in the Literature

Several researchers have stated that quality of planning increases the likelihood of achieving project success. For instance, Pinto and Slevin (1987, 1988), Johnson et al. (2001), Belout and Gauvreau (2004), Zwikael and Globerson (2004) and Sudhakar (2012) concluded that planning is considered one of the major contributors to project success. Gornik (2007) from IBM argued that planning is the most critical project phase for software development projects.

However, some researchers have suggested that effectiveness of planning in project success has been overplayed. Dvir and Lechler (2004) recognised that planning is necessary, but it is not a sufficient condition for a successful project because it is difficult to determine precisely which activities—and estimated costs and duration—must be carried out in order to complete the project. This is also valid for software development projects (Rose et al., 2007). Dvir et al. (2003) and Dvir and Lechler (2004) suggested that success is insensitive to the level of implementation of management processes and procedures, but that requirements management—part of the project management plan—has a positive correlation with success. Rodriguez-Repiso et al. (2007a) and Conforto and Amaral (2010) argued that traditional planning approaches present limitations for the development of innovative products because they are characterised by project complexity, unpredictable activities and changes. Ika and Saint-Macary (2012) further claimed that the effect of planning on success is a ‘myth’.

Some researchers have identified planning factors that may lead to project success, such as level of collaboration, level of risk and type of projects:

a) level of collaboration between project managers should be high in international development projects (Guzmán et al., 2010), otherwise one person may not be aware of overall planning (Ika and Saint-Macary, 2012)

b) level of risk, where planning is more effective in high-risk projects than in low-risks projects (Zwikael and Sadeh, 2007)

c) type of project, where the effect of planning of construction projects is higher than in software projects (Zwikael, 2009).

Others have suggested that project managers should focus on subsidiary plans such as cost (Butler and Fitzgerald, 1999), schedule, scope and HR management plans (Linberg, 1999).

Recent studies have indicated that project managers should have appropriate planning for each type of project (Shenhar and Dvir, 2007), reduced to a minimum required level (Dvir and Lechler, 2004), and be able to handle uncertainty (Bakker et al., 2010), constant requirements and goal changes (Karlström and Runeson, 2005; Fitzgerald et al., 2006; Noor et al., 2008; Chow and Cao, 2008). The next section presents a model aimed at helping project managers define the best way to plan and manage projects according to the project's characteristics.

2.4.3 Research Model and Hypotheses

To contribute to this debate, this thesis developed a model for testing the effectiveness of planning on project success, as presented in Figure 2.2. This model was developed based on the model proposed by Zwikael and Sadeh (2007), with two constructs to represent the most recent concept of project success (Section 2.2.3), and success measures defined by Lechler and Dvir (2010). Quality of planning will be detailed in Chapter 4 (QPEM model).

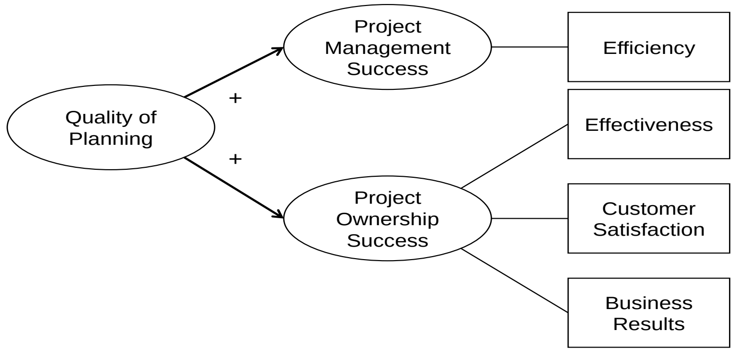

Figure 2.2: Research model for testing the effectiveness of quality of planning in project management success and project ownership success

For testing the effectiveness of planning on project management success, two opposing hypotheses were raised: H_1 assumes a positive causal relationship between planning and success, and the null hypothesis (H_{01}) is opposed to this affirmative:

> *H_1—A higher level of quality of planning is associated with enhancement in project management success.*

> *H_{01}—A higher level of quality of planning is not associated with enhancement in project management success.*

Likewise, for testing the effectiveness of planning on project ownership success, two opposing hypotheses were raised: H_2 assumes a positive causal relationship between planning and success, and the null hypothesis (H_{02}) is opposed to this affirmative:

> *H_2—A higher level of quality of planning is associated with enhancement in project* ownership *success.*

H_{02}*—A higher level of quality of planning is not associated with enhancement in project* ownership *success.*

2.4.4 Conclusion

This section discussed the debate in the literature about the effectiveness of quality of planning in project management success and project ownership success in relation to software development projects. To contribute to this debate, this thesis developed a research model and a set of hypotheses.

2.5 Chapter Summary

This chapter reviewed the relevant literature related to project success and planning. It described the evolution of the project success concept over time and the different points of views, and it presented a recent and more detailed concept. The planning was then investigated intensively. It started by presenting the planning characteristics that have opportunities and risks that may lead to project success, how several project management approaches deal with it, and three methods used to evaluate the quality of planning in software development projects. The chapter then outlined the debate in the literature about the effectiveness of quality of planning in project success. This motivated the development of a new model for evaluating the quality of planning of software development projects, and hypotheses were raised to test the model.

Chapter 3: Method

3.1 Introduction

The selection of the method for conducting research is not random; rather, it is driven by several factors, such as the research problem, objectives of the study, and the background and views of the researcher (Truex et al., 2006). In this study, DSR was the selected research method for supporting the design and development of the QPEM and QPLAN artefacts. This decision was justified by the fact that DSR focuses on knowledge-intensive designing (Van Aken, 2007), seeks a solution for solving real problems (Hevner et al., 2004) through the development of innovative artefacts for the IT field (Arnott and Pervan, 2012; Baskerville, 2008) and can be applied in the management field (Van Aken, 2004).

Given the complexity of the architecture design of QPEM and QPLAN, the evaluation of both artefacts was performed using a variety of approaches, including quantitative and qualitative methods. It aimed at evaluating them in terms of functionality, completeness, accuracy, reliability, usability and demonstrating their utility, which is the essence of DSR (Hevner et al., 2004).

This chapter is organised as follows. Section 3.2 provides an overview of DSR by showing the differences between design, design science and DSR, modelling processes for generating DSR knowledge and for carrying out DSR studies, as well as the types of DSR outputs dealt with in DSR theory. Section 3.3 positions this DSR study in terms of philosophical grounding, level of artefact abstraction and type of knowledge contribution. Section 3.4 describes the research process adopted for developing, evaluating and presenting this DSR study, while Section 3.6 summarises the chapter.

3.2 Design Science Research Overview

3.2.1 Design, Design Science and Design Science Research

Design deals with the creation of artefacts. If the knowledge required for creating such artefacts does not exist, then the design is innovative; otherwise, the design is routine. However, attempts at routine design may lead to innovative design, when the researcher uses existing knowledge to find the missing knowledge in a new area of design (Vaishnavi and Kuechler, 2004).

To bring the design activity into focus at an intellectual level, Simon (1996) revealed the need for a ‘science of the artificial’ for dealing with man-made phenomena, which differ from natural sciences that deal with natural phenomena. A science of the artificial (design science) is a body of knowledge about the design of artefacts in the form of constructs, techniques and methods, and models and theory (Vaishnavi and Kuechler, 2004), which are aimed at designing solutions for real problems (Hevner et al., 2004).

Design Science Research (DSR) is research that creates this type of missing knowledge using design primarily as a research method (Vaishnavi and Kuechler, 2004).

3.2.2 Generating DSR Knowledge

Takeda et al. (1990) analysed the reasoning that occurs in the course of a general design cycle and proposed a model aimed at explaining how design is conceptually performed in terms of knowledge manipulation. This is a cognitive model (Vaishnavi and Kuechler, 2004) that considers the design process as an iterative logical process realised by abduction (the logical inference that goes from observation to a hypothesis for explaining some evidence), deduction (attempts to provide a formal model of logical reasoning as it naturally occurs) and circumscription (formalises the common-sense assumption that things are as expected).

Based on this analysis, Vaishnavi and Kuechler (2004) proposed a model called the general design cycle (GDC), as applied to DSR. This model comprises five iterative stages: (1) awareness of the problem, (2) suggestions for solving it, (3) development, (4) evaluation and (5) conclusion. Awareness of the problem is identified from the literature review or from practice (Vaishnavi and Kuechler, 2012). The identification of suggestions for solving this problem arises from the existing knowledge or theory base for the problem area. An attempt is then made to develop an artefact for solving the identified problem according to the proposed solution. After this stage, the artefact is evaluated to determine whether it works according to expectations (Hevner et al., 2004). The development and evaluation of an artefact is an iterative cycle that creates opportunities to enhance the artefact through insights and suggestions. The conclusion indicates the termination of the cycle. Figure 3.1 shows this cognition schema in the DSR cycle.

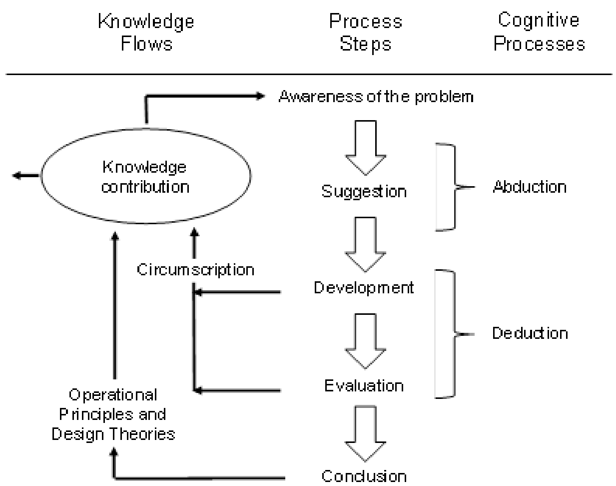

Figure 3.1: Cognition in DSR cycle
(adapted from Vaishnavi and Kuechler, 2012)

Vaishnavi and Kuechler (2012) later extended the GDC model. Termed the aggregate design general cycle (AGDC), this model included: (1) the aggregation of research and development efforts from multiple research programs in multiple communities into an interest network for the artefact, and (2) the dissemination of the knowledge and insights from the network back to individual research efforts.

3.2.3 Models for Conducting DSR Studies

Hevner et al. (2004) argued that behavioural science and design science are complementary research approaches, where the former aims to develop and verify theories that explain or predict human or organisational behaviour, and the latter aims to extend the boundaries of human and organisational capabilities by creating new and innovative artefacts. Likewise, based on March and Smith's (1995) work, Hevner et al. (2004) proposed seven guidelines for developing, evaluating and presenting DSR in IS research:

(1) design as an artefact, for addressing a business problem, in the form of a construct, model, method or instantiation
(2) problem relevance, for providing solutions to relevant business problems
(3) design evaluation, for demonstrating the utility, quality and efficacy of the artefact through proven evaluation methods
(4) research contribution, for providing clear and verifiable contributions in the areas of the design artefact, foundations or methodologies
(5) research rigor, for the development and validation of the design artefact
(6) design as a search process, which requires utilising available means to achieve desired ends while satisfying laws in the problem environment
(7) communication of research to both technology- and management-oriented audiences.

However, Hevner et al.' (2004) work is not a consensus in the literature (Venable, 2010). Pries-Heje et al. (2008) proposed a framework that has two dimensions. The first dimension contrasts ex ante (evaluation performed prior to artefact construction) versus ex post (evaluation of an instantiated artefact, such as a model). The second dimension contrasts artificial (evaluation of the artefact through lab experiments, simulations and mathematical proofs) versus naturalistic (evaluation of the artefact in real environment, e.g., case studies). Venable et al. (2012) proposed two frameworks based on Pries-Heje et al.' (2008) work: DSR evaluation strategy selection framework, for defining an evaluation based on contextual factors (e.g. resources, goals and priorities), and DSR evaluation method selection framework, for defining a method based on this strategy.

Peffers et al. (2006) proposed the DSRP model for carrying out design science studies and aimed to build consensus from the literature. This model aims to be consistent with design science processes in prior literature (e.g., Nunamaker et al., 1991; Walls et al., 1992; Hevner et al., 2004) and fill two gaps in the literature by providing a nominal process for conducting DSR and a mental model for the research outputs. The DSRP has six steps, which are summarised below. The DSRP was applied in this study (Section 3.4), as it now has wide acceptance for DSR:

(1) Problem identification and motivation, to identify the research problem, define the scope properly and justify the value of the proposed solution.

This step serves to motivate the stakeholders interested in the research and to understand the researcher’s reasoning for addressing the problem.

(2) Objectives of a solution, to define the objectives of a solution inferred rationally from the problem definition, which can be either quantitative or qualitative.

(3) Design and development, to design and develop artefacts for addressing the research problem. This involves requirements definition and design of the architecture for developing the desired artefact, which can be constructs, models, methods or instantiations (Hevner et al., 2004; March and Smith, 1995).

(4) Demonstration, to demonstrate the efficacy of the artefact to solve the problem in a suitable context (e.g., case study).

(5) Evaluation, to observe and measure how effectively and efficiently the artefact addresses the research questions and satisfies the design objectives. In natural science, methodologies are typically based on data collection and quantitative and qualitative analyses. However, in DSR, computational and mathematics methods can also be employed for evaluating an artefact (Hevner et al., 2004).

(6) Communication to both researchers and practitioners about the research problem, objectives and contributions, the rigor of the artefact’s design, how it was developed and evaluated, as well its utility, novelty and effectiveness.

3.2.4 DSR Outputs

March and Smith (1995) demonstrated the relationship, activities and outputs of design and natural science research and defined four types of outputs for DSR: constructs, models, methods and instantiations. Constructs describe the problem and its solution. Models represent how things are. Methods aim to set steps that specify how to perform a task. Instantiations are the realisations of an artefact in its environment.

Purao (2002) proposed three levels of abstraction for defining outputs types: specific artefacts (e.g., products and processes), more general contributions (e.g., constructs, methods and models) and more abstract contributions in the form of emergent design theories (Gregor and Hevner, 2013). The first two levels can be mapped directly to March and Smith's (1995) list, but the last level (emergent design theories) provides a significant contribution to the list of design science output types (Vaishnavi and Kuechler, 2012).

3.2.5 Design Theory

Walls et al. (1992) provided an initial attempt to define systems design theory, which is based on design products and processes. This definition has four components: (1) meta-requirements, to describe the class of goals to which the theory applies; (2) meta-design, to describe a class of artefacts hypothesised to meet the meta-requirements; (3) kernel theories (i.e., the theories that govern design requirements); and (4) testable hypotheses, to test whether the meta-design satisfies the meta-requirements.

Gregor and Jones (2007) identified missing components in Walls et al.'s (1992) framework and extended the specification of a design theory for ISs with eight identifying components: (1) purpose and scope (what the system is for); (2) constructs, for the definitions of the entities of interest in the theory; (3) principles of form and function, for describing the architecture of the artefact and its functions; (4) artefact mutability, related to changes in the artefact; (5) testable propositions (i.e., hypotheses); (6) justificatory knowledge, to show the underlying knowledge that gives a basis and explanation for the design; (7) principles of implementation, to describe the processes for implementing the theory; and (8) expository instantiation, which is the physical implementation of the artefact.

3.3 Positioning This DSR Study

Gregor and Hevner (2013) argued that DSR is yet to attain its full potential because of gaps in the understanding and application of its concepts and methods. To address this issue, the authors suggested positioning a DSR study according to a taxonomy derived from the DSR literature.

Given this context, the next sections will position this DSR study in terms of the philosophical grounding that underpins it, the level of artefact abstraction and the type of knowledge contribution.

3.3.1 Philosophical Grounding

Philosophical grounding for research is usually synthesised into two dominant research traditions (Purao, 2002): positivism and interpretative. The former is based on the view that observation and measurement are at the core of the scientific endeavour, while the latter is concerned with gathering an in-depth understanding of the phenomenon—usually human-related (Healy and Perry, 2000).

However, DSR differs from these traditional views, as it can incorporate aspects of both (Vaishnavi and Kuechler, 2004). DSR is a problem-driven method (Baskerville, 2008), where knowledge is created from iterations between the design and the explanation of artefacts (Nunamaker et al., 1991).

Different worldviews are expressed in terms of ontology, epistemology, methodology and axiology elements (Vaishnavi and Kuechler, 2012). Ontology is the study that deals with the reality of the phenomenon under investigation (Shadish et al., 2002; Healey and Perry, 2000). That is, in order to understand this world, the researcher must represent or reconstruct it as seen by others (Sedoglavich, 2008). Epistemology is the study that deals with the ways of knowing this phenomenon (Shadish et al., 2002; Rossman and Rallis, 2003). It describes the nature of the relationship between the researcher and the reality (Sedoglavich, 2008). Methodology is the technique used by the researcher to discover that reality (ontology) (Sedoglavich, 2008). Finally, axiology is the study of values that individuals and groups hold for sharing with others (Vaishnavi and Kuechler, 2012).

This study assumes that the phenomenon of software development projects can be viewed as a systematic process whose behaviour is governed by interconnected factors that that impact project planning. It also assumes that the software development process can be enhanced through measurement over the project lifecycle and lessons learnt from past projects developed by the organisation. This assumption is consistent with the worldview for design (Vaishnavi and Kuechler, 2012). In terms of ontology, it assumes that there are different aspects of the reality (multiple realities). In terms of epistemology, this view deals with both objective and subjective factors that can be analysed through quantitative and qualitative methods for understanding this phenomenon. This improved knowledge can lead to enhance the success rate of projects (axiology). Table 3.1 summarise the philosophical grounding that underpins this study.

Table 3.1: Philosophical grounding that underpins this study

	Positivism	Interpretative
Ontology		Multiple realities
Epistemology	Objective (factors that impact project planning)	Subjective (factors that impact project planning)
Methodology	Qualitative (measurement over the project lifecycle)	Quantitative
Axiology		Understanding (lessons learnt from past projects)

3.3.2 Level of Artefact Abstraction

Hevner et al. (2004) and March and Smith (1995) stated that DSR studies should contribute to the literature through a viable artefact in terms of a construct, a model, a method or an instantiation. Walls et al. (1992) and Gregor and Jones (2007) proposed that DSR studies should produce a design theory. These apparent contradictions can be addressed by distinguishing research contributions through levels of contribution using Purao's (2002) framework (Gregor and Hevner, 2011, 2013).

Purao's (2002) framework has three levels of abstraction, which range from specific artefacts at Level 1 in the form of products and processes, to more general contributions at Level 2 in the form of nascent design theory, such as constructs, methods and models, and more abstract contributions in the form of emergent design theories about the phenomena at Level 3 (Gregor and Hevner, 2013).

This study provides two contributions: the QPEM model for the project management literature and the QPLAN tool for the software industry (Section 1.7). Hence, according to Purao's (2002) framework, the former contribution (a model) is classified in the second level of artefact abstraction, while the latter (a software product) is classified in the first level of artefact abstraction.

3.3.3 Type of Knowledge Contribution

Gregor and Hevner (2013) proposed a framework for classifying knowledge contributions in four quadrants: invention, improvement, exaptation and routine design (Figure 3.2). Improvement is a quadrant dedicated to contributions that provide new solutions for known problems—that is, better solutions in the form of more efficient artefacts (much of the previous and current DSR in ISs can be classified as improvement research). Invention is a quadrant dedicated to contributions that provide new solutions for new problems—that is, recognisably novel artefacts that can be applied and evaluated in a real-world context. Routine design is a quadrant dedicated to contributions that provide existing solutions for existing problems. In this case, research opportunities are not obvious, but this work may lead to new findings. Finally, exaptation is a quadrant dedicated to contributions that provide known solutions extended to new problems—that is, the design knowledge that already exists in one field is extended in a new field.

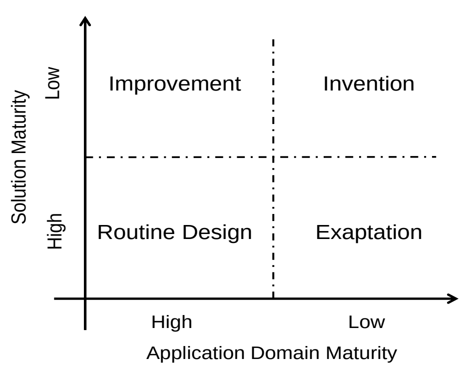

Figure 3.2: Knowledge contribution framework
(adapted from Gregor and Hevner, 2013)

In this study, the knowledge contribution from this research should be classified as improvement (second quadrant), as both QPEM and QPLAN are new artefacts that are designed to fill gaps found in the literature (known problems) and in the software industry (Section 1.3).

3.4 Research Process Approach

The process for conducting this study follows the DSRP model (Section 3.2), which is described next. Section 3.4.1 starts by showing the problem identification motivation that triggered this research: that is, the low success rate of software projects development that has plagued the IT industry for many years (Krishnan et al., 2000). Section 3.4.2 shows the research objectives for reversing this scenario, the in-depth investigation of software development projects in the business environment, and the development of the QPEM and QPLAN artefacts. Section 3.4.3 presents a summary of the design and development of the QPEM and QPLAN artefacts. Given the complexity of the design of the architecture for both artefacts, their complete descriptions have been separated into individual chapters (Chapters 4 and 5, respectively). Section 3.4.4 summarises the demonstration, testing and evaluation phases of these artefacts. Given the variety of evaluation methods applied, their description is detailed in Chapter 6. In addition, rather than split the demonstration and evaluation into two steps, as Peffers et al. (2006) defined, it was decided to check the efficacy and efficiency of QPEM and QPLAN together, as Nunamaker et al. (1991) did. Finally, Section 3.4.5 summarises the main communication events of this research to both academics and practitioners (details are also in Chapter 6). Figure 3.3 shows the process model applied to this study. The next sections describe each step of the process.

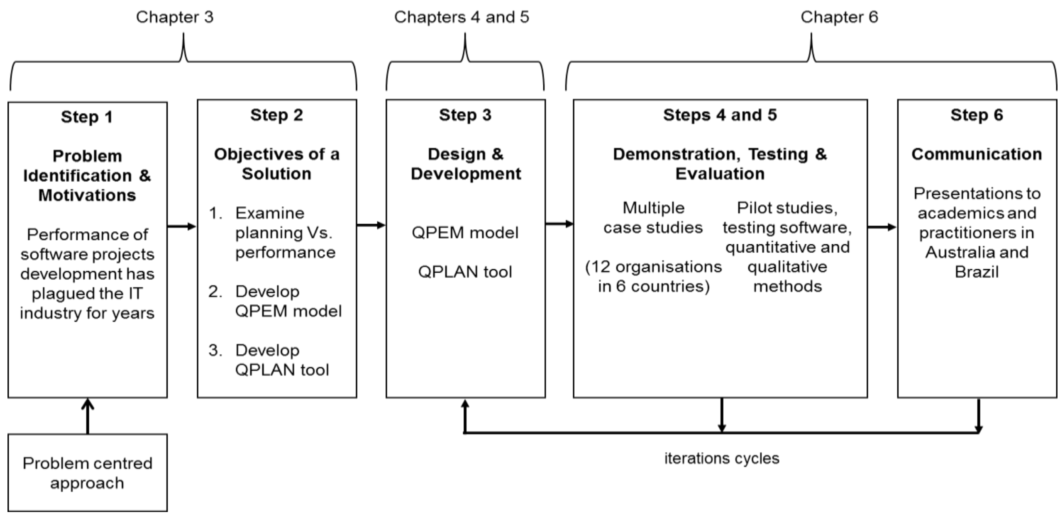

Figure 3.3: DSRP model applied to this research
(adapted from Peffers et al., 2006)

3.4.1 Step 1—Problem Identification and Motivation

In the first step of the DSRP model (problem identification and motivation), this research identified that the low success rate of software development projects has plagued the IT industry for many years (Krishnan et al., 2000). It is a significant economic segment that should have generated US$3.8 trillion in 2014 (Lovelock, 2013). In 2009, only 32 per cent of software projects were considered successful (i.e., completed on time and on budget, and offering all features and functions as initially specified), while 24 per cent failed, and of the remaining fraction, costs were higher than original estimates, or they were completed behind schedule or offered fewer features or functions than originally specified (Eveleens and Verhoef, 2010). For customers, unsuccessful projects may lead to a lack of productivity or loss of business, and the implications are equally problematic for organisations (Moløkken-Østvold and Jørgensen, 2005). In 2013, the results were slightly better, but the success rate was still low; only 39 per cent of projects were completed successfully (Obeidat and North, 2014), leading to estimated annual losses for the US and EU markets of around US$100 billion each (Symons, 2010).

To overcome these difficulties, researchers have aimed to reverse this scenario. A large number of researchers have focused on planning, which is characterised by opportunities and risks that may lead to project success (Pinto and Slevin, 1987; Belout and Gauvreau, 2004; Zwikael and Globerson, 2004), while others have claimed that planning importance is being overplayed (Dvir and Lechler, 2004; Conforto and Amaral, 2010). This debate is more pronounced in software projects whose characteristics differ from other engineering projects (Rodriguez-Repiso et al., 2007b). For example, volatility of requirements, intangibility of software products and high level of complexity of the system continuously challenge project managers (Napier et al., 2009).

Motivated by this context, the first research question concerns the investigation of the effectiveness of planning in project success:

- *RQ1: Does improvement in the quality of planning of software development projects enhance project success?*

Considering that quality of planning enhances project success, the second research question concerns the evaluation and improvement of the quality of planning when software development project success has not been effective over time (Bakker et al., 2010):

- *RQ2: How can the effectiveness of the quality of planning of software development projects be better evaluated in order to enhance project success?*

3.4.2 Step 2—Objectives of a Solution

In the second step of the DSRP model (objectives of a solution), this research defined three main objectives aimed at contributing to the project management literature and the software industry. The first is an exploratory objective to gain further insights into the problem domain and support the development of the next two, which are the contributions from this research. The objectives are:

1. Examine the influence of the quality of planning in project success by investigating prior work and the phenomenon of software development projects in depth in the business environment.
2. Develop and evaluate QPEM, which is a model that evaluates the quality of project planning of software development projects. This is motivated by the fact that current models were not designed specifically for software development projects, do not evaluate specific factors that affect planning

processes and do not consider the relationships among them, which are significantly correlated with project success (Ling et al., 2009).

3. Develop and evaluate QPLAN, which is a tool for the software industry aimed at enhancing project success by assessing the quality of planning and introducing best practices in the software development process.

3.4.3 Step 3—Design and Development

> *Design deals with creating some new artefact that does not exist. If the knowledge required for creating such an artefact already exists then the design is routine; otherwise, it is innovative. Innovative design may call for the conduct of research (design science research) to fill the knowledge gaps and result in research publication(s) or patent(s) (Vaishnavi and Kuechler, 2004).*

This research describes the third step of the DSRP model (design and development) of two artefacts: QPEM, a model for the project management literature that evaluates the quality of planning of software development projects, and QPLAN, a tool for the software industry that enhances project success by evaluating the quality of planning and introducing best practices in the software development process.

QPEM comprises two measures for evaluating the quality of planning: QPM, which was described in Section 2.3.4.2, and quality of planning through cognitive maps (QCM), which was developed in this research. QPM evaluates the quality of planning using an evaluation framework for the quality of 16 planning products from 16 core planning processes defined in the PMBOK (Zwikael and Globerson, 2004). QCM evaluates the quality of planning (QIPlan) from the evaluation of 55 factors that affect project success positively or negatively, which are organised in a hierarchical structure of 21 cognitive maps (see Figure 3.4 and a complete description of QPEM in Chapter 4).

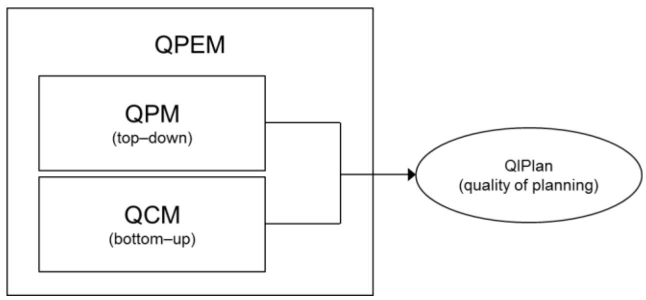

Figure 3.4: QPEM

QPLAN is a software tool comprising four components: the QPEM model for evaluating the quality of planning, the extended Karnaugh map for identifying the strengths and weaknesses of planning (Sedoglavich, 2008), the NTCP diamond model for identifying project characteristics (Section 5.3.2) and a knowledge base for allowing learning from past projects developed by the organisation (Iversen et al., 2004). The main screen is shown in Figure 3.5, and a complete description of QPLAN in given in Chapter 5.

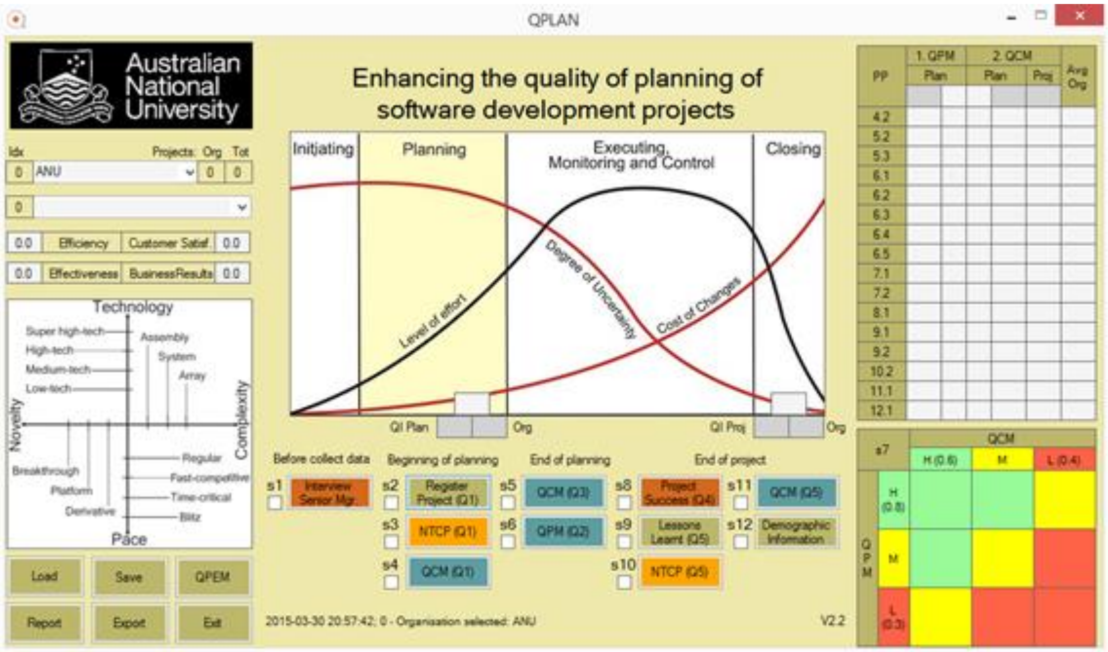

Figure 3.5: QPLAN tool main screen

3.4.4 Steps 4 and 5—Demonstration, Testing and Evaluation

Given the complexity of the design of the architecture of QPEM and QPLAN, the fourth and fifth steps of the DSRP model (demonstration and evaluation of both artefacts) were performed through two phases and used a variety of approaches, including quantitative and qualitative methods. This strategy aimed to test and evaluate QPEM and QPLAN in terms of functionality, completeness, accuracy, reliability and usability, and to demonstrate their utility, which is the essence of DSR (Hevner et al., 2004).

Phase 1 assured that QPLAN was developed according to its specification by performing White Box Testing (test of the calculation of quality indices) and Black Box Testing (test of functionality, completeness and usability).

Phase 2 examined QPLAN intensively within the business environment by obtaining a rich universe of data and analysing them through a variety of quantitative and qualitative methods. Phases 1 and 2 and their steps are outlined in Table 3.2.

Table 3.2: QPLAN testing and evaluation design

Phase	Goal	Step	How	Reference
1	Examine if QPLAN was developed to conform to its specification	a	Perform White Box Testing (structural tests with simulation and artificial data)	Hevner et al., 2004
		b	Perform Black Box Testing (functional tests)	
2	Examine QPLAN intensively within the business environment	a	Interviews with senior managers	Rossman and Rallis, 2003
		b	Collect data from current and past projects	Hevner et al., 2004
		c	Effectiveness of quality of planning in project management success and project ownership success	Zwikael and Globerson, 2011b
		d	Amount of alignment between QPM and QCM	Salkind, 2009
		e	Long-term effect of QPLAN in enhancing the quality of planning over time	Breyfogle, 2003
		f	Discuss QPLAN with project managers —a qualitative study	Gopal et al., 2002

Table 3.3 shows the steps presented in Table 3.2 classified according to Pries-Heje et al.'s (2008) framework (Section 3.2.3).

Table 3.3: Testing and evaluation steps according to Pries-Heje et al.'s (2008) framework

	Ex Ante	Ex Post
Artificial	Step 1a—Perform White Box Testing	Step 1b—Perform Black Box Testing
Naturalistic	Step 2a—Interviews with senior managers	Step 2b—Collect data from current and past projects Step 2c—Effectiveness of quality of planning in project management success and project ownership success Step 2d—Amount of alignment between QPM and QCM Step 2e—Long-term effect of QPLAN in enhancing the quality of planning over time Step 2f—Discuss QPLAN with project managers—a qualitative study

This was an iterative search process (Simon, 1996) that helped to find an effective solution to the problem that motivated this research (Hevner et al., 2004). It served to improve the research design and QPEM and QPLAN artefacts, and it demonstrated their utility to researchers and practitioners, which is the essence of DSR (Hevner et al., 2004).

3.4.5 Step 6—Communication

The sixth step of the DSRP model (communication of this research) took place during several events in Australia and Brazil over the past four years. For example, this research was presented in a workshop promoted by the Australian and New Zealand Academy of Management (ANZAM) in Sydney (2010), in a seminar promoted by the Brazilian chapter of the Project Manager Institute (PMI) in Porto

Alegre (2011), and in a seminar promoted by P&D Brasil (R&D Brazil), a Brazilian association of organisations in the electronic field, in Cachoerinha (2014).

3.5 Chapter Summary

This chapter began by justifying the use of DSR as the research method for supporting the design and development of QPEM and QPLAN artefacts, and the use of a variety of approaches, including quantitative and qualitative methods for evaluating these artefacts. Likewise, this chapter provided an overview of DSR and showed the differences between design, design science and DSR. It presented DSR models for generating DSR knowledge and carrying out DSR studies, showed the types of DSR outputs, and dealt with DSR theory. The study was positioned in terms of philosophical grounding, level of artefact abstraction and type of knowledge contribution. Finally, this chapter described the use of the DSRP model for developing, evaluating and presenting this study, and provided a link to Chapters 4, 5 and 6.

Chapter 4: Quality of Planning Evaluation Model (QPEM)

4.1 Introduction

As discussed in Chapter 2, the literature offers several methods for evaluating the quality of planning. Significant examples are the PMPQ model, checklists and metrics. Nonetheless, current tools have limitations for evaluating the quality of planning of software development projects. For instance, they are not designed specifically for software projects, or they depend on expert knowledge to be effective. There was a need to develop a new approach for evaluating the quality of planning of software development projects that could integrate the best of each method and overcome their limitations.

This chapter describes the design and development of the QPEM to address this need. Section 4.2 begins by proposing a combination of top–down and bottom–up—two planning approaches (Alblas and Wortmann, 2012) aimed at contributing to the development of a successful planning strategy (Baker et al., 2011) and enhancing the accuracy of the evaluation (Jørgensen, 2004). Section 4.4 describes the use of QPM, which evaluates the quality of planning through a top–down approach. Section 4.5 describes the design and development of QCM, which evaluates the quality of planning through a bottom–up approach. Section 4.6 concludes this chapter.

4.2 Two Measures for Enhancing the Accuracy of Estimations

Estimation efficiency varies according to the phase of the project in which it is carried out. Estimation accuracy increases with the phase of the project (Kaczmarek and Kucharski, 2004). In the planning, which is characterised by a high level of uncertainty (Section 2.3.2), effort estimation is one of the most critical and complex activities (Lee et al., 1998). The literature offers several methods for performing this task. The main ones are: expert judgment, which is based on the accumulated experience of a team of experts; analogy, which is based on similar projects developed by the organisation; algorithmic, which is based on a mathematical model derived through statistical data analysis (O’Brien, 2009; Stamelos et al., 2003); and function point, which is based on the amount of business functionality a system provides to a user (O’Brien, 2009).

Expert judgment is the most commonly used method for software effort estimations in planning (Stamelos et al., 2003). Experts can perform this task in the planning (Jørgensen, 2004) by examining a project from a broad view to provide the effort estimation (top–down approach) or by decomposing the project into activities, estimating them individually and then calculating the sum of all activities (bottom–up approach) (Shepperd and Cartwright, 2001; Jørgensen, 2004).

Each of these approaches has advantages and disadvantages, but both can provide reasonable estimations. In the top–down approach, the time required to perform the effort estimation is lower compared to the bottom–up approach, and it does not require much technical expertise. Conversely, the bottom–up approach leads to understanding the project requirements in detail, and this knowledge will be useful during project execution. There are certain situations where it is better to use the top–down approach for project effort estimation, while it is better to use the bottom–up approach in other situations (Jørgensen, 2004).

This research combines these two planning approaches (Alblas and Wortmann, 2012) in order to contribute to the development of a successful planning strategy (Baker et al., 2011) and enhance the accuracy of the evaluation (Jørgensen, 2004).

QPEM was designed with two measures: QPM, which evaluates the quality of planning through the evaluation of the planning products from planning processes (top–down approach), and QCM, which evaluates the quality of planning through the evaluation of factors that affect planning processes (bottom–up approach) (See Figure 4.1). QPEM's output is an index called QIPlan, which is calculated from the average of QPM and QCM. QIPlan ranges from 0.0 (lowest) to 1.0 (highest) (Section 6.3.4).

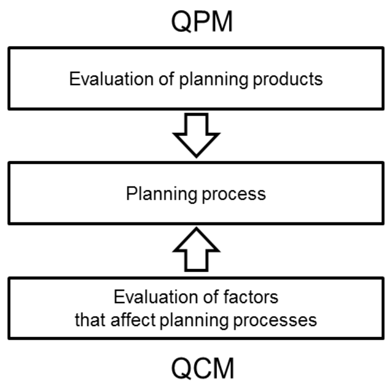

Figure 4.1: Design of the QPEM model

4.3 Evaluating the Quality of Planning through a Top–Down Approach

The evaluation of the quality of planning through a top–down approach is made through QPM, an index from the PMPQ model described in Section 2.3.4.2. QPM evaluates the quality of planning through a weighted linear combination of the quality of single planning products from planning processes defined in the PMBOK (Zwikael and Sadeh, 2007). These planning products are measured with an established 16-item scale, validated and utilised extensively in the literature (e.g., Zwikael and Globerson, 2004, 2006; Masters and Frazier, 2007; Zwikael and Sadeh, 2007; Papke-Shields et al., 2010; Zwikael and Ahn, 2011; Barry and Uys, 2011; Rees-Caldwell and Pennington, 2013; Zwikael et al., 2014). The items are: develop project management plan, define scope, create work breakdown structure, define activities, sequence activities, estimate activity resources, estimate activity durations, develop schedule, estimate costs, determine budget, plan quality, develop HR plan, acquire project team, plan communications, plan risk management and plan procurements.

Questionnaire Q2 (Appendix A) was created to implement QPM in this research. The following scale was used for evaluating the quality of the 16 core planning products: ‘Strongly agree’, ‘Agree’, ‘Neutral’, ‘Disagree’ and ‘Strongly disagree’. ‘Irrelevant’ and ‘Do not know’ were used for capturing missing data.

The quality of planning of each planning product was then converted according to Table 4.1, ranging from 0.0 (lowest) to 1.0 (highest). This conversion allows compare QPM with QCM.

Table 4.1: Conversion scale for QPM

From 5-point Likert Scale	To Decimal Scale
Strongly agree	1.00
Agree	0.80
Neutral	0.50
Disagree	0.30
Strongly disagree	0.00

This conversion allowed the calculation of the QPM index from the average of the quality of planning of each planning product. For example, the project manager answered the questionnaire as follows: questions 1 to 8 were evaluated as “Agree”, questions 9 to 14 as “Neutral” and questions 15 and 16 as “Disagree”. Then, using the conversion from the 5-point Likert Scale to the decimal scale (Table 4.1), QPM index will be calculated as follows:

$$\text{QPM index} = \frac{0.8 \text{ x } 8 + \ 0.5 \text{ x } 6 \ + \ 0.30 \text{ x } 2}{16} = 0{,}63$$

4.4 Evaluating the Quality of Planning through a Bottom–Up Approach

The evaluation of the quality of planning through a bottom–up approach is made by QCM, which was developed in this study. It evaluates the quality of planning of software development projects from the evaluation of factors that affect project planning. These factors are organised in cognitive maps (Stach et al., 2005).

4.4.1 Cognitive Maps

Cognitive maps are a methodology based on expert knowledge (Stach et al., 2005) aimed at describing the behaviour of a system graphically (Rodriguez-Repiso et al., 2007a). This is used in numerous areas (e.g., electrical engineering, supervisory systems and medicine) (Alizadeh et al., 2008), to solve a variety of practical problems (e.g., transportation planning, technology management) (Osei-Bryson, 2004) and in decision-making systems (Sharif et al., 2010). For project planning, cognitive maps are used to identify critical paths (Banerjee, 2009), help structure issues (Eden, 2004), support risk analysis (Salmeron and Lopez, 2012; Ngai et al., 2005) and model success factors (Salmeron, 2009).

A cognitive map consists of three elements: nodes, for identifying the most relevant factors in the system; edges, for representing the relationships between factors (Rodriguez-Repiso et al., 2007a); and weights, for indicating the weights of the causal relationships between nodes (Stach et al., 2005) (Figure 4.2).

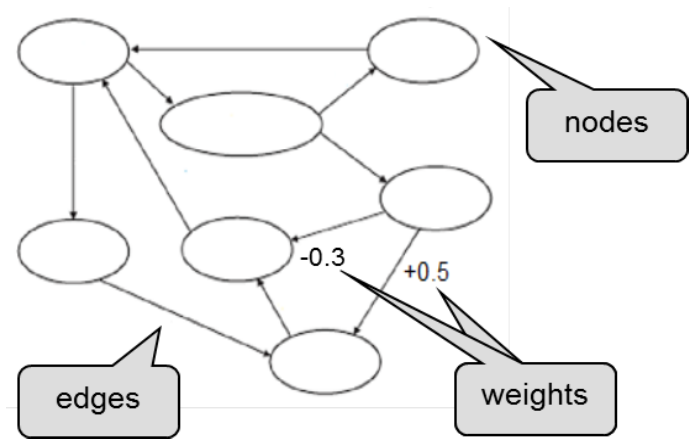

Figure 4.2: Cognitive map (adapted from Stach et al., 2005)

The graphical representation of the cognitive map aims to show the behaviour of a system in a transparent form and close to how humans perceive it (Rodriguez-Repiso et al., 2007a). To facilitate the understanding of the system, a cognitive map usually has fewer than 10 nodes and low density (about 20–30 per cent) of all possible connections (Stach et al., 2005).

In addition, a cognitive map can have a machine-learning algorithm for adjusting weights between nodes automatically, without human intervention. For instance: Differential Hebbian Learning Law (DHL), Balanced Differential Algorithm (BDA) and Real-Coded Genetic Algorithm (RCGA) (Stach et al., 2005).

QCM has 21 cognitive maps that are organised in a hierarchical structure (Figure 4.3), comprising 16 cognitive maps representing the 16 core planning processes used by QPM (Table 2.1), and five cognitive maps representing categories of success factors for software projects (Sudhakar, 2012). They are: project manager characteristics, technological expertise, top management support, enterprise environmental factors and quality of methods and tools.

- project manager characteristics (Section 4.4.19) evaluates the fit between the personality of the project manager and the profile of the project, and it is associated with quality of planning (Malach-Pines et al., 2008)
- technological expertise (Section 4.4.20) evaluates the knowledge and experience available in the project team for the project (Jørgensen and Gruschke, 2009; Scott-Young and Samson, 2008)
- top management support (Section 4.4.21) evaluates the level of support that the top management provide to the project (Kloppenborg et al., 2009; Zwikael, 2008a)
- enterprise environmental factors (Section 4.4.22) evaluates the environmental factors that affect quality of planning (PMI, 2013; Zwikael and Sadeh, 2007; Zwikael and Globerson, 2004; Krishnamoorthy and Douglas, 1995)
- quality of methods and tools (Section 4.4.23) evaluates the infrastructure that surrounds the project (Jørgensen and Shepperd, 2007; Zwikael and Sadeh, 2007; Zwikael and Globerson, 2004).

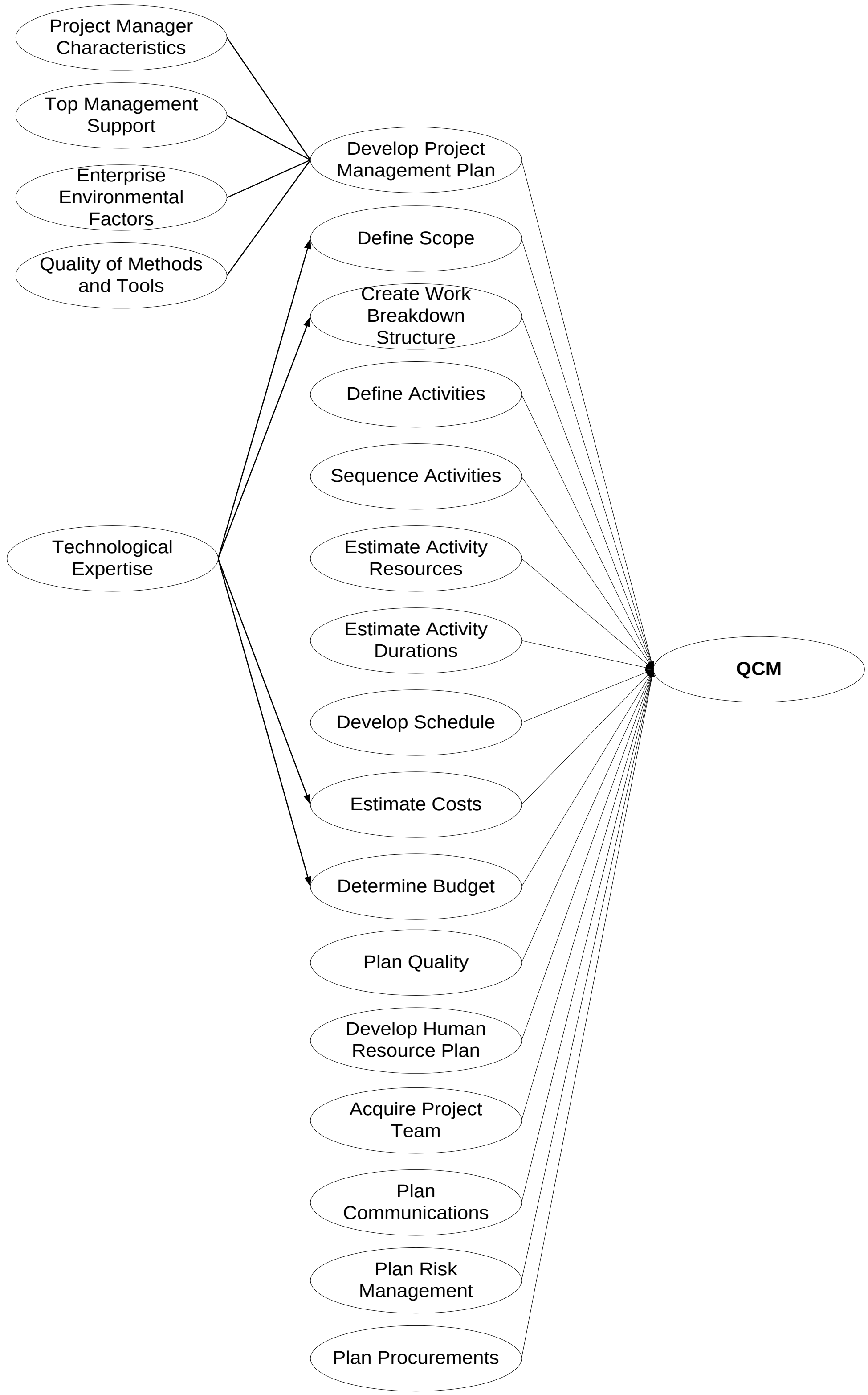

Figure 4.3: Design of QCM

4.4.2 Factors That Affect the Quality of Planning

The following process was used to identify a concise list of generic project management factors and specific software development factors that affect planning. After extensive investigation in 37 articles published in project management, general management, and computer science leading journals between 1986 and 2012, 211 factors that impact project planning were identified through the keywords “project success”, “project management” and “software development”. They are listed in Appendix B with their references. For instance, sound basis for project (Pinto and Slevin, 1986; Loh and Koh, 2004), clear realistic objectives (Fortune and White, 2006; Reel, 1999; Johnson et al., 2001; Pinto and Slevin, 1986) and time pressure on the project (Wohlin and Andrews, 2001).

Motivated by the fact that many factors to be evaluated by the project managers would cause an additional workload that could derail this study (Gopal et al., 2002), the number of factors was reduced from 211 to 55 (Tables B.2 and B.4). The criterion adopted to reduce the number of factors was the knowledge expertise from the researcher as a project manager (according to Stach et al., 2005, the development of cognitive maps by a single expert is an acceptable approach; however, a group of experts usually improves its reliability. Moreover, according to Rodriguez-Repiso et al., 2007a, even if the initial mapping of the factors is incomplete or incorrect, further additions to the map may be included).

These 55 factors were grouped by similarities into 21 cognitive maps (Figure 4.3) that are described in the next sections. In addition, Figure 4.4 shows all of the factors and cognitive maps together. This is QCM represented as a unique cognitive map, without weights, which are specific for each project.

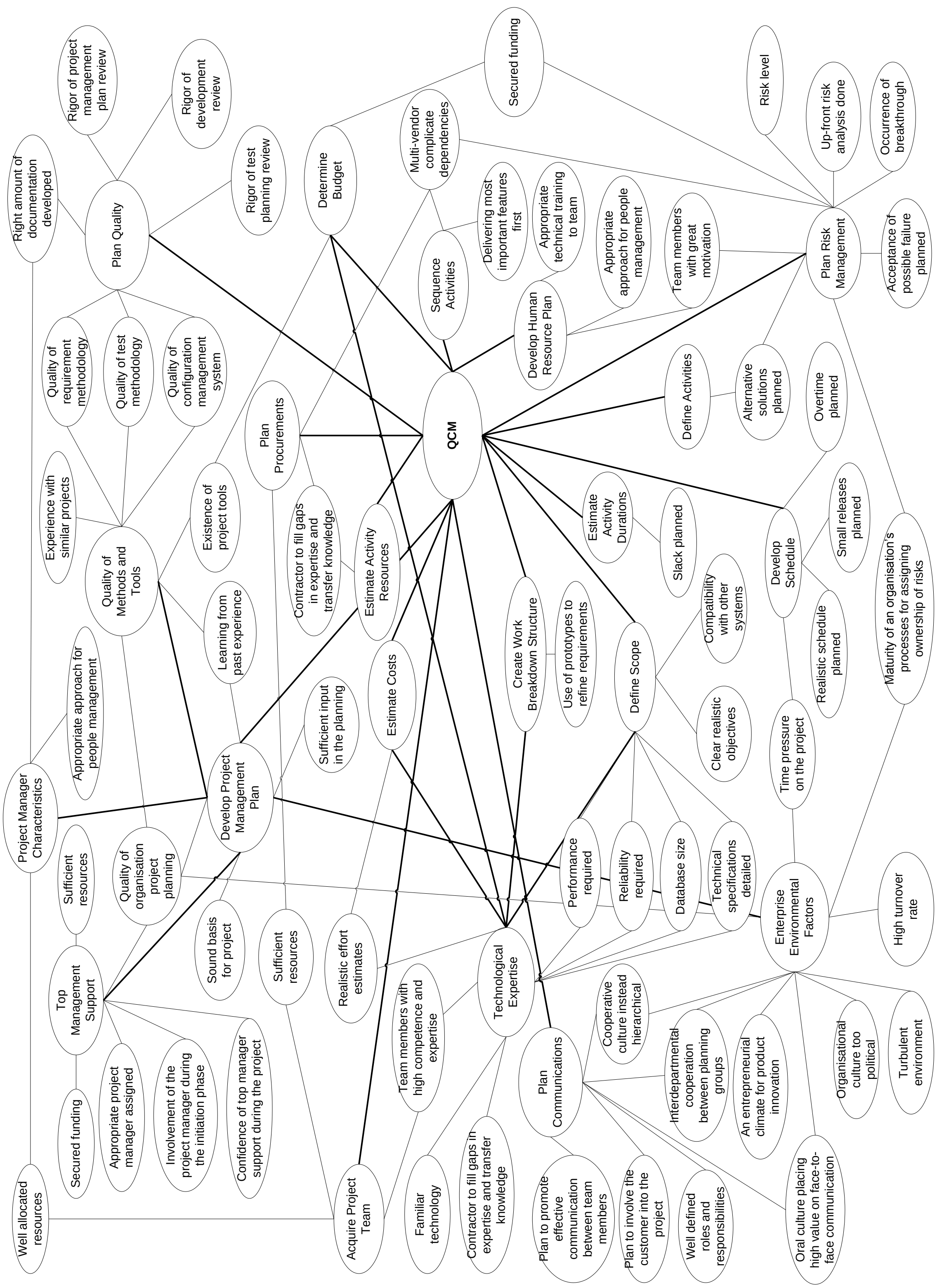

Figure 4.4: QCM model

4.4.3 Develop Project Management Plan

The cognitive map develop project management plan, shown in Figure 4.5, includes factors that refer to processes and activities needed to identify, define, combine, unify and coordinate the various processes and project management activities within the project management process groups (PMI, 2013).

Eight nodes form this cognitive map. The first node is the quality of organisation project planning (i.e., quality of projects already undertaken by the organisation). The next four nodes are outputs from other cognitive maps: project manager characteristics (Section 4.4.19), top management support (Section 4.4.21), enterprise environmental factors (Section 4.4.22), and quality of methods and tools (Section 4.4.22). The remaining three nodes evaluate factors that affect the development of the project management plan: sound basis for project (Fortune and White, 2006; Pinto and Slevin, 1986; Loh and Koh, 2004), learning from past experience (Willcocks and Griffiths, 1994; Fortune and White, 2006) and sufficient input in the planning (Pinto and Slevin, 1986).

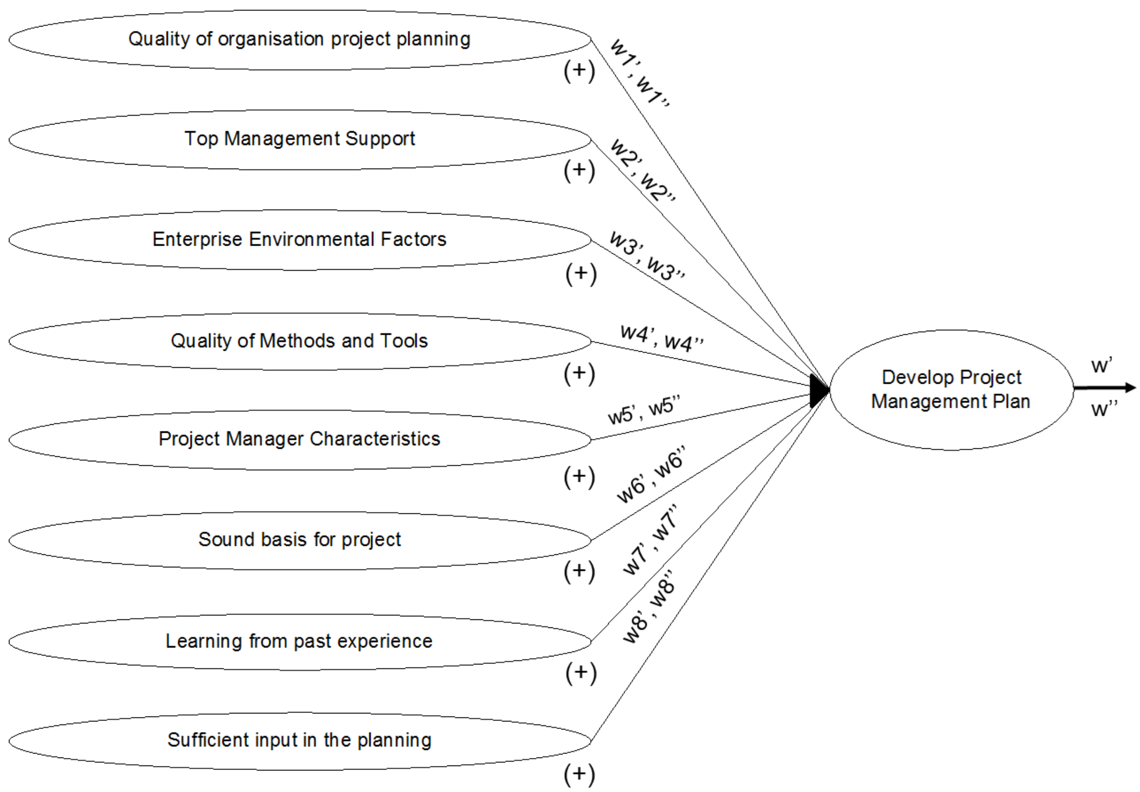

Figure 4.5: Develop project management plan

Note that this cognitive map indicates the edges that have a positive causal relationship with quality of planning ('+'). It also indicates edge's weights (w' and w'') with the number of the node.

The first weight (w') has the evaluation made by the project manager. This is made through the questionnaires Q1 and Q3 (Appendix A) and measured in a five-point Likert scale that was converted from 0.0 to 1.0, according to Table 4.2. This conversion allows compare QCM with QPM.

Table 4.2: Conversion scale for QCM
(for edges that have a positive causal relationship with quality of planning)

From 5-point Likert Scale	To Decimal Scale
Strongly agree	1.00
Agree	0.60
Neutral	0.50
Disagree	0.40
Strongly disagree	0.00

The second weight (w’’) is the average of weights from projects developed by the organisation (i.e., the past experience of the organisation). Likewise, each cognitive map has two weights that are indicated by w’ and w’’ (right-hand side of the cognitive map name).

The first weight is calculated by the average of evaluations made by the project manager that are converted according to Tables 4.2 and 4.3 (Section 4.4.7) (i.e., the average of edge’s weights). The generic mathematical equation for calculating the weights of the 21 QCM cognitive maps (Sections 4.4.3 to 4.4.23) is:

$$\text{w}' = \frac{\text{w1}' + \text{w2}' + \text{w3}' + \text{w4}' + \text{w5}' + \text{w6}' + \text{w7}' + \text{w8}' + \text{w9}' + \text{w10}'}{\text{number of nodes}}$$

Hence, as the cognitive map *Develop project management plan* has eight nodes (Figure 4.5), the equation applied for calculating its weight is the following:

```
w′ = (Quality of organisation planning
     + Top management support
     + Enterprise environment factors
     + Quality of methods and tools
     + Project manager characteristics
     + Sound basis for project
     + Learning from past experience
     + Sufficient input in the planning) /8
```

For example,

```
Quality of organisation planning  = 0.60
Top management support            = 0.80
Enterprise environment factors    = 0.30
Quality of methods and tools      = 0.30
Project manager characteristics   = 0.70
Sound basis for project           = 0.60
Learning from past experience     = 0.40
Sufficient input in the planning  = 0.50
```

Then,

```
w′ = (0.60+0.80+0.30+0.30+0.70+0.60+0.40+0.50)/8
w′ = 0.53
```

The generic equation for calculating the second weight of each node (i.e., the past experience of the organisation) is the following:

$$w'' = \sum_{1}^{np} w'$$

Where:

```
np: number of projects developed by the organisation
w’ edge’s weights of each project.
```

For example, the organisation developed two projects. In the first project, the project manager evaluated the node *Sound basis for project* as *Disagree*, then the edge’s weight is 0.4 (Table 4.2). In the second project, the project manager evaluated the same node as *Strongly agree*, then the edge’s weight is 1.00 (Table 4.2).

Then,

```
w" = (0.40+1.00)/2
w” = 0.70
```

4.4.4 Define Scope

The cognitive map define scope, shown in Figure 4.6, includes factors that refer to the processes required to ensure that the project includes the work required to complete the project successfully by developing a detailed description of the project and product (PMI, 2013).

Seven nodes form this cognitive map. The first node is the output from the technological expertise cognitive map (Section 4.4.20). The others are clear realistic objectives (Fortune and White, 2006; Reel, 1999; Johnson et al., 2001; Pinto and Slevin, 1986), compatibility with other systems (Büyüközkan and Ruan, 2008; Bradford and Florin, 2003), performance required (Fairley and Willshire, 2003), reliability required (Krishnamoorthy and Douglas, 1995; Reddy and Raju, 2009; Lui et al., 2009; Ngai et al., 2004), database size (Krishnamoorthy and Douglas, 1995; Reddy and Raju, 2009), and technical specifications detailed (Fairley and Willshire, 2003; Pinto and Slevin, 1986).

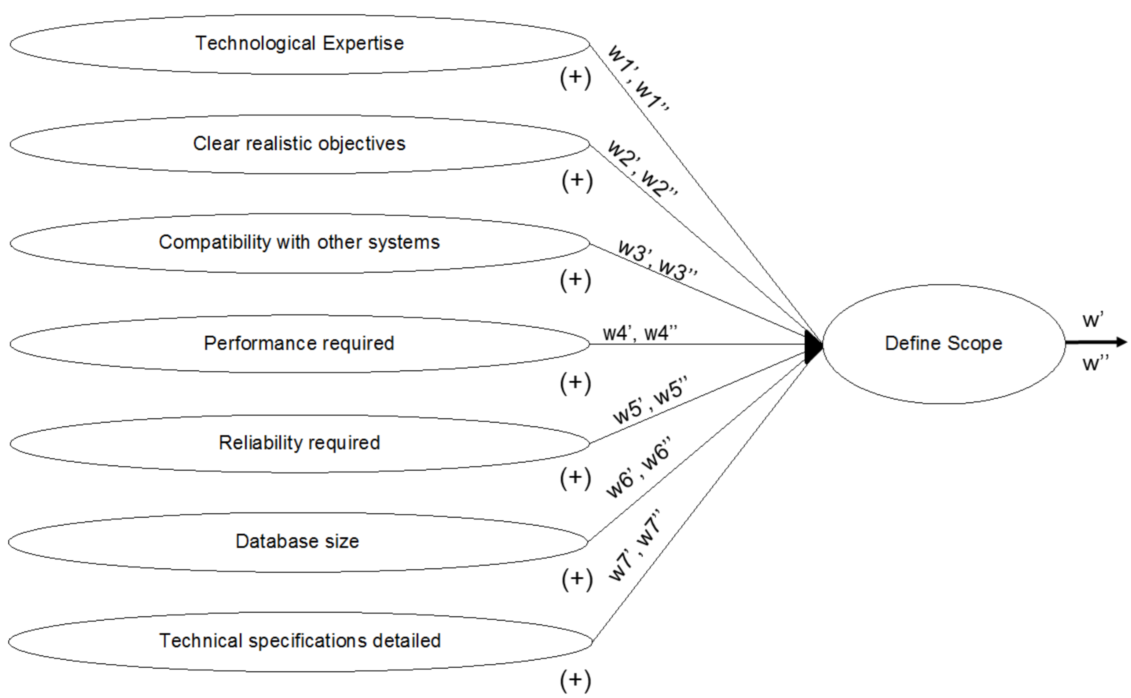

Figure 4.6: Define scope

The equation for calculating the weight of this cognitive map (derived from the generic equation presented in Section 4.4.3) is the following:

```
w' = (Technological Expertise
     + Clear realistic objectives
     + Compatibility with other systems
     + Performance required
     + Reliability required
     + Database size
     + Technical specifications detailed)/7
```

4.4.5 Create Work Breakdown Structure

The cognitive map create work breakdown structure (WBS), shown in Figure 4.7, includes factors that refer to the processes required to ensure that the project includes the work required to complete the project successfully by subdividing project work into smaller and more manageable components (PMI, 2013).

Two nodes form this cognitive map: the output from the technological expertise cognitive map (Section 4.4.20), and the use of prototypes to refine requirements (Butler and Fitzgerald, 1999).

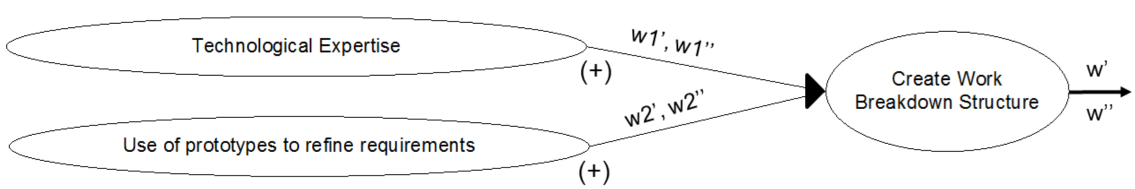

Figure 4.7: Create work breakdown structure

The equation for calculating the weight of this cognitive map (derived from the generic equation presented in Section 4.4.3) is the following:

```
w' = (Technological Expertise
     + Use of prototypes to refine requirements)/2
```

4.4.6 Define Activities

The cognitive map define activities, shown in Figure 4.8, includes factors that refer to processes required to accomplish the timely completion of the project by identifying specific actions to be performed to produce the project deliverables (PMI, 2013).

This cognitive map is formed by one node: alternative solutions planned (Alblas and Wortmann, 2012; Bannerman, 2008; Willcocks and Griffiths, 1994).

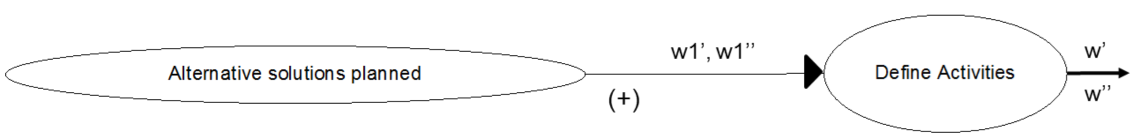

Figure 4.8: Define activities

The equation for calculating the weight of this cognitive map (derived from the generic equation presented in Section 4.4.3) is the following:

```
w' = (Alternative solutions planned)/1
```

4.4.7 Sequence Activities

The cognitive map sequence activities, shown in Figure 4.9, includes factors that refer to processes required to accomplish timely completion of the project, by identifying and document relationships among activities (PMI, 2013).

Two nodes form this cognitive map: multi-vendor complicate dependencies (Schmidt et al., 2001) and delivering most important features first (Chow and Cao, 2008; Napier et al., 2009).

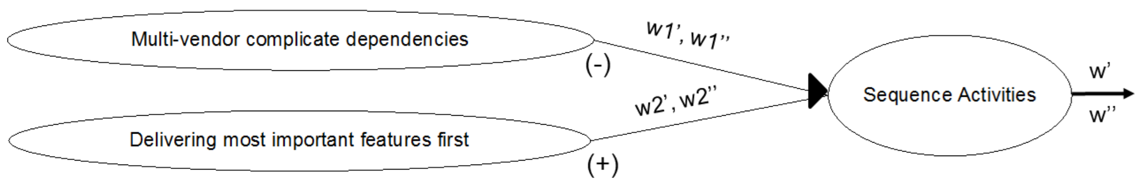

Figure 4.9: Sequence Activities

The equation for calculating the weight of this cognitive map (derived from the generic equation presented in Section 4.4.3) is the following:

```
w' = (Multi-vendor complicate dependencies
     + Delivering most important features first)/2
```

Note that the edge of ‘multi-vendor complicate dependencies’ has a negative causal relationship with quality of planning (‘-’). In this case, it is required to convert the scale according to Table 4.3 rather than Table 4.2.

Table 4.3: Conversion scale for QCM

(for edges that have a negative causal relationship with quality of planning)

From 5-point Likert Scale	To Decimal Scale
Strongly agree	0.00
Agree	0.40
Neutral	0.50
Disagree	0.60
Strongly disagree	1.00

4.4.8 Estimate Activity Resources

The cognitive map estimate activity resources, shown in Figure 4.10, includes factors that refer to processes required to accomplish timely completion of the project by estimating type/quantities of material/people/equipment/supplies required to perform each activity (PMI, 2013).

This cognitive map is formed by one node: contractor to fill gaps in expertise and transfer knowledge (Bradley, 2008; Loh and Koh, 2004), whether the organization does not have enough resources or expertise to perform certain project task.

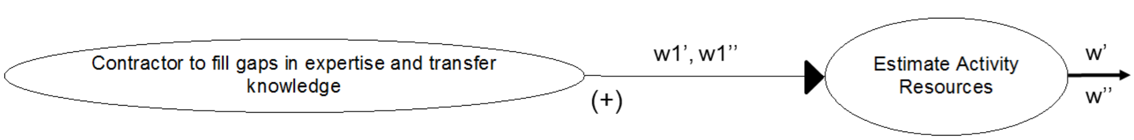

Figure 4.10: Estimate activity resources

The equation for calculating the weight of this cognitive map (derived from the generic equation presented in Section 4.4.3) is the following:

```
w' = (Contractor to fill gaps in expertise and transfer knowledge)/1
```

4.4.9 Estimate Activity Durations

The cognitive map estimate activity durations, shown in Figure 4.11, includes factors that refer to processes required to accomplish timely completion of the project by approximating the number of work periods needed to complete each activity (PMI, 2013).

This cognitive map is formed by one node: slack planned (Pinto and Slevin, 1986).

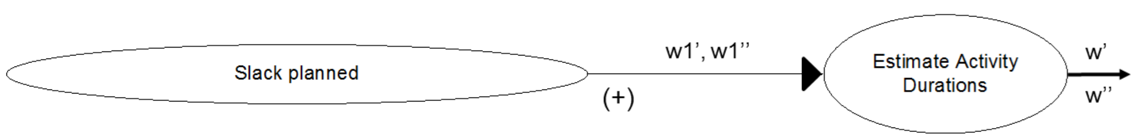

Figure 4.11: Estimate activity durations

The equation for calculating the weight of this cognitive map (derived from the generic equation presented in Section 4.4.3) is the following:

```
w' = (Slack planned)/1
```

4.4.10 Develop Schedule

The cognitive map develop schedule, shown in Figure 4.12, includes factors that refer to processes required to accomplish the timely completion of the project by analysing activity sequences, durations, requirements and constraints to create the schedule (PMI, 2013).

This cognitive map is formed by four nodes: time pressure on the project (Wohlin and Andrews, 2001), realistic schedule planned (Fortune and White, 2006; Reel, 1999; White, 2002; Dvir et al., 1998) and small releases planned (Fitzgerald et al., 2006; Johnson et al., 2001; Chow and Cao, 2008), which have a positive causal relationship with quality of planning, and overtime planned (Chow and Cao, 2008; Linberg, 1999), which has a negative causal relationship with quality of planning.

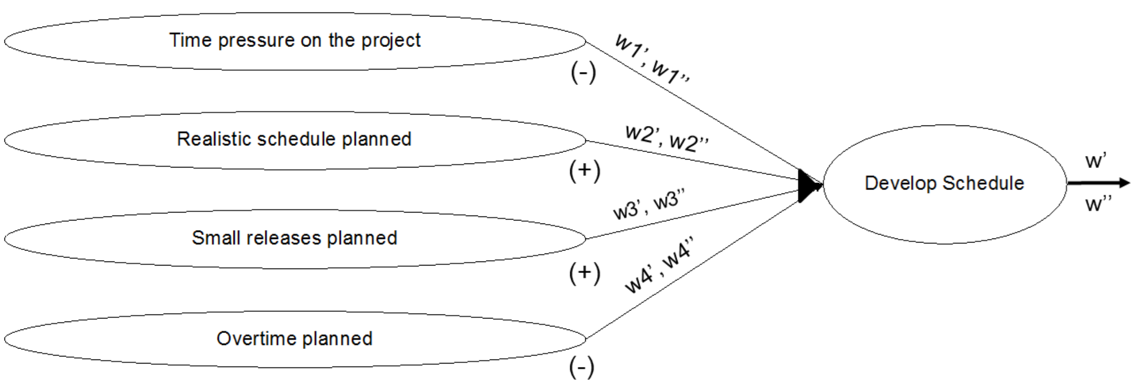

Figure 4.12: Develop schedule

The equation for calculating the weight of this cognitive map (derived from the generic equation presented in Section 4.4.3) is the following:

```
w' = (Time pressure on the project
     + Realistic schedule planned
     + Small releases planned
     + Overtime planned)/4
```

4.4.11 Estimate Costs

The cognitive map estimate costs, shown in Figure 4.13, includes factors that refer to processes involved in estimating, budgeting and controlling costs so that the project can be completed within the approved budget by developing an approximation of the monetary resources needed to complete project activities (PMI, 2013).

Two nodes form this cognitive map: the output from the technological expertise cognitive map (Section 4.4.20) and realistic effort estimates (Linberg, 1999; Reel, 1999; Jørgensen and Gruschke, 2009; Fortune and White, 2006; White, 2002; Napier et al., 2009).

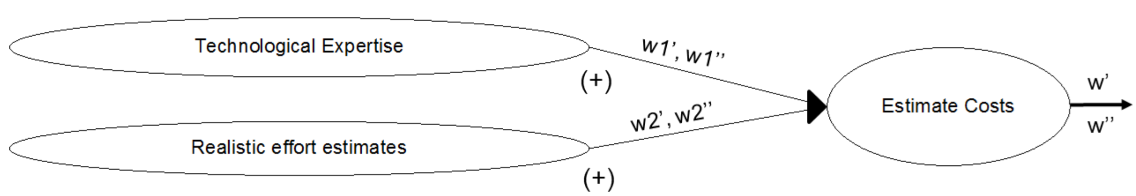

Figure 4.13: Estimate costs

The equation for calculating the weight of this cognitive map (derived from the generic equation presented in Section 4.4.3) is the following:

```
w' = (Technological Expertise
     + Realistic effort estimates)/2
```

4.4.12 Determine Budget

The cognitive map determine budget, shown in Figure 4.14, includes factors that refer to processes involved in estimating, budgeting and controlling costs (PMI, 2013).

Three nodes form this cognitive map: the output from the technological expertise cognitive map (Section 4.4.20), existence of project tools (Raymond and Bergeron, 2008; Johnson et al., 2001; Zwikael, 2008b) and secured funding (Loh and Koh, 2004; Tesch et al., 2007).

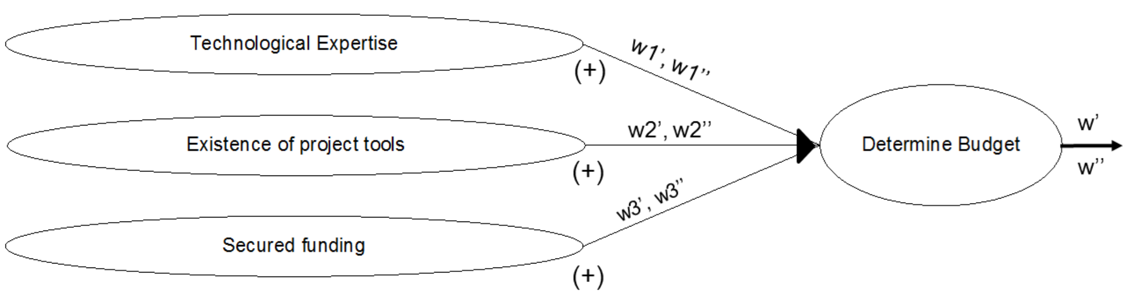

Figure 4.14: Determine budget

The equation for calculating the weight of this cognitive map (derived from the generic equation presented in Section 4.4.3) is the following:

```
w' = (Technological Expertise
     + Existence of project tools
     + Secure funding)/3
```

4.4.13 Plan Quality

The cognitive map plan quality, shown in Figure 4.15, includes factors that refer to processes and activities that determine organisation quality policies, objectives and responsibilities (PMI, 2013).

Seven nodes form this cognitive map: quality of requirement methodology, quality of test methodology, quality of configuration management system (Wohlin and Andrews, 2001), right amount of documentation developed (Chow and Cao, 2008; Fortune and White, 2006), rigor of project management plan review, rigor of development review and rigor of test planning review (Wohlin and Andrews, 2001; Linberg, 1999).

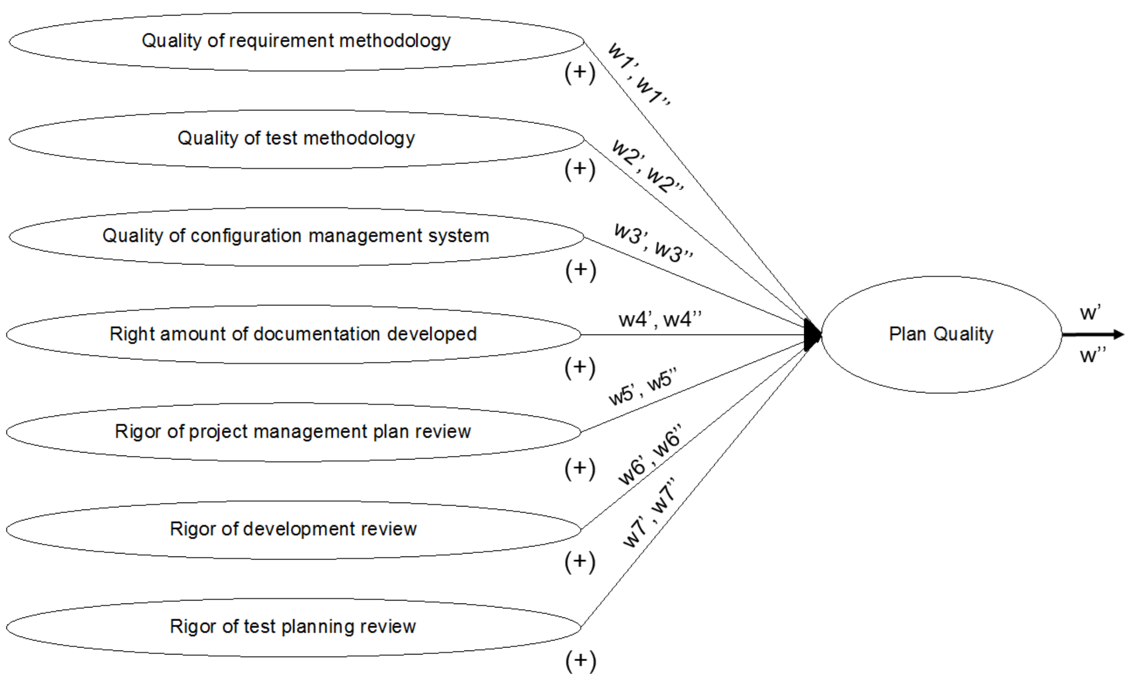

Figure 4.15: Plan quality

The equation for calculating the weight of this cognitive map (derived from the generic equation presented in Section 4.4.3) is the following:

```
w’ = (Quality of requirement methodology
    + Quality of test methodology
    + Quality of configuration management system
    + Right amount of documentation
    + Rigor of project management plan review
    + Rigor of development review
    + Rigor of test planning review)/7
```

4.4.14 Develop Human Resource Plan

The cognitive map develop HR plan, shown in Figure 4.16, includes factors that refer to processes that deal with the project team by identifying and documenting roles, responsibilities and required skills, and reporting relationships (PMI, 2013).

Three nodes form this cognitive map: appropriate technical training to team (Chow and Cao, 2008; Fortune and White, 2006; Pinto and Slevin, 1986), team members with great motivation (Chow and Cao, 2008; Willcocks and Griffiths, 1994; Linberg, 1999) and an appropriate approach for people management (Pinto and Slevin, 1986).

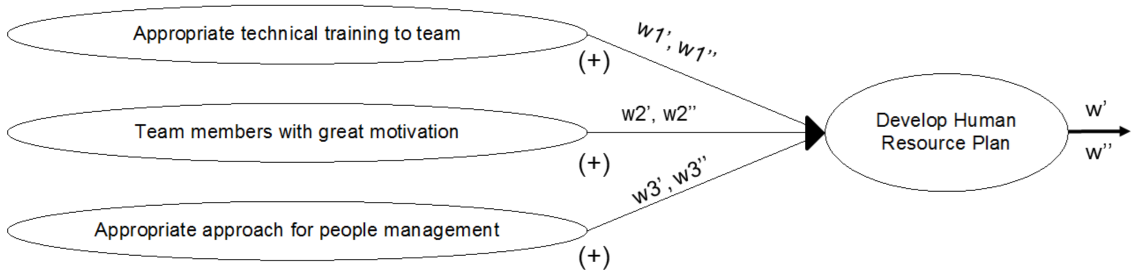

Figure 4.16: Develop human resource plan

The equation for calculating the weight of this cognitive map (derived from the generic equation presented in Section 4.4.3) is the following:

```
w' = (Appropriate technical training to team
     + Team members with great motivation
     + Appropriate approach for people management)/3
```

4.4.14 Acquire Project Team

The cognitive map acquire project team, shown in Figure 4.17, includes factors that refer to processes that deal with the allocation of HR required to complete project assignments (PMI, 2013).

Three nodes form this cognitive map: well-allocated resources (Chow and Cao, 2008; Fortune and White, 2006; Loh and Koh, 2004; Pinto and Slevin, 1986), sufficient resources (Fortune and White, 2006; Loh and Koh, 2004; Pinto and Slevin, 1986) and team members with high competence and expertise (Chow and Cao, 2008).

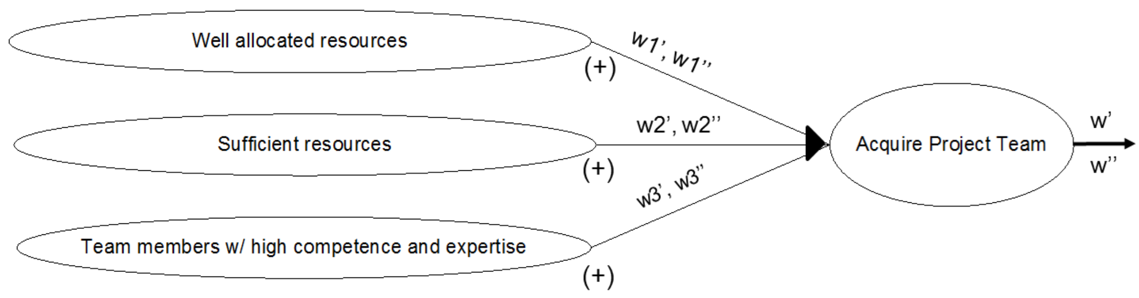

Figure 4.17: Acquire project team

The equation for calculating the weight of this cognitive map (derived from the generic equation presented in Section 4.4.3) is the following:

```
w' = (Well allocated resources
     + Sufficient resources
     + Team members with high competence and expertise)/3
```

4.4.16 Plan Communications

The cognitive map plan communications, shown in Figure 4.18, includes factors that refer to processes required to ensure timely and appropriate generation, collection, distribution, storage, retrieval and ultimate disposition of project information (PMI, 2013).

Six nodes form this cognitive map: cooperative organisational culture (Somers and Nelson, 2004; Chow and Cao, 2008), interdepartmental cooperation between planning groups (Somers and Nelson, 2004; Zwikael et al., 2005), oral culture placing high value on face-to-face communication (Chow and Cao, 2008), plan to promote effective communication between team members (White, 2002; Fortune and White, 2006), plan to involve the customer in the project (Chow and Cao, 2008; Fortune and White, 2006), and well-defined roles and responsibilities (Schmidt et al., 2001).

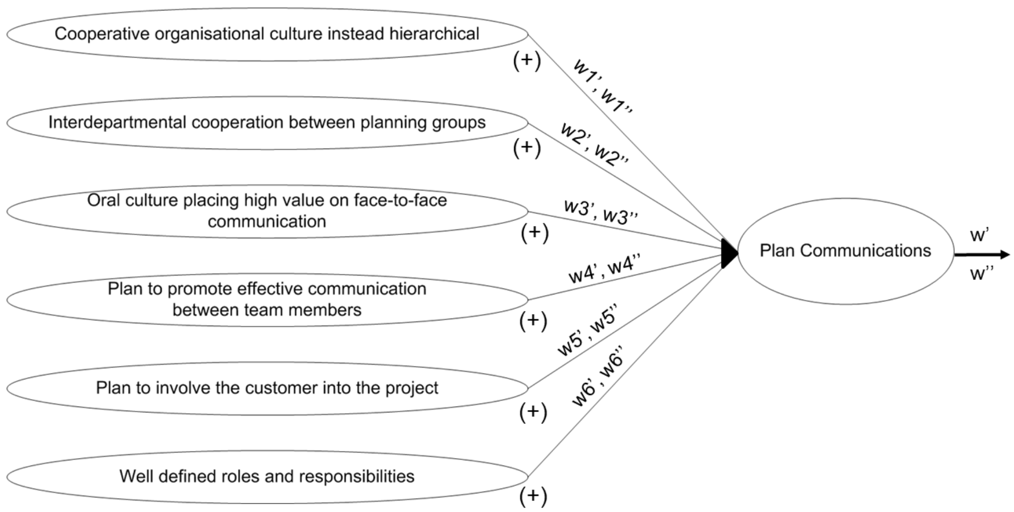

Figure 4.18: Plan communications

The equation for calculating the weight of this cognitive map (derived from the generic equation presented in Section 4.4.3) is the following:

```
w' = (Cooperative organisational culture instead hierarchical
     + Interdepartmental cooperation between planning groups
     + Oral culture placing high value on face-to-face communication
     + Plan to promote effective communication between team members
     + Plan to involve the customer into the project
     + Well defined roles and responsibilities)/6
```

4.4.17 Plan Risk Management

The cognitive map plan risk management, shown in Figure 4.19, includes factors that refer to processes of conducting risk management planning, identification, analysis, response planning, and monitoring and control on a project (PMI, 2013).

Nine nodes form this cognitive map: maturity of an organisation's processes for assigning ownership of risks (Cooke-Davies, 2002), multi-vendor complicates dependencies (Schmidt et al., 2001), risk level (Zwikael and Sadeh, 2007), secured funding (Loh and Koh, 2004; Tesch et al., 2007), team members with great motivation (Chow and Cao, 2008; Willcocks and Griffiths, 1994; Linberg, 1999), alternative solutions planned (Alblas and Wortmann, 2012; Bannerman, 2008; Willcocks and Griffiths, 1994, acceptance of possible failure planned (Fortune and White, 2006), occurrence of breakthrough (Dvir and Lechler, 2004; Reel, 1999) and up-front risk analysis done (Chow and Cao, 2008; Bannerman, 2008).

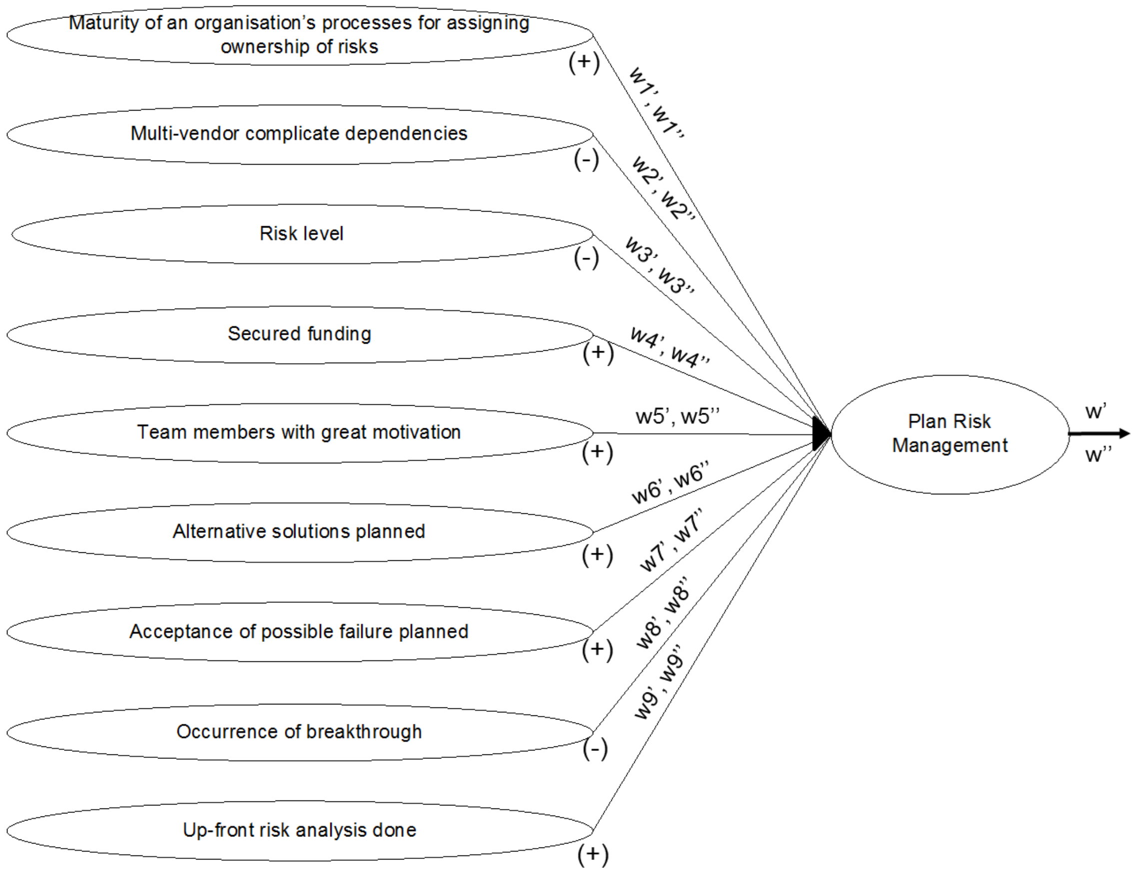

Figure 4.19: Plan risk management.

The equation for calculating the weight of this cognitive map (derived from the generic equation presented in Section 4.4.3) is the following:

```
w' = (Maturity of an organisation's processes for assigning ownership of risks
     + Multi-vendor complicate dependencies
     + Risk level
     + Secured funding
     + Team members with great motivation
     + Alternative solutions planned
     + Acceptance of possible failure planned
     + Occurrence of breakthrough
     + Up-front risk analysis done)/9
```

4.4.18 Plan Procurements

The cognitive map plan procurements, shown in Figure 4.20, includes factors that refer to the processes necessary to purchase or acquire products, services or results needed from outside the project team to perform the work (PMI, 2013).

Three nodes form this cognitive map: multi-vendor complicates dependencies (Schmidt et al., 2001), sufficient resources (Fortune and White, 2006; Loh and Koh, 2004; Pinto and Slevin, 1986) and contractor to fill gaps in expertise and transfer knowledge (Bradley, 2008; Loh and Koh, 2004).

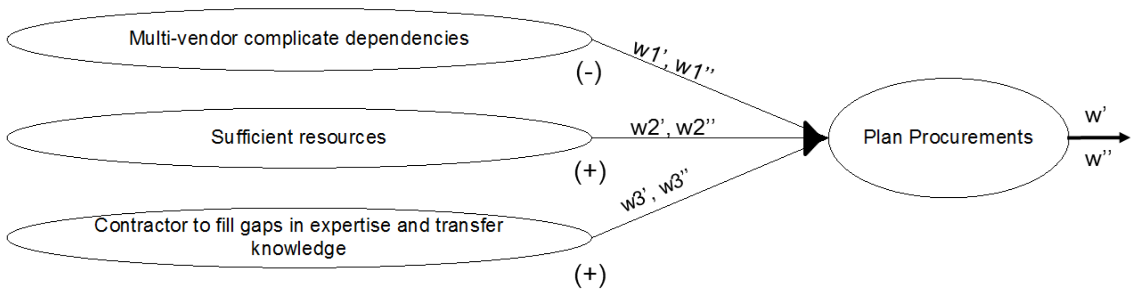

Figure 4.20: Plan procurements

The equation for calculating the weight of this cognitive map (derived from the generic equation presented in Section 4.4.3) is the following:

```
w' = (Multi-vendor complicate dependencies
     + Sufficient resources
     + Contractor to fill gaps in expertise and transfer of knowledge)/3
```

4.4.19 Project Manager Characteristics

The cognitive map project manager characteristics, shown in Figure 4.21, includes factors that refer to the project manager characteristics because of the fit between the personality of the project manager, level of knowledge and skills in project management (Patanakul and Milosevic, 2008), and the profile of the project it is associated with quality of planning (Malach-Pines et al., 2008; Patanakul et al., 2007).

Three nodes form this cognitive map: right amount of documentation developed (Chow and Cao, 2008; Fortune and White, 2006), well-allocated resources (Chow and Cao, 2008; Fortune and White, 2006; Loh and Koh, 2004; Pinto and Slevin, 1986) and appropriate approach for people management (Pinto and Slevin, 1986).

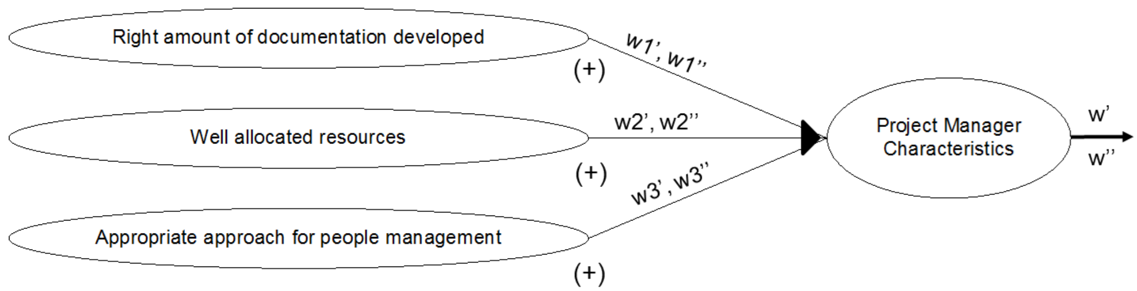

Figure 4.21: Project manager characteristics

The equation for calculating the weight of this cognitive map (derived from the generic equation presented in Section 4.4.3) is the following:

```
w' = (Right amount of documentation
     + Well allocated resources
     + Appropriate approach for people management)/3
```

4.4.20 Technological Expertise

The cognitive map technological expertise, shown in Figure 4.22, includes factors that refer to the knowledge and experience available in the project team, which are associated with quality of planning (Jørgensen and Gruschke, 2009; Scott-Young and Samson, 2008).

Eight nodes form this cognitive map: familiar technology (Fortune and White, 2006), performance required (Fairley and Willshire, 2003), reliability required (Krishnamoorthy and Douglas, 1995; Reddy and Raju, 2009; Lui et al., 2009; Ngai et al., 2004), database size (Krishnamoorthy and Douglas, 1995; Reddy and Raju, 2009), realistic effort estimates (Linberg, 1999; Reel, 1999; Jørgensen and Gruschke, 2009; Fortune and White, 2006; White, 2002; Napier et al., 2009), technical specifications detailed (Fairley and Willshire, 2003; Pinto and Slevin, 1986), team members with high competence and expertise (Chow and Cao, 2008), and contractor to fill gaps in expertise and transfer knowledge (Bradley, 2008; Loh and Koh, 2004).

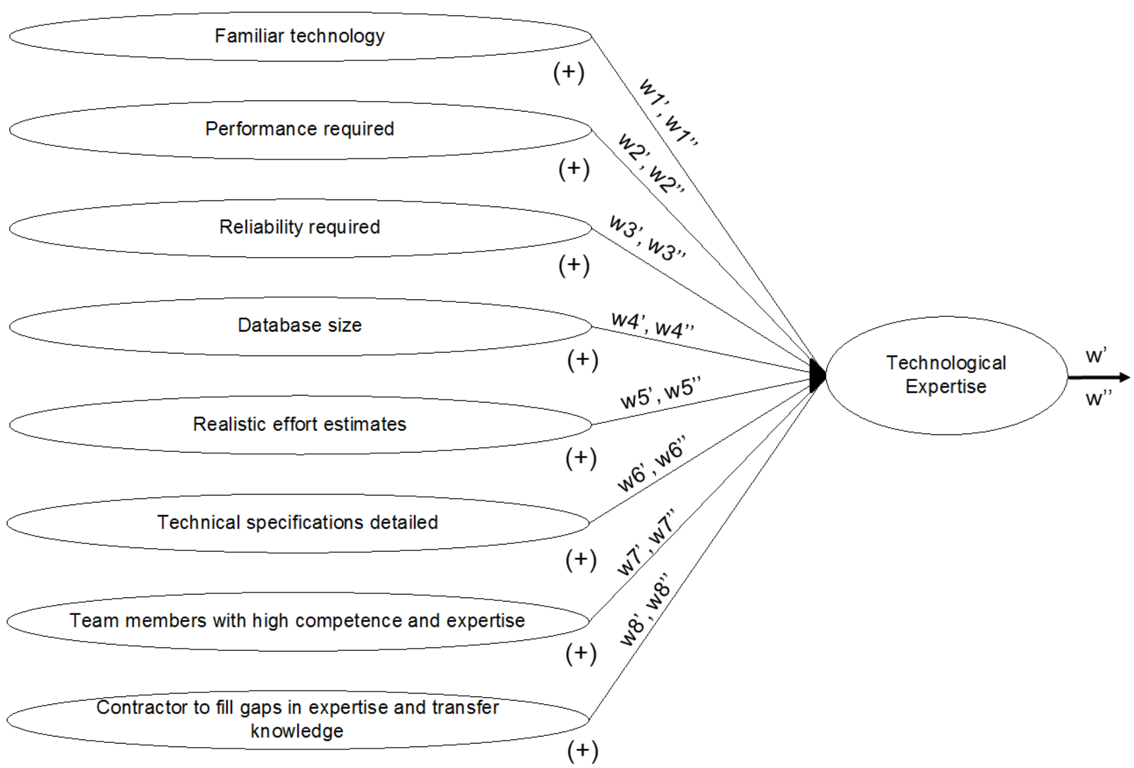

Figure 4.22: Technological expertise

The equation for calculating the weight of this cognitive map (derived from the generic equation presented in Section 4.4.3) is the following:

```
w' = (Familiar technology
     + Performance required
     + Reliability required
     + Database size
     + Realistic effort estimates
     + Technical specifications detailed
     + Team members with high competence and expertise
     + Contractor to fill gaps in expertise and transfer of knowledge)/8
```

4.4.21 Top Management Support

The cognitive map top management support, shown in Figure 4.23, includes factors that refer to the support from the top management to the project, which can lead to its success or failure (Kloppenborg et al., 2009; Zwikael, 2008a).

Six nodes form this cognitive map: quality of organisation project planning (quality of projects already undertaken by the organisation), appropriate project manager assigned (Zwikael and Globerson, 2004; Fortune and White, 2006; Pinto and Slevin, 1986; Bannerman, 2008; Patanakul et al., 2007), involvement of the project manager during the initiation phase (Zwikael et al., 2005), confidence of top manager support during the project (Chow and Cao, 2008; Fortune and White, 2006; Johnson et al., 2001; Pinto and Slevin, 1986; Bannerman, 2008), secured funding (Loh and Koh, 2004; Tesch et al., 2007) and sufficient resources (Fortune and White, 2006; Loh and Koh, 2004; Pinto and Slevin, 1986).

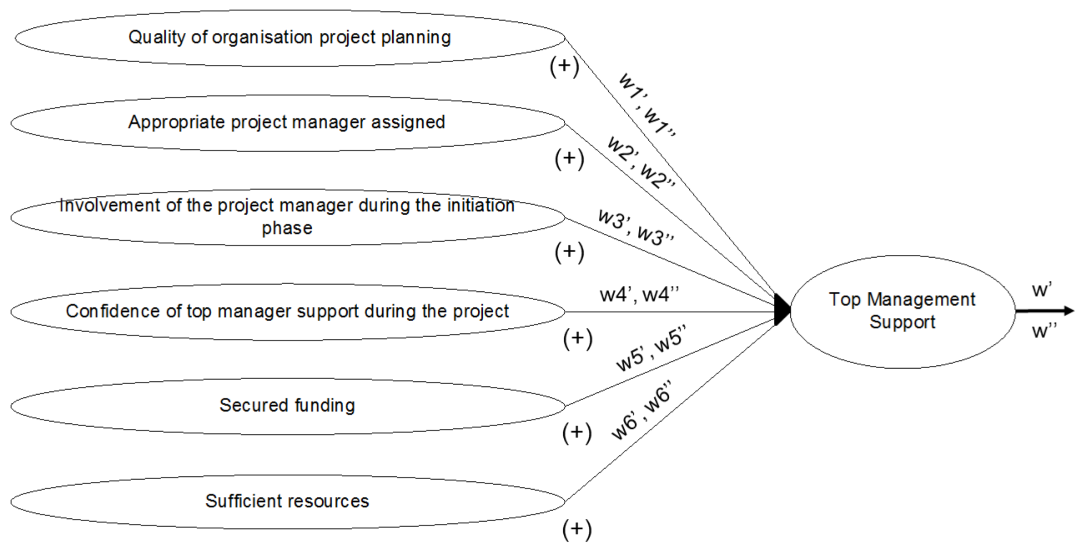

Figure 4.23: Top management support

The equation for calculating the weight of this cognitive map (derived from the generic equation presented in Section 4.4.3) is the following:

```
w' = (Quality of organisation project planning
     + Appropriate project manager assigned
     + Involvement of the project manager during the initiation phase
     + Confidence of top management support
     + Secure funding
     + Sufficient resources)/6
```

4.4.22 Enterprise Environmental Factors

The cognitive map enterprise environmental factors, shown in Figure 4.24, includes factors that refer to any or all environmental factors that affect quality of planning (Zwikael and Sadeh, 2007; Zwikael and Globerson, 2004; Krishnamoorthy and Douglas, 1995).

Ten nodes form this cognitive map: quality of organisation project planning and projects already undertaken by the organisation; time pressure on the project (Wohlin and Andrews, 2001), cooperative culture instead of hierarchical (Somers and Nelson, 2004; Chow and Cao, 2008), interdepartmental cooperation between planning groups (Somers and Nelson, 2004; Zwikael et al., 2005), oral culture placing high value on face-to-face communication (Chow and Cao, 2008), maturity of an organisation’s processes for assigning ownership of risks (Cooke-Davies, 2002), entrepreneurial climate for product innovation (Cooper and Kleinschmidt, 1995), organisational culture too political (Chow and Cao, 2008), turbulent environment (Willcocks and Griffiths, 1994; Fortune and White, 2006) and high turnover rate (Wohlin and Andrews, 2001).

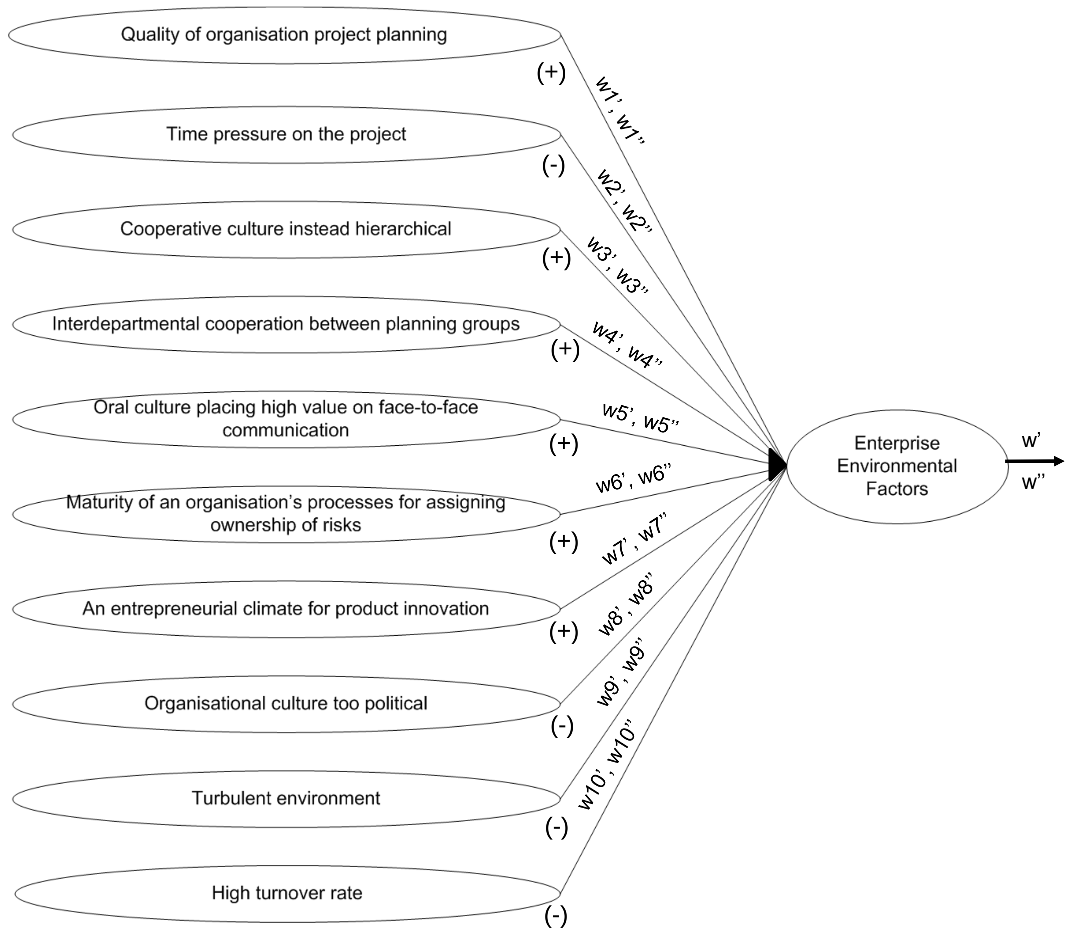

Figure 4.24: Enterprise environmental factors

The equation for calculating the weight of this cognitive map (derived from the generic equation presented in Section 4.4.3) is the following:

```
w′ = (Quality of organisation project planning
     + Time pressure on the project
     + Cooperative culture instead hierarchical
     + Interdepartmental cooperation between planning groups
     + Oral culture placing high value on face-to-face communication
     + Maturity of an organisation’s processes for assigning ownership of risks
     + An entrepreneurial climate for product innovation
     + Organisation culture too political
     + Turbulent environment
     + High turnover rate)/10
```

4.4.23 Quality of Methods and Tools

The cognitive map quality of methods and tools, shown in Figure 4.25, includes factors that refer to the infrastructure that surrounds or influences a project’s success (Jørgensen and Shepperd, 2007; Zwikael and Sadeh, 2007; Zwikael and Globerson, 2004).

Seven nodes form this cognitive map: quality of organisation project planning (i.e., the quality of projects already undertaken by the organisation); learning from past experience (Willcocks and Griffiths, 1994; Fortune and White, 2006), experience with similar projects (Willcocks and Griffiths, 1994; Dvir and Lechler, 2004), existence of project tools (Raymond and Bergeron, 2008; Johnson et al., 2001; Zwikael, 2008b), quality of requirement methodology, quality of test methodology and quality of configuration management system (Wohlin and Andrews, 2001).

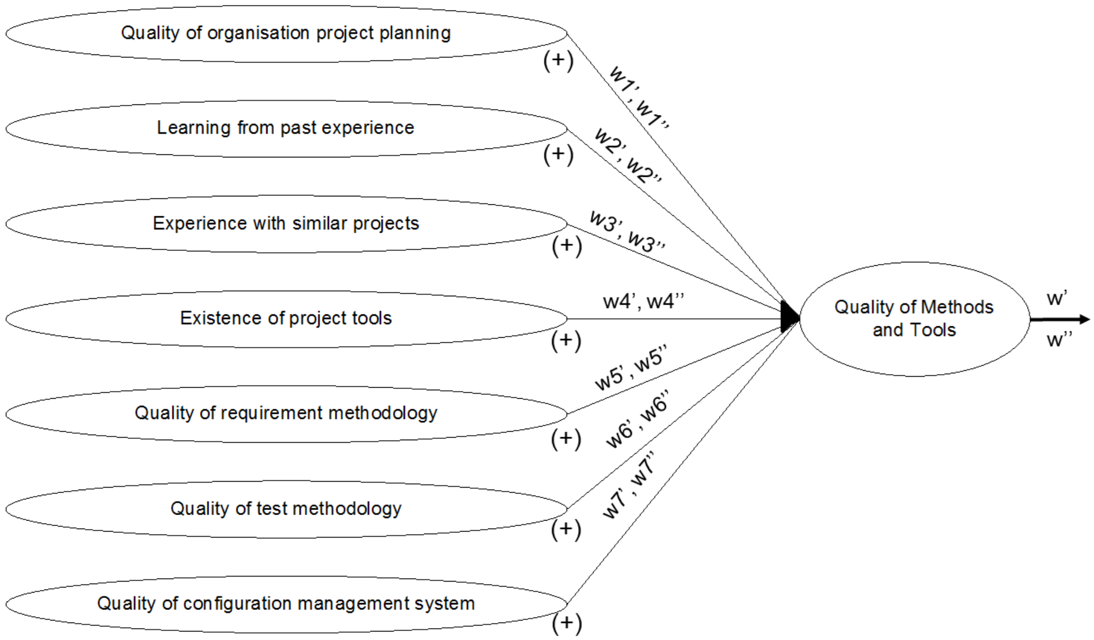

Figure 4.25: Quality of methods and tools

The equation for calculating the weight of this cognitive map (derived from the generic equation presented in Section 4.4.3) is the following:

```
w’ = (Quality of organisation project planning
     + Learning from past experience
     + Experience with similar projects
     + Existence of project tools
     + Quality of requirement methodology
     + Quality of test methodology
     + Quality of configuration management system)/7
```

4.5 Chapter Summary

In summary, this chapter described the QPEM model, an innovative artefact that evaluates the quality of planning of software development projects.

QPEM was designed to enhance the accuracy of the quality of planning evaluation through the use of two measures with top–down (QPM) and bottom–up (QCM) approaches (Alblas and Wortmann, 2012; Baker et al., 2011; Jørgensen, 2004). QPM comes from the project management literature (Zwikael and Globerson, 2004). It evaluates the quality of planning through top–down approach by evaluating the quality of 16 planning products from 16 core planning process defined in PMBOK (PMI, 2013). QCM is developed in this research. It is based on cognitive maps (Stach et al., 2005) and evaluates the quality of planning through a bottom–up approach by evaluating 55 factors that affect the same 16 core planning process used by QPM. This enables a comparison between both measures and the identification of strengths and weaknesses (Sedoglavich, 2008) of planning.

QPEM provides a means for estimating the quality of planning. QPEM's output is an index that ranges from 0.0 (lowest) to 1.0 (highest) that is classified in high, medium and low zones (Section 6.3.4). To be used by practitioners, QPEM needs to be embedded in a tool. QPLAN is the tool developed in this study that implements QPEM in practice (Chapter 5). This is complemented by Chapter 6, which evaluates both QPEM and QPLAN, Appendix A, which presents the questionnaires used for QPM and QCM, and Appendix B, which has the factors that are used by QCM.

Chapter 5: QPLAN Approach and Tool

> *A design artefact is complete and effective when it satisfies the requirements and constraints of the problem it was meant to solve* (Hevner et al., 2004, p.85).

5.1 Introduction

The software industry offers several tools aimed at helping project managers to do better planning: the project team builder (PTB) (Zwikael et al., 2015; Davidovitch et al., 2010), for training and teaching the concepts of project management and improving the decision-making process through simulation; SEER-SEM (Lagerström et al., 2012), for providing an estimation of project costs, schedule and risk; Spider Project Team (Bodea and Purnus, 2012), for managing risks; and ScrumDo (McHugh and Acton, 2012), who provides a set of tools for managing Scrum (an agile software development framework), such as tools for planning iterations and for checking iteration progress. Nonetheless, the software industry does not offer an effective tool for evaluating the quality of planning of software development projects, to be used by project managers, regardless of the project management approach adopted by the organisation. This was discussed in Section 1.3.

This chapter describes the design and development of the QPLAN approach and tool, which enhance project success by evaluating the quality of planning of software development projects and introducing best practices that enhance the planning process. Section 5.2 provides an overview of the QPLAN. Section 5.3 describes the QPLAN’s design, which comprises five components from the project management, computer science, electronic and international business literature. Section 5.4 presents the QPLAN approach for enhancing the success of software development projects, which comprises 12 steps to be performed in the planning and at the end of the project. Section 5.5 concludes this chapter.

5.2 Overview

The QPLAN tool is a desktop application for Microsoft Windows. It was developed by the researcher in C# (pronounced C sharp), an object-oriented programming language from Microsoft (Lutz and Laplante, 2003), through the integrated development environment (IDE) Microsoft Visual Studio (Rezaei et al., 2011). The software design and development was done concurrently with the examination within the business environment (Section 6.3). On the one hand, the validity of the software implementation (Section 6.2) was more complicated, due to the need to have to maintain compatibility with data already collected. On the other hand, the data collected and feedback received from the research participants allowed improve the software. The main screen of QPLAN has 1024 x 600 pixels and is divided into three areas (Figure 5.1).

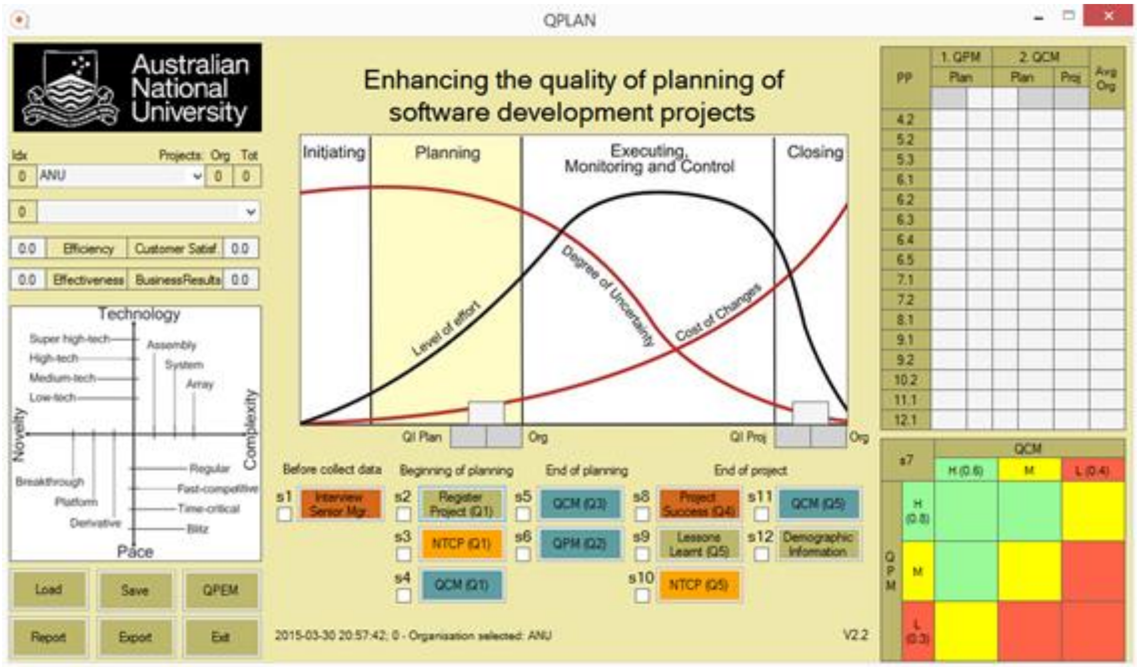

Figure 5.1: QPLAN main screen

On the left-hand side, from top to bottom, there is the logo of the organisation that participated in this research, index of the organisation in the QPLAN knowledge base (Section 5.3.5), organisation name, number of projects provided by the organisation and total number of projects in the QPLAN knowledge base (Section 5.3.5). Below that, there is an indication of project success according to Lechler and Dvir (2010) definition (Section 2.2.4) and the graphic representation of the NTCP diamond model (Section 5.3.2). In addition, there are six buttons:

1. load: load data from QPLAN knowledge base (Section 5.3.5)
2. save: save data to QPLAN knowledge base (Section 5.3.5)
3. QPEM: access the QPEM (Chapter 4)

4. report: generate project and organisation reports, which are readable by MS Word (Collins, 2013)
5. export: export raw data (Section 5.4.7.5), which are readable by MS Excel (Collins, 2013), and by a statistical tool such as SPSS (Hair et al., 2010)
6. exit: exit QPLAN tool.

The centre part shows the typical project life cycle (Section 2.3.2), with the level of effort, degree of uncertainty and cost of changes across the four project phases. At the end of planning, and at the end of the project, the level of risk is represented by high, medium or low (Section 6.3.4), and quality of planning index (QIPlan) and the organisation project quality index (QIPlanOrg). Below that, there are 11 buttons associated with the step number that correspond to the QPLAN approach for enhancing project success (Section 5.5). Moreover, there is the QPLAN version number and the register of the last QPLAN activity that is recorded in a log file.

The right-hand side contains a table with the evaluations made by QPM and QCM measures (Sections 4.3 and 4.4), the average of the planning processes evaluation from past projects developed by the organisation (then the project manager can compare if he or she is overestimating or underestimating the quality of each of the planning processes) and the quality indices calculated for each of the 16 core planning processes (Section 2.3.4.2). Below this table, there is an expanded Karnaugh map for contrasting results from QPM and QCM two measures (Section 5.3.3), which is graphically represented by a 3x3 matrix.

5.3 QPLAN Tool Design

The design of QPLAN is based on five main components, including:

1. QPEM: to evaluate the quality of planning
2. NTCP diamond model: to classify the project according to its characteristics (Shenhar and Dvir, 2007)
3. expanded Karnaugh map: to identify the strengths and weaknesses (Sedoglavich, 2008) of planning
4. lessons learnt: to identify the project's good and poor practices
5. knowledge base: to register the project experience and help the current planning through data from past projects developed by the organisation.

These components are used by QPLAN for enhancing the success of software development projects at the beginning of planning, at the end of planning and at the end of the project. This is described further in Section 5.4.

5.3.1 QPEM

As described in Chapter 4, QPEM evaluates the quality of planning through two measures: QPM, which has a top–down approach (Section 4.3), and QCM, which has a bottom–up approach (Section 4.4).

In QPLAN, the QPEM is used in Step 4 (Section 5.4.4), Step 5 (Section 5.4.5), Step 6 (Section 5.4.6) and Step 11 (Section 5.4.11) (see Figure 5.2).

5.3.2 NTCP Diamond Model

The NTCP is a model developed by Shenhar et al. (2001) for project classification. Based on contingency theory (Burns and Stalker, 1961), this is a free-of-context model that helps the project manager to plan the project according to its characteristics. However, if the project is classified incorrectly, it could negatively affect the project because of an increase in risks and resource allocation (Sauser et al., 2009). The NTCP diamond model has four dimensions: novelty, technology, complexity and pace.

- Novelty: the uncertainty of requirements. The scale is composed of derivative (extensions or improvements in currents products), platform (new generation of current product) and breakthrough (new product).
- Technology: the uncertainty of know-how. The scale is composed of low-tech, medium-tech, high-tech and super high-tech, which are technologies that did not previously exist; for example, the memristor developed by HP (Williams, 2008).
- Complexity: the number and diversity of elements in the system. The scale is composed of assembly (performs a single function), system (set of subsystems in a product) and array (dispersed set of systems interconnected).
- Pace: the urgency and available timeframe and effects in time management activities and team autonomy. The scale is composed of

regular (delays not critical), fast-competitive (time is important), time-critical (crucial) and blitz (need immediate solution).

In QPLAN, the NTCP diamond model is used in Step 3 (Section 5.4.3) and Step 10 (Section 5.4.10).

5.3.3 Expanded Karnaugh Map

The Karnaugh map is a method from the electronics literature that was developed by Karnaugh (1953) to simplify real-world logic requirements. In summary, rather than the use of extensive calculations, Karnaugh maps make use of the human brain's pattern-matching capability to get the simplest expression.

This method is mostly used in the electronics industry; however, there are creative exceptions. In 2008 for example, Sedoglavich (2008) expanded the original Karnaugh map to firm's status into three discrete zones (low, medium and high) for identifying strengths and weakness of New Zealand high-tech small and medium enterprises (SMEs) in the agro-technology sector.

In QPLAN, the expanded Karnaugh Map is used in Step 7 (Section 5.4.3).

5.3.4 Lessons Learnt

Lessons learnt are a critical factor of knowledge management and may come from current or past projects. The analysis of lessons learnt allows estimates to be obtained in the preliminary phases of the projects close to reality, support process improvement and for communicating with senior managers (Garon, 2006). In addition, the learning effect of this analysis may contribute to avoiding potential problems in future projects (Jørgensen and Gruschke, 2009). As lessons learnt are usually not effectively captured (Garon, 2006), in QPLAN, the lessons learnt are performed in three steps:

- Step 9 has a qualitative approach (Section 5.4.9) for getting the story behind a participant's experiences (Rossman and Rallis, 2003).
- Step 10 uses the NTCP diamond model (Section 5.4.10) for analysing the differences between project classification in the planning and at the end of project that will confirm whether the project management approach adopted was appropriate or not (this is a similar approach to that of Sauser et al., 2009, used to analyse NASA's Mars Climate Orbiter failures).
- Step 11 evaluates factors at the end of the project (Section 5.4.11). For example: during planning, the project manager may determine that the level of confidence that the senior manager will have in supporting the project is high (captured in question #22 as 'Agree' in Questionnaire 1, Appendix A). However, the senior manager may not have actually supported the project

as expected (captured in question #10 as ‘Disagree’ in Questionnaire 5, Appendix A). The project manager should then discuss this issue with the senior managers for the sake of future projects.

5.3.5 Knowledge Base

Knowledge management is the process of gathering, building, sharing and effectively using the knowledge, such as a set of techniques and methodologies (Sharma et al., 2007), within an organisation (Irani et al., 2009).

In QPLAN, the technology used for knowledge management in the organisation is a knowledge base, which is available during the entire project lifecycle. It is a database comprising qualitative and quantitative data formed from data from past projects developed by the participating organisation (i.e., the experience of the organisation in the development of software projects). It serves as a reference to the project manager to check whether the evaluation of a factor that affects the quality of planning, a planning process or even the final quality of planning, is being overestimated or underestimated. For example, the quality of planning calculated by QPLAN for a particular project is 0.32 (out of 1.0—see Tables 4.1 and 4.2). However, the average of past projects developed by the organisation is only 0.56. This should lead to reflection to determine why there is so much difference. This may lead to reworking of the project planning.

5.4 Enhancing Project Success

The QPLAN approach for enhancing project success is based on the evaluation of the quality of planning, and the introduction of best practices through 12 steps:

1. interview senior manager: identification of the success factors adopted in each organisation, and the barriers that had the most significant effect on project success
2. register project: register of the project in the QPLAN knowledge base
3. identify project characteristics: classification of the project according to its characteristics in the beginning of the planning
4. evaluate planning factors I: evaluation of 23 factors (out of 55 – Section 4.4.2; Table B.1) that affect the quality of planning in the beginning of planning
5. evaluate planning factors II: evaluation of 32 factors (out of 55 – Section 4.4.2; Table B.2) that affect the quality of planning at the end of planning
6. evaluate planning products: evaluation of 16 core planning products at the end of planning
7. analyse quality of planning: analyse of the quality of planning through a powerful set of resources provided by QPLAN (e.g., screens, reports and raw data)
8. evaluate project success: evaluation of the project success (Lechler and Dvir, 2010)

9. register lessons learnt: register of what went well and what should be different in the future
10. confirm project characteristics: classification of the project again at the end of the project
11. evaluate factors at the end of the project: evaluation of 12 factors at the end of the project
12. demographic information: register of the demographic information in the QPLAN knowledge base

See a graphic representation of this process in Figure 5.2, and the description of the 12 steps in the next sections.

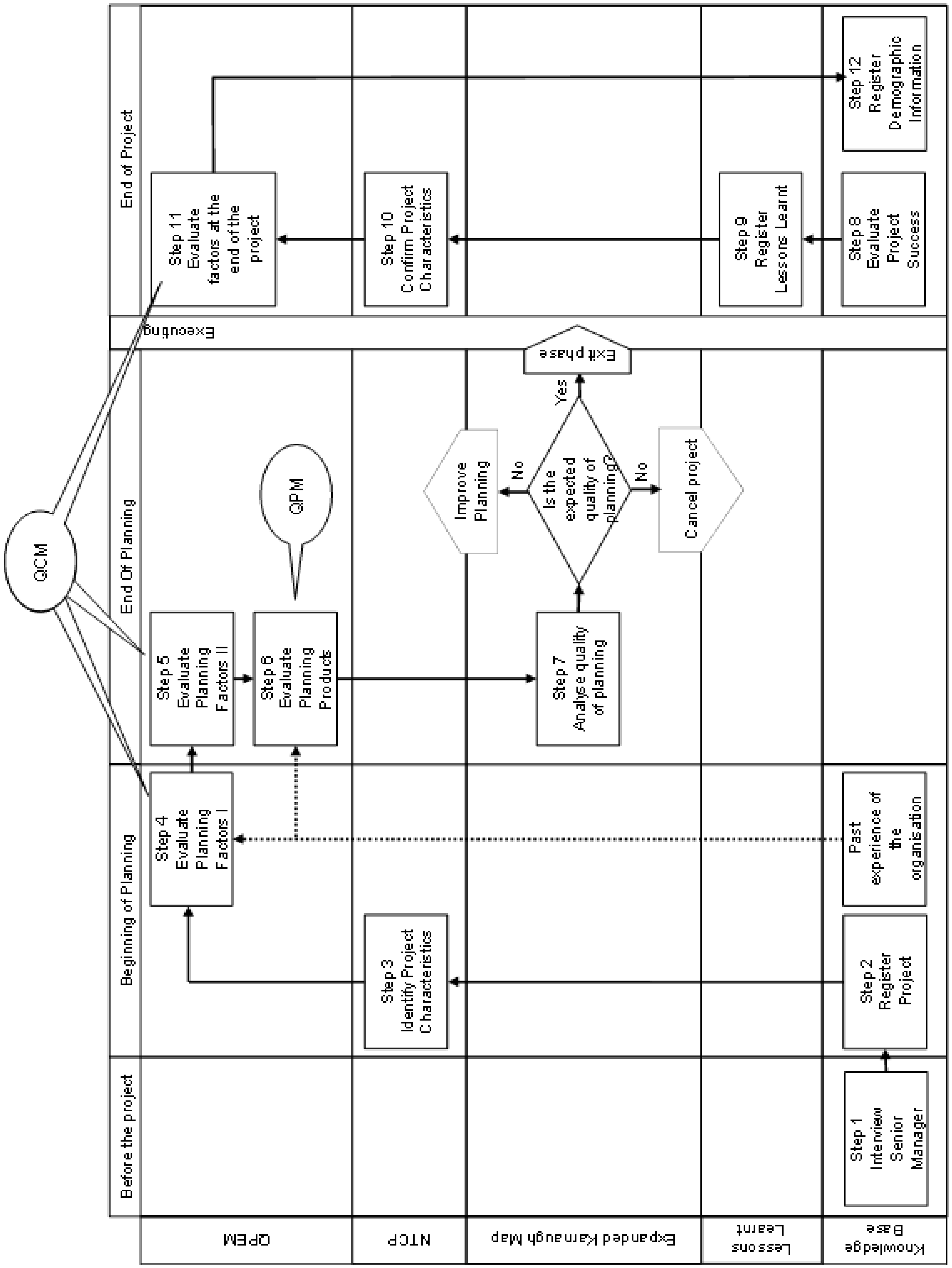

Figure 5.2: QPLAN approach for enhancing project success

5.4.1 Step 1—Interview Senior Manager

This step aims to register in the QPLAN knowledge base (Section 5.3.5) the interview with the senior manager (a senior manager in the organisation responsible for software development) (Appendix A). This step serves two purposes: a) validate whether success factors adopted by QPLAN (Lechler and Dvir, 2010) are suitable for software development projects (the success factors defined by Lechler and Dvir's (2010) work are not specific for software development projects; b) verify whether there are factors other than those considered by QPLAN that negatively affect the quality of planning. Sample, procedure, data analysis, results and discussion are presented in Section 6.3.2.

The interview with the senior manager is registered in the QPLAN knowledge base through the selection of the button 'Interview Senior Mgr.', which is located in the middle of the main screen (Figure 5.1). When the button is pressed, QPLAN shows a form to input data. This form has two questions: a) on the top, 'How do you measure success in software development projects?' b) on the bottom, 'Generally speaking, which barriers had the most significant effect on project performance? And, how did those factors affect various dimensions of project performance?' An example of an interview with a senior manager registered in QPLAN is shown in Figure 5.3.

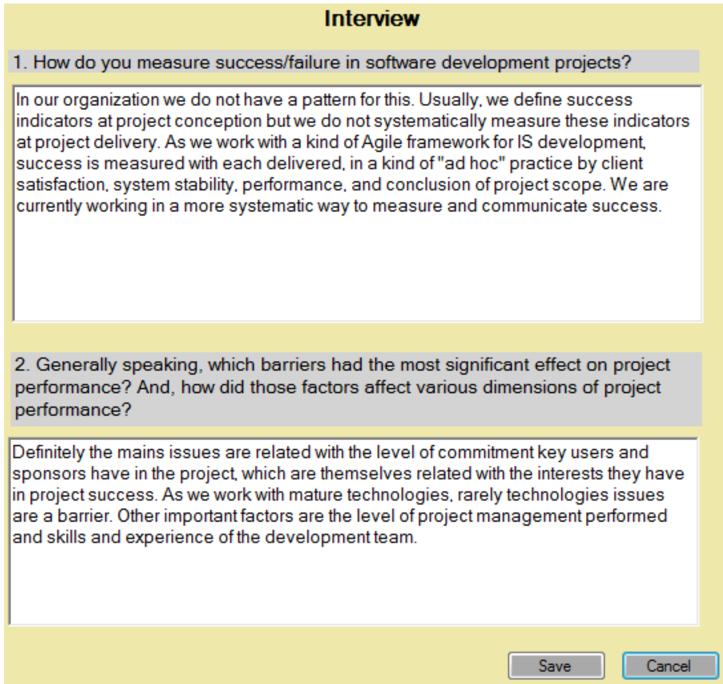

Figure 5.3: Example of interview

Likewise, there are two buttons located in the button of the form: (a) 'Save', which saves the data in the memory of QPLAN, and (b) 'Cancel', which discards all of the changes made in the form.

5.4.2 Step 2—Register Project

This step aims to register in the QPLAN knowledge base (Section 5.3.5) a new project to be developed by the organisation.

This is made by the project manager (the responsible for accomplishing the project objectives—PMI, 2013) at the beginning of planning by pressing the button 'Register Project (Q1)', which is located in the middle of the main screen (Figure 5.1). When pressing the button, QPLAN shows a form with the first eight questions from Questionnaire 1 (Appendix A): (1) project name, (2) project description, (3) start date, (4) duration, (5) programming language, (6) strategic goal (Shenhar and Dvir, 2007), (7) organisation software process maturity (Jiang et al., 2004) and (8) type of organisation structure (Belout and Gauvreau, 2004). In addition, there is a list box located at the top of the form, on the right-hand side, to indicate the country where the project is being developed (see Figure 5.4 for an example).

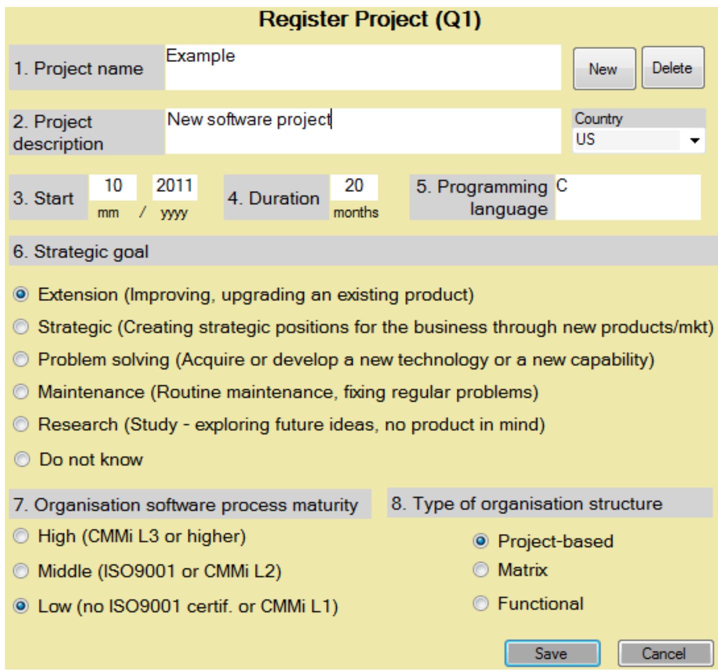

Figure 5.4: Example of registering a new project

This form has four buttons: (a) 'New', at the top of the form, which creates a new project in the QPLAN knowledge base; (b) 'Delete', at the top of the form, which deletes the entire project data from the QPLAN knowledge base; (c) 'Save', at the bottom of the form, which saves the data in the memory of QPLAN; and (d) 'Cancel', at the bottom of the form, which discards all of the changes made in the form.

5.4.3 Step 3—Identify Project Characteristics

This step aims to register in the QPLAN knowledge base (Section 5.3.5) the project classification made by the project manager through the NTCP diamond model (Section 5.3.2).

The project manager makes this classification at the beginning of the planning by selecting the button 'NTCP (Q1)', which is located in the middle of the main screen (Figure 5.1). When the button is selected, QPLAN shows a form with questions 9 to 12, which is part of Questionnaire 1 (Appendix A). An example is presented in Figure 5.5, where novelty was classified as breakthrough, technology as medium-tech, complexity as array, and pace (time frame) as fast.

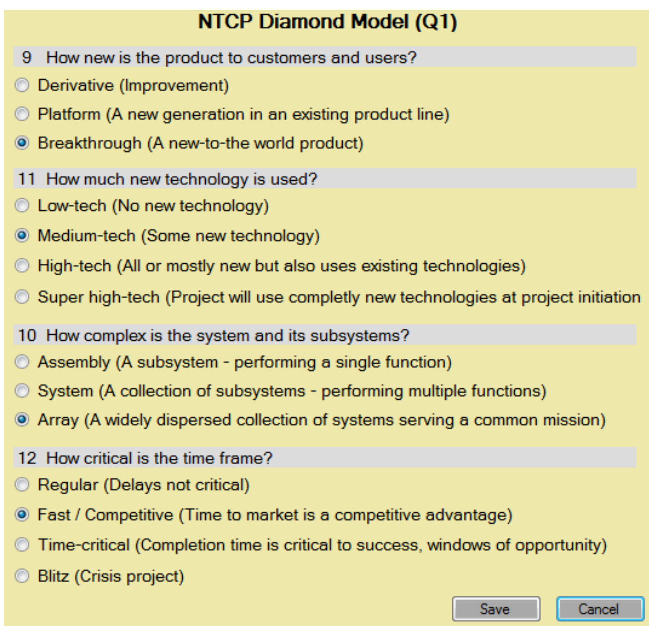

Figure 5.5: Example of project classification in planning

There are two buttons located at the button of the form: (a) ‘Save’, which saves the data in the memory of QPLAN and updates the graphical representation of the NTCP diamond model (see example in Figure 5.6); and (b) ‘Cancel’, which discards all of the changes made in the form.

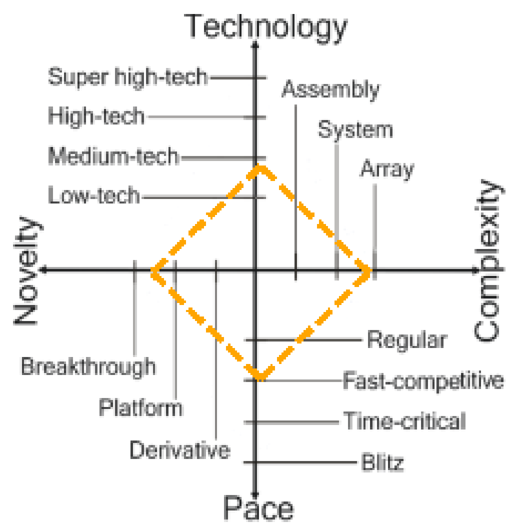

Figure 5.6: NTCP diamond model showing the project classification

5.4.4 Step 4—Evaluate Planning Factors I

This step aims to register in the QPLAN knowledge base (Section 5.3.5) the evaluation of 23 factors (out of 55 – Section 4.4.2; Table B.1). It is the first set of factors required by QPEM (Section 5.3.1) for evaluating the quality of planning through QCM (Section 4.4), and the data come from Questionnaire 1 (Appendix A).

The project manager makes this classification at the beginning of planning by selecting the button ‘QCM (Q1)’, which is located in the middle of the main screen

(Figure 5.1). When the button is selected, QPLAN shows a form with questions 13 to 20 (Figure 5.7).

Figure 5.7: Example of planning factors evaluation at the beginning of planning

Given the limited screen size, questions 13 to 35 are shown in three different screens (the first screen has questions 13–20, the second screen has questions 21–27 and the third screen has questions 28–35). The second and third screens are accessible through the button '>>', which is located at the bottom of the form. To return from the third to the second screen or from the second to the first screen, an additional button ('<<') must be pressed, which appears in the second and third screens.

In addition, there are two buttons: 'Save', which saves the data in the memory of QPLAN; and 'Cancel', which discards all of the changes made in the form.

5.4.5 Step 5—Evaluate Planning Factors II

This step aims to register in the QPLAN knowledge base (Section 5.3.5) the evaluation of 32 factors (out of 55 – Section 4.4.2; Table B.2). It is the second and last set of factors required by the QPEM (Section 5.3.1) for evaluating the quality of planning through QCM (Section 4.4), and the data come from Questionnaire 3 (Appendix A).

This is made by the project manager at the end of planning by selecting the button 'QCM (Q3)', which is located in the middle of the main screen (Figure 5.1). After pressing the button, QPLAN shows a form with questions 1 to 8 (Figure 5.8).

Figure 5.8: Example of planning factors evaluation at the end of planning

Given the limited screen size, questions 1 to 32 are shown in four different screens (the first screen has questions 1–8, the second screen has questions 9–16, the third screen has questions 17–24 and the fourth screen has questions 25–32). The second, third and fourth screens are accessible through the button ‘>>‘, which is located at the bottom of the form. To return from the fourth to the third screen, from the third to the second screen or from the second to the first screen, an additional button (‘<<‘) must be pressed, which appears in the second, third and fourth screens.

In addition, there are two buttons: ‘Save’, which saves the data in the memory of QPLAN; and ‘Cancel’, which discards all of the changes made in the form.

5.4.6 Step 6—Evaluate Planning Products

This step aims to register in the QPLAN knowledge base (Section 5.3.5) the evaluation of 16 planning products (Table 2.1 and Section 4.3) that are in Questionnaire 2 (Appendix A). It is the set of factors required by QPEM (Section 5.3.1) for evaluating the quality of planning through QPM (Section 4.3), and the data come from Questionnaire 2 (Appendix A).

This is made by the project manager at the end of planning by selecting the button ‘QPM (Q2)’, which is located in the middle of the main screen (Figure 5.1). When the button is selected, QPLAN shows a form with questions 1 to 8 (Figure 5.9).

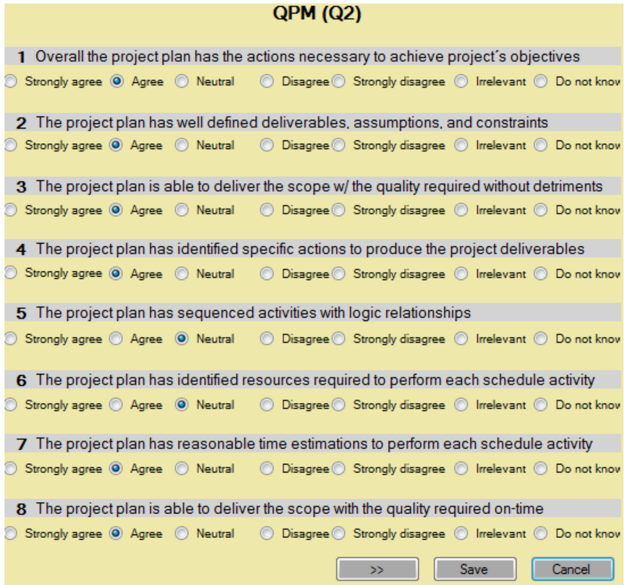

Figure 5.9: Example of planning products evaluation at the end of planning

Given the limited screen size, questions 1 to 16 are shown in two different screens (the first screen has questions 1–8 and the second screen has questions 9–16). The second screen is accessible through the button '>>', which is located at the bottom of the form. To return from the second to the first screen, an additional button ('<<') must be pressed, which appears in the second screen.

In addition, there are two buttons: 'Save', which saves the data in the memory of QPLAN; and 'Cancel', which discards all of the changes made in the form.

5.4.7 Step 7—Analyse Quality of Planning

This step aims to help project managers better plan and decide whether the project should go to the next phase, continue in the planning until better results are achieved (by focusing on the most important issues on planning) or even terminate the project before investing more resources.

This is made by the project manager through the analysis of the vast information about the quality of planning provided by QPLAN, which allows the manager to focus on the most important planning issues and check whether the quality of the project planning is in accordance with the organisation's expectations. They are: a) quality of planning indices at organisation, project, planning processes and cognitive maps levels (Section 5.4.7.1); and b) the identification of strengths and weakness of planning (Section 5.4.7.2). This information is available in QPLAN screens (Sections 5.4.7.1 and 5.4.7.2), project report (Section 5.4.7.3), organisation report (Section 5.4.7.4) and raw data exported by QPLAN (Section 5.4.7.5).

5.4.7.1 Planning Quality Indices

QPLAN provides four types of quality indices that allow the project manager to enhance the quality of planning by analysing the most important issues. They are:

a) Planning quality index (QIPlan): an index that represents the quality of project planning of software development projects. QIPlan is calculated by QPEM from the average of QPM (Section 4.3) and QCM (Section 4.4), ranges from 0.0 to 1.0, and is shown in the middle of the main screen. Figure 5.10 shows an example where QIPlan is 0.58.

b) Organisation planning quality index (QIPlanOrg): an index that represents the quality of project planning of software development projects of the organisation. QIPlanOrg is calculated by QPLAN from the average of QIPlan from the past projects developed by the organisation (Section 6.3.6), ranges from 0.0 to 1.0, and is shown in the middle of the main screen. Figure 5.10 shows an example where QIPlanOrg is 0.53.

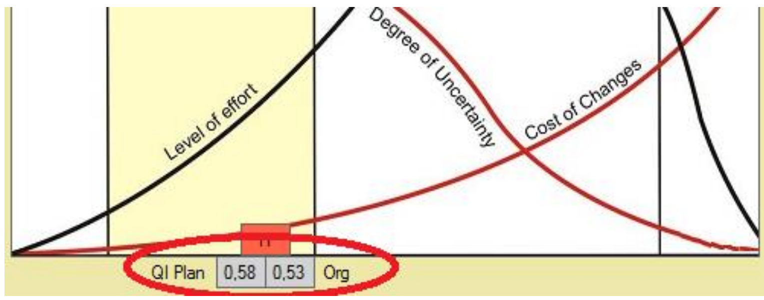

Figure 5.10: Example of QIPlan and QIPlan Org

c) Planning processes quality indices: a set of 32 indices that represents the quality of the 16 core planning processes (Section 2.3.4.2) evaluated by QPM and QCM. QPM planning processes quality indices are calculated according a weighted linear combination of the quality of single planning products from planning processes defined in the PMBOK (Section 4.3); QCM planning processes quality indices are calculated according to QCM cognitive maps (Section 4.4). These indices ranges from 0.0 to 1.0 and are shown on the left-hand side of the main screen. See an example in Figure 5.11 (given the limited screen space, the 16 core planning processes were coded in numbers according to Table 5.1, following the definition made by PMBOK—PMI, 2013).

Table 5.1: Planning processes code for showing in QPLAN

Code	Planning Processes	Code	Planning Processes
4.2	Develop Project Management Plan	7.1	Estimate Costs
5.2	Define Scope	7.2	Determine Budget
5.3	Create Work Breakdown Structure	8.1	Plan Quality
6.1	Define Activities	9.1	Develop Human Resource Plan
6.2	Sequence Activities	9.2	Acquire Project Team
6.3	Estimate Activity Resources	10.2	Plan Communications
6.4	Estimate Activity Durations	11.1	Plan Risk Management
6.5	Develop Schedule	12.1	Plan Procurements

Note that in Figure 5.11, the first column contains the planning processes coded according to Table 5.1, and there are two columns for QPM and QCM evaluations, with the planning processes quality indices calculated, and high-, medium- and low-level zones (Section 6.3.5). On the top, there are the overall QPM and QCM quality indices (i.e., the average of the 16 core planning processes).

PP	1. QPM		2. QCM	
	Plan		Plan	
	0,66	H	M	0,51
4.2	0,80	H	M	0,51
5.2	0,80	H	L	0,44
5.3	0,80	H	M	0,51
6.1	0,80	H	M	0,50
6.2	0,50	M	H	0,60
6.3	0,50	M	L	0,40
6.4	0,80	H	H	0,60
6.5	0,80	H	M	0,53
7.1	0,50	M	L	0,46
7.2	0,50	M	L	0,47
8.1	0,80	H	M	0,56
9.1	0,80	H	H	0,67
9.2	0,30	L	L	0,43
10.2	0,50	M	M	0,52
11.1	0,80	H	M	0,50
12.1	0,50	M	M	0,47

Figure 5.11: Example of planning processes quality indices

d) Cognitive maps quality indices: a set of 21 indices that represents the quality of QCM cognitive maps (Section 4.4). These indices range from 0.0 to 1.0 and are accessible through button 'QPEM', which is located in located in the left-hand side of the main screen (Figure 5.1). See an example in Figure 5.12, where quality index of the enterprise environment factors cognitive map (Section 4.4.22) is 0.44, and the average of the organisation for this cognitive map is 0.44 (above and below the row, respectively).

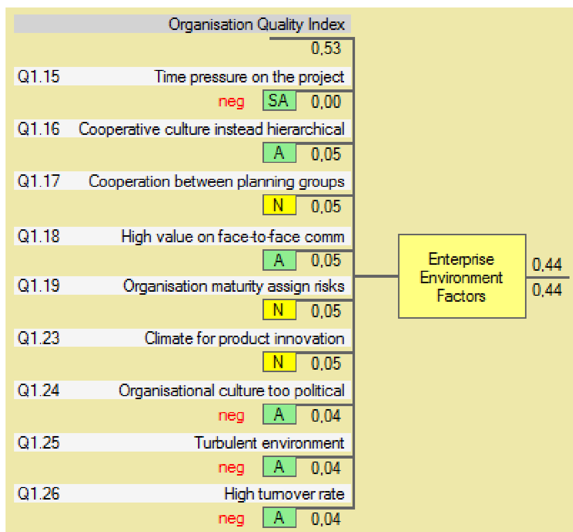

Figure 5.12: Example of enterprise environment factors cognitive map

Note that Figure 5.12 also shows the evaluation made by the project manager during the planning that generated these quality indices (Section 6.3.3). It has the node name and the questionnaire number with the number of the question (e.g., Q1.15 is question #15 in the questionnaire 1), the evaluation made by the project manager and an indication whether the causal relationship is negative ('neg').

The analysis of planning quality indices starts by checking whether QIPlan achieved the expected planning quality, which can be determined by the organisation or use a criterion such as used by QPLAN for determining quality zones (Section 6.3.4), such as a threshold of 0.7 out of 1.0. If QIPlan is equal to or higher than the threshold, the project manager can exit the planning.

Otherwise, the project manager can continue planning until better results are achieved. He or she can start by identifying the planning processes quality indices that are in the low-quality zones and work to improve them (in the example of Figure 5.11, it the planning process 9.2—Acquire Project Team for QPM, and the planning processes 5.2—Define Scope, 7.1—Estimate Costs, 7.2—Determine Budget and 9.2—Acquire Project Team for QCM). From this list of planning processes in the low-quality zone evaluated by QCM, the project manager can go deeper to identify the root causes by analysing the cognitive maps quality indices and the factors that led to the low rating. In addition, the project manager can compare QIPlan with QIPlanOrg to check whether the quality of project planning is lower or higher than the average of the organisation (perhaps it is an organisation issue that is affecting the quality of the project and not the quality of the project itself).

5.4.7.2 Strengths and Weaknesses of Planning

QPLAN provides the strengths and weakness of planning that allow the project manager to enhance the quality of planning by focusing on the planning processes with the lowest ratings.

This is made by QPLAN from the contrast of the 16 core planning processes (Section 2.3.4.2) evaluations made by QPM (Section 4.3) and CQM (Section 4.4), which are shown in an expanded Karnaugh map (Section 5.3.3) with high-, medium- and low-quality zones (Section 6.3.4) (given the limited screen space, the 16 core planning processes were coded in numbers according to Table 5.1). For example, in Figure 5.13, the low zone (in red) has planning processes 5.3, 7.1, 7.2, 8.1, 9.2 and 12.1. The medium zone (in yellow) has planning processes 4.2, 5.2, 6.1, 6.3, 6.4, 9.1 and 10.2. The high zone (in green) has planning processes 6.2, 6.5 and 11.1.

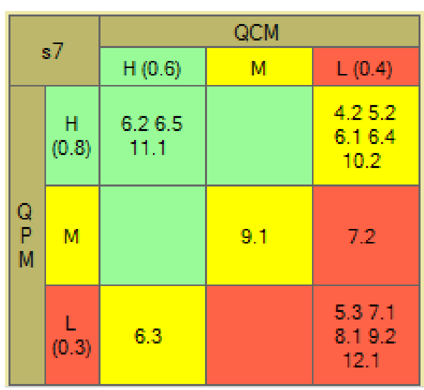

Figure 5.13: Example of expanded Karnaugh map

That is, QPLAN suggests focusing on the planning processes 5.3, 7.1, 7.2, 8.1, 9.2 and 12.1 (Table 5.1). The analyses of only five planning processes to enhance the quality of planning, rather than 16 core planning processes, is a substantial saving of time for the project manager during the work for enhancing the quality of planning.

5.4.7.3 Project Report

The project report helps project managers to better plan by providing quality indices, strengths and weakness of planning, all of the project data, suggestions for enhancing planning quality, and success comparisons and factors evaluations with past projects.

This is done by selecting the button ‘Report’, which is located on the left-hand side of the main screen (Figure 5.1). QPLAN opens a dialog box, and ‘Project Report’ should be selected in the list box named ‘Type’. QPLAN then creates a report that is readable by Microsoft Word (Collins, 2013). See an example in Figure 5.14 with suggestions for enhancing the quality of planning at the project level (Section 4.1 from the project report).

4.1. Suggestions for improving the quality of planning

a) Compare QPM and QCM measures

QPM	QCM	Planning Processes
H	H	6.2 6.5 11.1
H	M	
M	H	
M	M	9.1
H	L	4.2 5.2 6.1 6.4 10.2
L	H	6.3
M	L	7.2
L	M	
L	L	5.3 7.1 8.1 9.2 12.1

and focus on

a) Low:

5.3. Create WBS
7.1. Estimate costs
8.1. Plan quality
9.2. Acquire project team
12.1. Plan procurements
7.2. Determine budget

b) Medium:

4.2. Develop project management plan
5.2. Define scope
6.1. Define activities
6.4. Estimate activity durations
10.2. Plan communications
9.1. Develop human resource plan

Figure 5.14: Example with suggestions for enhancing the quality of planning

5.4.7.4 Organisation Report

The organisation report helps organisations to enhance project success and planning processes by providing a roadmap of projects developed by the organisation, the project's quality indices and a list of common issues reported by project managers during the development.

This is done by selecting the button 'Report', which is located on the left-hand side of the main screen (Figure 5.1). QPLAN opens a dialog box, and 'Organisation Report' should be selected in the list box named 'Type'. QPLAN then creates a report that is readable by Microsoft Word (Collins, 2013). See an example in Figure 5.15 with the performance of the organisation on planning processes, and Figure 5.16 provides an example of common issues reported by project managers during project development at the organisation level.

3. Average Quality of Planning Processes

High

- 4.2. Develop project management plan
- 9.1. Develop human resource plan
- 9.2. Acquire project team
- 10.2. Plan communications

Medium

- 5.2. Define scope
- 5.3. Create WBS
- 6.1. Define activities
- 6.2. Sequence activities
- 6.4. Estimate activity durations
- 6.5. Develop schedule
- 7.1. Estimate costs
- 7.2. Determine budget
- 8.1. Plan quality
- 11.1. Plan risk management

Low

- 6.3. Estimate activity resource
- 12.1. Plan procurements

Figure 5.15: Example of average quality of planning processes

4. Common Issues

1	30%	Lack of slack planned
2	20%	Database size not reasonable to manage
3	20%	Not delivering most important features first
4	15%	Lack of quality of configuration management system
5	15%	Risk of obsolescence
6	10%	Multi-vendor complicated dependencies
7	10%	Lack of existence of project tools
8	10%	Software development not subject to rigorous review
9	10%	Lack of plan to involve customer in the project
10	10%	Lack of alternative solutions planned
11	5%	Lack of sound basis for project
12	5%	Lack of cooperation between planning groups
13	5%	Lack of sufficient input in the planning
14	5%	Lack of prototypes to refine requirements
15	5%	Compatibility with other systems
16	5%	Performance required not reasonable to achieve
17	5%	Reliability required not reasonable to achieve
18	5%	Unrealistic effort estimates
19	5%	Unsecured funding
20	5%	Inadequate amount of documentation
21	5%	Lack of acceptance of possible failure planned

Figure 5.16: Example of issues reported by project managers

5.4.7.5 Raw Data

The raw data existing in the QPLAN knowledge base can be exported to other tools, such as Microsoft Excel (Collins, 2013) and SPSS (Hair et al., 2010). This is done by selecting the button ‘Export’, which is located on the left-hand side of the main screen (Figure 5.1).

The project manager should type the filename, and QPLAN will export the data existing in its knowledge base (Section 5.3.5) in .xls file format (Figure 5.17).

4.2. Develop project management plan_(weight_QCM_plan)	4.2. Develop project management plan_(weight_QCM_proj)	4.2. Develop project management plan_(weight_plan_org)	5.2. Define scope_(QPM)	5.2. Define scope_(weight_QCM_plan)	5.2. Define scope_(weight_QCM_proj)	5.2. Define scope_(weight_plan_org)	5.3. Create WBS_(QPM)	5.3. Create WBS_(weight_QCM_plan)	5.3. Create WBS_(weight_QCM_proj)	5.3. Create WBS_(weight_plan_org)	6.1. Define activities_(QPM)
0,26875	0,263333333	0,464701172	Low1	0,574285714	0,572857143	0,505833333	Low2	0,26	0,3525	0,395416667	Medium
0,419269051	0,461521495	0,464701172	High1	0,268571429	0,268571429	0,505833333	N.A	0,44	0,37	0,395416667	High1
0,70685346	0,761515717	0,464701172	High2	0,917142857	0,917142857	0,505833333	High2	0,91	0,855	0,395416667	High2
0,364672643	0,279905782	0,464701172	Low1	0,378571429	0,368571429	0,505833333	Medium	0,475	0,22	0,395416667	High1
0,216981054	0,156558439	0,464701172	Low2	0,234285714	0,227142857	0,505833333	Low1	0,12	0,0475	0,395416667	Low1
0	0	0,464701172	Low2	0	0	0,505833333	Low2	0	0	0,395416667	Low2
0,249308241	0,20054365	0,464701172	Low2	0,057142857	0,057142857	0,505833333	Low2	0	0	0,395416667	Low2
0,275294909	0,19251296	0,464701172	Low1	0,897142857	0,877142857	0,505833333	DNK	0,64	0,285	0,395416667	High1
0,473914346	0,475245018	0,769172707	High2	0,45138544	0,444920763	0,709134957	Medium	0,353232693	0,262889069	0,70226728	High1
0,717307533	0,598140426	0,769172707	High1	0,666001179	0,641613964	0,709134957	High1	0,587336084	0,31825955	0,70226728	High2
0,691247163	0,574899543	0,769172707	High1	0,70941879	0,682439098	0,709134957	High1	0,788643843	0,435414737	0,70226728	High2
0,794447526	0,651068814	0,769172707	High1	0,899060753	0,864225504	0,709134957	Medium	0,864475091	0,469915705	0,70226728	High2
0,808748276	0,662518492	0,769172707	High1	0,917447432	0,882217855	0,709134957	High2	0,907377341	0,495104997	0,70226728	High1

Figure 5.17: Example of raw data exported by QPLAN

5.4.8 Step 8—Evaluate Project Success

This step aims to register in the QPLAN knowledge base (Section 5.3.5) the evaluation of project success. The concept of project success follows Lechler and Dvir's (2010) work (Section 2.2.4) and is measured through 12 factors (Table B.3), and the data come from Questionnaire 4 (Appendix A).

This is made by the project manager's supervisor (the manager of the project manager) at the end of the project by selecting the button 'Project Success (Q4)', which is located in the middle of the main screen below (Figure 5.1). When the button is selected, QPLAN shows a form with questions 1 to 8 (Figure 5.18).

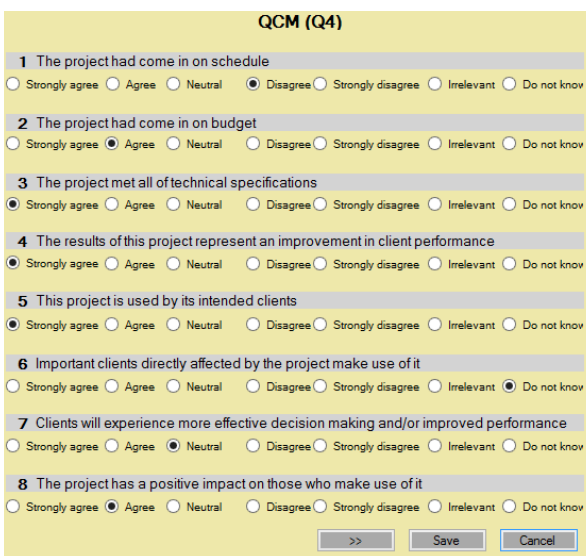

Figure 5.18: Example of project success valuation at the end of planning

Given the limited screen size, questions 1 to 12 are shown in two different screens (the first screen has questions 1–8 and the second screen has questions 9–12). The second screen is accessible through the button '>>', which is located at the bottom of the form. To return from the second to the first screen, an additional button (‘<<‘) must be pressed, which appears in the second screen.

In addition, there are two buttons: ‘Save’, which saves the data in the memory of QPLAN; and ‘Cancel’, which discards all of the changes made in the form. When the button ‘Save’ is selected, QPLAN updates the main screen (left-hand side, on the top). Figure 5.19 shows an example of project success indication according to the example presented in Figure 5.18.

0,50	Efficiency	Customer Satisf.	0,55
0,82	Effectiveness	BusinessResults	1,00

Figure 5.19: Indication of project success in the main screen

5.4.9 Step 9—Register Lessons Learnt

This step aims to register in QPLAN knowledge base (Section 5.3.5) the lessons learnt from the project (Section 5.3.4). This is the first part of the lessons-learnt process (Section 5.3.4), and the data come from Questionnaire 5 (Appendix A).

This is made by the project manager and team members at the end of the project by selecting the button ‘Lessons Learnt (Q5)’, which is located in the middle of the main screen (Figure 5.1). When the button is selected, QPLAN shows a form to register what went well in the project and what should be done differently in the future (Reel, 1999;

Jørgensen and Gruschke, 2009). See an example of lessons learnt registered in QPLAN in Figure 5.20.

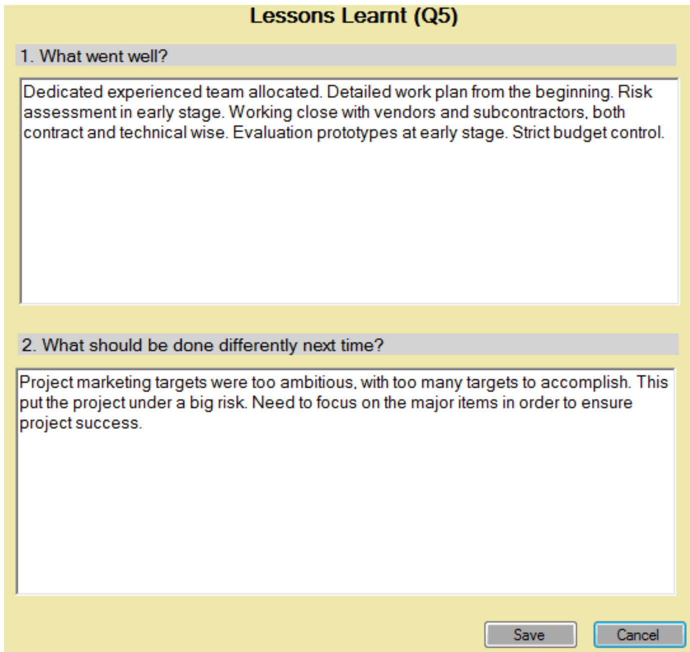

Figure 5.20: Example of lessons learnt

5.4.10 Step 10—Confirm Project Characteristics

This step aims to confirm the project classification made by the project manager in the beginning of planning and register in QPLAN knowledge base (Section 5.3.5). It serves to analyse the differences between project classifications made in the planning (Step 3, Section 5.4.3) and at the end of the project by confirming whether the management approach adopted was appropriate. This is a similar approach to that of Sauser et al. (2009), who analysed NASA's Mars Climate Orbiter failures through the NTCP diamond model (Section 5.3.2). It is the second part of the lessons-learnt process (Section 5.3.4), and the data come from Questionnaire 5 (Appendix A).

This is made by the project manager at the end of the project by selecting the button ‘NTCP (Q5)’, which is located in the middle of the main screen (Figure 5.1). When the button is selected, QPLAN shows a form with questions 13 to 16. See an example in Figure 5.21, where novelty was classified as derivative, technology as medium-tech, complexity as system, and pace as fast.

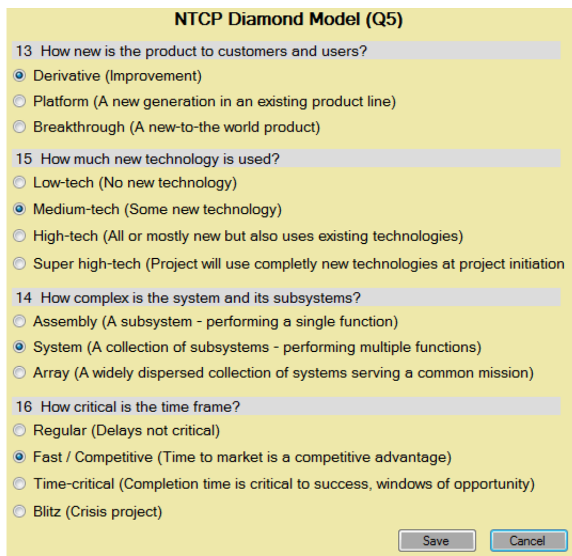

Figure 5.21: Example of project classification at the end of project

In addition, there are two buttons: ‘Save’, which saves the data in the memory of QPLAN; and ‘Cancel’, which discards all of the changes made in the form.

When the button ‘Save’ is selected, QPLAN updates the graphical representation of the NTCP diamond mode, which is located on the left-hand side of the main screen (Section 5.2). Figure 5.22 shows a comparison to the examples from Figures 5.5, 5.6 (dashed line) and 5.21 (solid line).

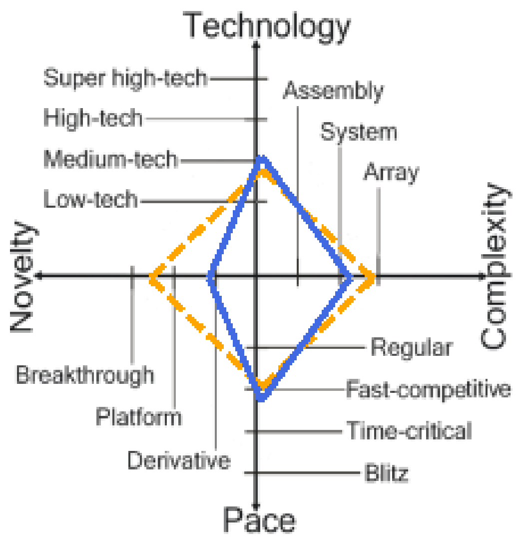

Figure 5.22: Differences founded in the project classification made at the beginning of planning and at the end of the project

This information is also available in project report (Section 5.4.7.3). See an example in Figure 5.23 that shows suggestions for improving the next project: to check answers provided in questionnaire 1 (Q1), questionnaire 2 (Q2), questionnaire 3 (Q3) and questionnaire 5 (Q5), and to compare the classification made at the beginning of planning (column ‘Planning’) and at the end of the project (column ‘Closing’).

4.2. Suggestions for improving the next project

a) Consider findings from lesson learnt (check Q3)
b) Compare planning processes indices V average of the organisation (check item 3)
c) Compare your answers V average of the organisation (check Q1, Q2, Q3, Q5)
d) Compare project classification on planning V on closing

Dimension	Planning	Closing
Novelty	Breakthrough	Derivative
Technology	Medium tech	Medium tech
Complexity	Array	System
Pace	Fast competitive	Fast competitive

Figure 5.23: Project report showing the differences founded in the project classification made in the beginning of planning and at the end of the project

5.4.11 Step 11—Evaluate Factors at the End of the Project

This step aims to register in the QPLAN knowledge base (Section 5.3.5) the evaluation of 10 factors (Table B.4). It is the third part of the lessons-learnt process (Section 5.3.4), and the data come from Questionnaire 5 (Appendix A).

This is made by the project manager at the end of project by selecting the button ‘QCM (Q5)’. QPLAN then shows a form with questions 3 to 10 (Figure 5.24).

Figure 5.24: Example of planning factors evaluation at the end of the project

Given the limited screen size, questions 3 to 12 are shown in two different screens (the first screen has questions 3–10 and the second screen has questions 11–12). The second screen is accessible through the button '>>', which is located at the bottom of the form. To return from the second to the first screen, an additional button ('<<') must be pressed, which appears in the second screen.

In addition, there are two buttons: 'Save', which saves the data in the memory of QPLAN; and 'Cancel', which discards all of the changes made in the form.

5.4.12 Step 12—Demographic Information

This step aims to register in the QPLAN knowledge base (Section 5.3.5) the demographic information (Appendix A) about the project manager (e.g., gender, age and experience), which methodology or framework he or she adopted in the project development, and information about the organisation (e.g., number of employees and type of industry).

This is made at the end of the project by selecting the button 'Demographic Information', which is located in the middle of the main screen (Figure 5.1). When the button is selected, QPLAN shows a form with questions 1 to 5 (see an example in Figure 5.25).

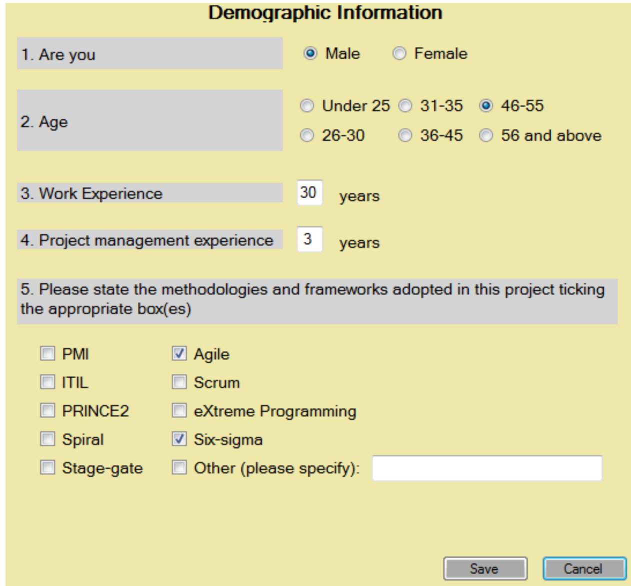

Figure 5.25: Example of demographic information

5.5 Chapter Summary

In summary, this chapter described the QPLAN approach and tool, which increases project success by evaluating the quality of planning of software development projects and by introducing best practices in the software development planning process.

The evaluation of the quality of planning is made by QPEM (Section 5.3.1). This is supported by the QPLAN knowledge base (Section 5.3.5), which provides information about quality of planning, as well as data from past projects developed by the organisation. Hence, the project manager can focus on the most important planning issues, check whether the quality of project planning is in accordance with the organisation’s expectations, and decide whether the project should go to the next phase, continue planning until better results are achieved, or terminate the project before investing more resources.

The introduction of best practices that enhance the planning process occurs at the planning and at the end of the project. In the planning, there is the NTCP diamond model (Section 5.3.2), which helps the project manager plan according to the project's characteristics, and the expanded Karnaugh Map (Section 5.3.3), which helps the project manager to focus on the weaknesses of planning. At the end of the project, there is the lessons-learnt process (Section 5.3.4), which aims to identify what went well and what should be done differently in future projects. This is registered in the knowledge base (Section 5.3.5) so that future projects can take advantage of it.

This chapter is complemented by the QPEM described in Chapter 4, the interviews with senior managers in Appendix A (Step 1), the five questionnaires (Steps 2–6 and 8–11) and the demographic information questions (Step 12), and the factors (and references) used by QPLAN in Appendix B. Likewise, Chapter 6 describes the testing and evaluation of QPLAN.

Chapter 6: QPEM and QPLAN Testing and Evaluation

6.1 Introduction

This chapter describes the testing and evaluation of the QPEM model and the QPLAN tool. Section 6.2 begins by ensuring that the implementation of the QPLAN worked as expected, performing the White Box test, which tested the calculation of the quality indices, and the Black Box test, which tested QPLAN functionality, completeness and usability. Section 6.3 examines the QPLAN intensively within the business environment through multiple case studies and a variety of quantitative and qualitative methods. Section 6.4 concludes this chapter.

It should be noted that six out of eight software quality characteristics defined by the quality model from ISO/IEC 25010 were taken into account in the test of QPLAN to ensure that its implementation worked as expected. They are: functional suitability — because of the white box and black box testings (Sections 6.22 and Section 6.2.3), reliability and compatibility — because the knowledge base can be accessed by other tools (Section 5.4.7.5), operability — because of the usability characteristics of the dashboard screen style (Section 5.2) and maintainability and transferability — because of the programming language adopted (Section 5.4.7.5). QPLAN is not compliance with performance efficiency (as QPLAN is applied across the project life cycle by a single user, the time behaviour and resource utilisation are not required characteristics) and security (the knowledge base can be accessed by other tools.

6.2 Phase 1— The Validity of QPLAN Implementation

6.2.1 Goal

This phase ensured that the implementation of the QPLAN worked as expected, by performing two types of tests identified by ISO/IEC/IEEE 29119, an international software testing standard (Reid, 2013): White Box, for testing the calculation of quality indices, and Black Box, for testing QPLAN functionality, completeness and usability.

6.2.2 Step 1a—White Box Testing

6.2.2.1 The Goal

White Box tested the accuracy and reliability of the algorithms that calculate the QPLAN quality indices by analysing the QPLAN source code and internal structure (Hevner et al., 2004).

6.2.2.2 Sample and Procedure

The procedure is based on input to the Input-Process-Output (IPO) model (presented in Figure 6.1), where a set of test scenarios is created for simulating user’s answers (inputs), and is imported into QPLAN. This is processed by algorithms that calculate quality indices, and the results are shown in QPLAN screens and reports (outputs).

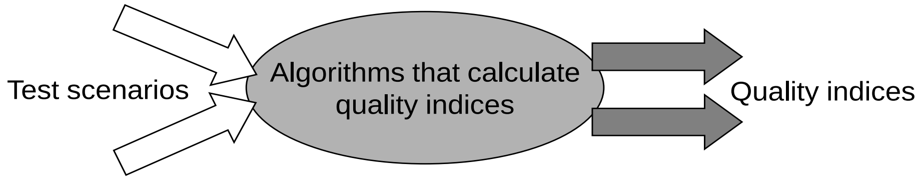

Figure 6.1: IPO modified to test QPLAN
(adapted from Zwikael and Smyrk, 2011)

A set of 21 test scenarios using artificial data (created in a file compatible with .xls format) was used for testing QPM and QCM. As an example, Table 6.1 presents the set of test scenarios created for testing the QPM quality index (the columns represent the 16 planning products, and the rows represent user options for each one).

Table 6.1: Test scenarios for QPM quality index

Test Scenario		4.2. Develop PMP	5.2. Define scope	5.3. Create WBS	6.1. Define activities		10.2. Plan comm	11.1. Plan risk mgnt	12.1. Plan proc
1	Test of 'Strongly agree' option	High2	High2	High2	High2		High2	High2	High2
2	Test of 'Agree' option	High1	High1	High1	High1		High1	High1	High1
3	Test of 'Neutral' option	Medium	Medium	Medium	Medium	…	Medium	Medium	Medium
4	Test of 'Disagree' option	Low1	Low1	Low1	Low1		Low1	Low1	Low1
5	Test of 'Strongly disagree' option	Low2	Low2	Low2	Low2		Low2	Low2	Low2

These scenarios were imported into the QPLAN tool to calculate the quality indices. The algorithm for QPM index considers the average of the 16 planning products evaluation.

The algorithm for generating QCM index is much more complex: it considers 55 factors that are organised in a hierarchical structure of 21 cognitive maps. The number of factors per cognitive map varies if they are used in more than one cognitive map and if they affect project success positively or negatively. To complicate matters, there are 19 additional factors that are considered only at the end of the project. Outputs from the algorithms are presented in screens and reports. See an example of the test performed in the QCM index in Figure 6.2.

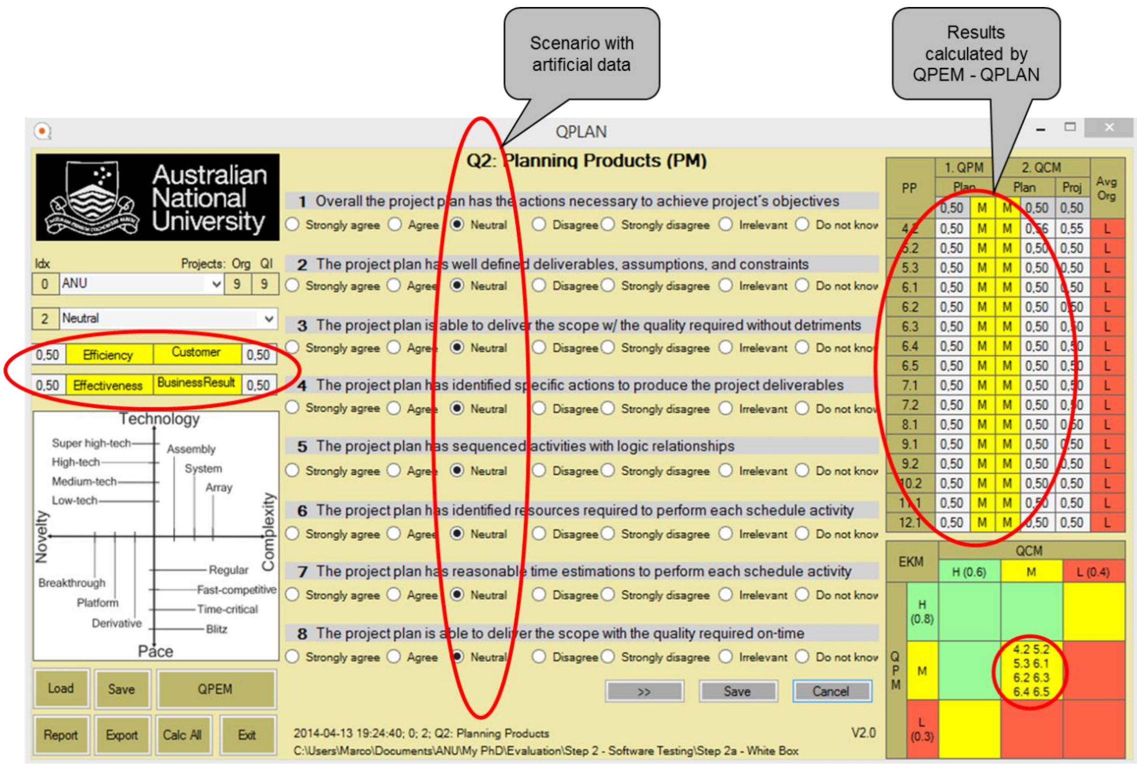

Figure 6.2: QPM index test

In the middle of the screen, all of the answers were selected as 'Neutral'. Consequently, on the right-hand side, the quality indices have a value of 0.5. This is correct, as ‘Neutral’ = 0.5 (Table 4.1). Note also that the planning products are positioned in the center in the extended Karnaugh map.

Likewise, the same information appears in the QPLAN project report for this project. Figure 6.3 shows the quality indices calculated by QPM and QCM at the end of planning and at the end of the project (item 3.1 in the report), and the quality indices calculated for each planning process (item 3.2 in the report).

3. Quality of planning

3.1. Project quality indices

Instrument	Planning	Closing
QPM	0,50	-
QCM	0,50	0,50
QI (average)	0,50	0,50

3.2. Planning processes quality indices

Instrument / Planning Process	QPM Plan	QPM Org	Dif	CM Plan	CM Proj	Org Plan
4.2. Develop project management plan	M	L	+	M	M	L
5.2. Define scope	M	L	+	M	M	L
5.3. Create WBS	M	L	+	M	M	L
6.1. Define activities	M	L	+	M	M	L
6.2. Sequence activities	M	L	+	M	M	L
6.3. Estimate activity resource	M	L	+	M	M	L
6.4. Estimate activity durations	M	L	+	M	M	L
6.5. Develop schedule	M	L	+	M	M	L
7.1. Estimate costs	M	L	+	M	M	L
7.2. Determine budget	M	L	+	M	M	L
8.1. Plan quality	M	L	+	M	M	L
9.1. Develop human resource plan	M	L	+	M	M	L
9.2. Acquire project team	M	L	+	M	M	L
10.2. Plan communications	M	L	+	M	M	L
11.1. Plan risk management	M	L	+	M	M	L
12.1. Plan procurements	M	L	+	M	M	L

Figure 6.3: QPLAN project report and the quality indices calculated

Table 6.2 shows a summary of the expected results provided by QPLAN of five scenarios created with artificial data for testing the most important quality indices. They simulate users’ answers as ‘Strongly agree’, ‘Agree’, ‘Neutral’, ‘Disagree’ and ‘Strongly disagree’ in all questions from Questionnaires 1–5. Appendix D complements this section by describing these test scenarios. QPM is calculated from the average of the quality of planning of the 16 planning products (Section 4.3), while QCM is calculated from the average of the weights of the 16 cognitive maps (Sections 4.4.3 to 4.4.18; Tables C1—C5); QIPlan is calculated from the average of QPM and QCM (Sections 4.2), and QIPlanOrg is calculated from the average of the QIPlan for all projects within the organisation.

Table 6.2: Expected results

Users' answers	QPM	QCM	QIPlan	QIPlanOrg
Strongly agree	1.00	0.88	0.94	0.00
Agree	0.80	0.58	0.69	0.94
Neutral	0.50	0.50	0.50	0.82
Disagree	0.30	0.44	0.37	0.71
Strongly disagree	0.00	0.11	0.06	0.63

6.2.3 Step 1b—Black Box Testing

6.2.3.1 Goal

Black Box tested the functionality and completeness of QPLAN by considering the user's perspective, without the user needing to know QPLAN's source code, internal structure or programming knowledge (Hevner et al., 2004).

6.2.3.2 Sample and Procedure

The test procedure is based on behaviour-driven development (BDD), an agile methodology whose objective is on writing small behaviour specifications focused on business values for driving out the appropriate design (Wirfs-Brock, 2007).

BDD has a template comprising user stories for describing features and test cases for defining the acceptance criteria (Wirfs-Brock, 2007). For example, the user story to test whether the interview form check box is marked automatically is:

As an check box for the interview form

I want to be filled after the user completes the interview form

So that *the main screen has to mark the checkbox after the user completes the form.*

And the acceptance criterion is:

Given the main screen

When the user completes the interview form

Then QPLAN has to mark the interview checkbox.

A set of 61 user stories and test cases were created for guiding test execution, and the outputs are presented in a binary form, showing whether each test set passed or failed.

6.2.4 Discussion

This section presented two types of test techniques performed on QPLAN: White Box, which was used for testing the calculation of quality indices (the core of QPLAN), and Black Box, which was used for testing the QPLAN user interface. In the first test, a detailed investigation of internal logic and code structure was performed. This is the most exhaustive and time-consuming type of testing. In the second test, analysis of the inputs and outputs of the QPLAN user interface was performed without knowing the internal logic and code structure. The combination of both techniques ensured that the QPLAN worked as expected in terms of accuracy, functionality, completeness and usability.

6.3 Phase 2—Examine QPLAN within the Business Environment

6.3.1 Goal

Case study is a methodology used to contribute to the knowledge through intensive investigation of a contemporary phenomenon within its real-life context (Yin, 1981). Given that the boundaries between the phenomenon and context are not evident (Benbasat et al., 1987), case studies are expected to rely on a variety of techniques and multiple sources of evidence, such as fieldwork, surveys, archival records, focus groups and in-depth interviews (Yin, 2003). Multiple case studies strengthen the results by replicating pattern-matching, thus increasing confidence in the robustness of the theory (Yin, 2003). This enables researchers to compare different perspectives to improve external validity (Yin, 2003). However, there are some limitations and criticisms, such as lack of construct validity due to subjectivity (Gummesson, 2006; Miles, 1979), lack of theoretical rigor if compared to quantitative methods (internal validity), lack of replication (external validity) and time-consuming data analysis (Miles, 1979).

In this research, the case studies aimed to examine QPLAN intensively within the business environment (Hevner et al., 2004) by obtaining a rich universe of data in order to analyse the data collected through a variety of quantitative and qualitative methods.

6.3.2 Step 2a—Interviews with Senior Managers

6.3.2.1 Goal

In this step, interviews were conducted with the senior manager responsible for software development in the organisation to identify the success factors adopted in each organisation, as well as the barriers that had the most significant effect on project success by performing an open-ended interview—a widely used method for exploratory studies (Espinosa et al., 2006) useful for probing, clarifying and learning more about the context in depth (Rossman and Rallis, 2003). This step served two purposes:

1. validate whether success factors adopted by QPLAN (Lechler and Dvir, 2010) are suitable for software development projects (the success factors defined by Lechler and Dvir's 2010 work are not specific for software development projects)
2. verify whether there are factors other than those considered by QPLAN that affect the quality of planning.

6.3.2.2 Sample and Procedure

The sample was comprised of six interviews with senior managers who were willing to participate in this study (out of 12 participating organisations). Data were collected between September 2011 and May 2012, and inputted in the QPLAN knowledge base. Participants, from researcher's professional network, consisted of six senior managers from 'AL', 'DL', 'PH', 'EL', 'PV' and 'SU' organisations that carry out software projects. The interviews were administered in English, by e-mail and face-to-face with the interviewer, and lasted about 20 minutes.

Senior managers were asked to report on how they measure project success in their organisation (Espinosa et al., 2006, p.369):

> *How do you measure success in software development projects?*

Likewise, they were asked to identify the common barriers that had the most significant effect on project performance (Espinosa et al., 2006, p.369):

> *Generally speaking, which barriers had the most significant effect on project performance? And, how did those factors affect various dimensions of project performance?*

6.3.2.3 Data Analysis

Following the approach suggested by Rose et al. (2007), the data analysis involved the interpretation of the answers in order to code them into relevant categories. For validating the success factors (former objective), the coding scheme used is based on the success dimensions found in the literature. For validating the factors that lead to project failure (latter objective), the coding scheme is based on factors from QPEM (Chapter 4).

6.3.2.4 Results

For the success factors adopted by each organisation, results from six interviews (out of 12 organisations that participated in this research—see Section 6.3.3) show that:

- for ‘AL’, success is the efficiency to deliver on time and on budget with less than 5 per cent of deviation
- ‘DL’ aims to deliver software products that meet business needs, but without defects during the production phase
- ‘PH’ aims to deliver software on time, on budget and with the quality required, but the most critical features should be delivered first
- ‘EL’ measures success by delivering on time, on cost and customer satisfaction
- ‘PV’ considers stability, performance, scope and customer satisfaction
- ‘SU’ considers quality, customer satisfaction and business effect.

For the common factors that lead to project failure by organisation, results show that:

- ‘AL’ is focused on unrealistic effort estimates
- ‘DL’ is concerned with ineffective change management, unrealistic schedules and lack of sufficient resources
- ‘PH’ is concerned with ineffective change management, inappropriate project manager assigned, high turnover rate, turbulent environment, lack of motivation and top management support
- ‘EL’ is focused on ineffective change management and unrealistic effort estimates
- ‘PV’ is concerned with lack of top management support, lack of commitment, inappropriate PM assigned and team members with lack of experience/skills
- ‘ST’ is concerned with a lack of top management support, inappropriate project manager assigned, lack of communication and high turnover rate.

6.3.2.5 Discussion

The interviews with senior managers had two purposes: the validation of the success factors adopted by QPLAN (Table B.5) and the identification of the most common factors that lead to project failure in each organisation.

It was found that the participating organisations considered *efficiency*, *effectiveness*, *customer satisfaction* and *business results* success factors, as defined by Lechler and Dvir (2010). However, it was also found that *deliver the most critical features first* (Chow and Cao, 2008; Napier et al., 2009) should be considered success factors too, given that software projects have peculiar characteristics (Austin, 2001) such as complexity, volatility of requirements and intangibility of products (Napier et al., 2009).

Likewise, it was found that all of the common factors that lead to project failure identified in the interviews are already covered by QPLAN. They are: ineffective change management, inappropriate project manager assigned, team members with a lack of experience and skills, unrealistic effort estimates and unrealistic schedules, high turnover rate, turbulent environment and lack of top management support, commitment, communication, sufficient resources and motivation.

This analysis of success factors adopted by each organisation and common factors that lead to project failure served to the researcher deliver better project reports, by interpreting the data provided by the QPLAN project report (Section 5.4.7.3) considering senior managers' views. That is, this analysis enabled the researcher to provide a qualitative analysis about the project considering the success factors adopted by the organisations, the common factors that lead to project failure and the QPLAN project report, which is created automatically from Questionnaires 1–5 (Appendix A) data (QPLAN helps project managers in better planning, but it does not replace the project management knowledge).

It should be noted that 70 percent of the total collected projects came from organizations in which senior managers participated in the interview.

6.3.3 Step 2b—Collect Data from Current and Past Projects

6.3.3.1 Goal

This step collected data for building QPLAN knowledge base that allows performing the quantitative and qualitative analyses that are described in the next steps.

6.3.3.2 Sample and Procedure

The sample was comprised of 66 projects, which were collected between January 2011 and October 2012 and inputted the QPLAN knowledge base. Participants, from researcher's professional network, consisted of 48 project managers and six supervisors from 12 organisations. They are: 'AL', 'AN', 'DL', 'PH', 'EL', 'PR', 'SA', 'PV', 'PY', 'SP', 'SU' and 'OH'. These organisations are of different sizes, and from eight types of industries: four from IT, two from defence and one from automation, banking, education, logistics, pharmaceutical and R&D.

Questionnaires were administrated in English by e-mail. Project managers were asked to identify the project, classify it, and evaluate the initial conditions in the beginning of the planning (Questionnaire 1—Appendix A). At the end of planning, project managers were asked to evaluate the quality of planning (Questionnaires 2 and 3—Appendix A). At the end of the project, supervisors were asked to evaluate project success (Questionnaire 4—Appendix A), and project managers were asked to identify enhancement opportunities and compare actual data against planned data (Questionnaire 5—Appendix A), as well as fill out the demographic information sheet (Appendix A). Questionnaires were completed in an average of 20 minutes (each). Table 6.3 describes the questionnaires used for collecting data from current and past projects, which includes the questionnaire's goal, when they should be applied, who should answer them, the scale adopted, examples of questions and references in this thesis that details them.

Table 6.3: Questionnaires used for collecting data from current and past projects

Questionnaire	Goal	When	Who	Scale	Example of question	References
1	Register Project	Beginning of planning	Project manager		Project name	Chapter 5, Section 5.4.2; Appendix B, Table B.1
	Identify Project Characteristics			4-factor scale from the literature	How new is the product to customers and users	Chapter 5, Section 5.4.3; Appendix B, Table B.1
	Evaluate Planning Factors I			23-factor scale, measured on a 5-point Likert scale	This project has clear and realistic objectives	Chapter 5, Section 5.4.4; Appendix B, Table B.1
2	Evaluate Planning Products	End of planning	Project manager	16-factor scale, measured in a 5-point Likert scale from the literature	The project plan is able to deliver the scope with the quality required on-time	Chapter 5, Section 5.4.6
3	Evaluate Planning Factors II	End of planning	Project manager	32-factor scale, measured in a 5-point Likert scale	The project plan had enough input	Chapter 5, Section 5.4.5; Appendix B, Table B.2
4	Evaluate Project Success	End of the project	Project manager's supervisor	12-factor scale, measured in a 5-point Likert scale from the literature	The project had come in on schedule	Chapter 5, Section 5.4.8; Appendix B, Table B.3
5	Register Lessons Learnt	End of the project	Project manager	Two open-ended questions	What went well?, What should be done differently next time?	Chapter 5, Section 5.4.9
	Confirm Project Characteristics			Established 4-factor scale from the literature	How complex is the systems and its subsystems	Chapter 5, Section 5.4.10; Appendix B, Table B.4
	Evaluate Factors at the End of the Project			10-factor scale, measured in a 5-point Likert scale	Team meetings were effective	Chapter 5, Section 5.4.11; Appendix B, Table B.4
Demographic Information	Register information about project manager	Any phase of the project	Project manager		Age, project management experience	Chapter 5, Section 5.4.12; Appendix A
	Methodology adopted				Agile, Stage-Gate	
	Organisation characteristics				Number of employees	

6.3.3.3 Results

A total of 66 projects of ongoing (38) and past (28) software development projects were collected from the 12 participating organisations in eight types of industries (Table 6.4).

Table 6.4: Data collected by industry type and ongoing and past projects

	Ongoing projects	Past projects
Automation	2	5
IT	9	4
Education	6	2
R&D	5	6
Defence	10	11
Pharmaceutical	1	-
Logistics	4	-
Banking	1	-
Total	38	28

In this sample, project duration ranges between two and 60 months, with a mean of 1.8 years. Table 6.5 shows the stratification of projects collected by industry type and country.

Table 6.5: Data collected by industry type and country

	Australia	Brazil	US	Israel	Germany	Italy	Total
Automation		7					7
IT		9	1			3	13
Education	8						8
R&D		10	1				11
Defence		18		2	1		21
Pharmaceutical		1					1
Logistics		4					4
Banking		1					1
Total	8	50	2	2	1	3	66

In this sample, it was identified that 28 different programming languages were used to develop software projects. Table 6.6 presents the list of programming languages and the number of times that they were used.

Table 6.6: List of programming languages used

#	Programming	Quantity	#	Programming Language	Quant
1	C	20	15	ATG	1
2	Java	18	16	CSS3	1
3	C++	8	17	Delphi	1
4	C#	7	18	Dynamo	1
5	PL/SQL	7	19	Oracle Forms 6i / Reports	1
6	HTML	4	20	Flex	1
7	Mathlab	3	21	Grails	1
8	Scade	3	22	OpenCms	1
9	Cobol	2	23	Python	1
10	PHP	2	24	Ruby	1
11	ABAP	1	25	VAPS	1
12	Ada	1	26	VB script	1
13	AJAX/JQuery	1	27	VHDL	1
14	Apache Solr	1	28	Visual Basic	1

Some projects used more than one programming language to develop the software (the total of the 'Quantity' column is 92, which is more than the sample size), but only six programming languages represent 70 per cent of the sample. This was caused by the type of software project developed by the participating organisations, where many of them can be considered analogous.

6.3.3.4 Discussion

The data collected represents a significant and rich sample of software development projects. It comprises 66 projects that used 28 types of programming languages from 12 organisations belonging to eight types of industries located in six countries. This sample was inputted in the QPLAN knowledge base and served as a base for the quantitative and qualitative analyses that are described in the next four steps.

6.3.4 Step 2c—Effectiveness of Quality of Planning in Project Management Success and Project Ownership Success

6.3.4.1 Hypotheses Development

This step tested the effectiveness of planning on project success, which has provoked a debate in the literature (Section 2.4.2) because of specific characteristics of software projects, such as high level of complexity, volatility of requirements and intangibility of products (Napier et al., 2009). This test is based on the model developed by Zwikael and Sadeh (2007) and success measures defined by Lechler and Dvir (2010) (Figure 6.4).

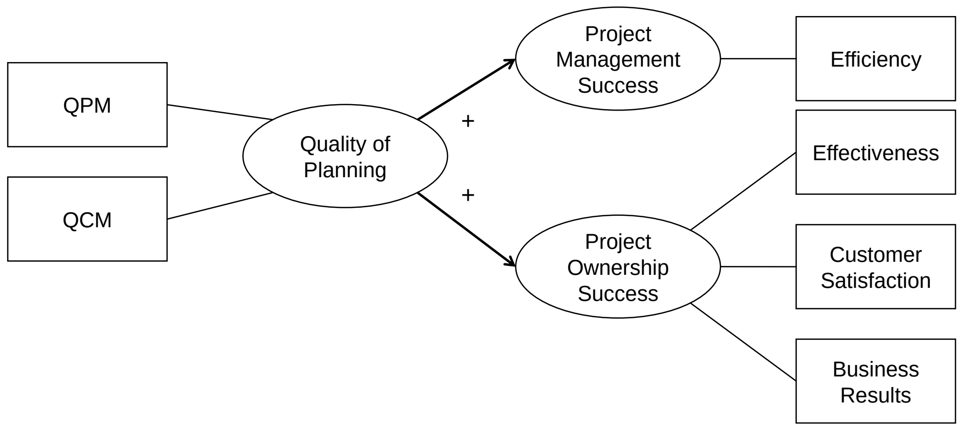

Figure 6.4: Research model for testing the effectiveness of quality of planning in project management success and project ownership success

The hypotheses H_1 and H_{01} (Section 2.4.3) will investigate the effectiveness of planning on project management success, while H_2 and H_{02} (Section 2.4.3) will investigate the effectiveness of planning on project ownership success.

The expectation is to confirm both H_1 and H_2 (Zwikael and Globerson, 2004), finding no influence from gender, age, work experience and project manager experience because in software development projects, the success is little affected by demographic similarities (Kang et al., 2006).

6.3.4.2 Sample and Procedure

The sample was comprised of 36 projects that have been completed (out of 66 projects collected) from the QPLAN knowledge base. The procedure was described in Section 6.3.3.2.

6.3.4.3 Measures

Quality of Planning

Quality of Planning is calculated from the average of QPM and QCM indices, which values range from 0.0 to 1.0. The use of two independent measures with top–down and bottom–up approaches is a method suggested by Jørgensen (2004) for improving the accuracy of estimations in the planning. The scale's alpha coefficient was .872. The measure of QPM and QCM were presented in Section 6.3.4.3, and their scale's alpha coefficients were 0.938 and 0.909, respectively.

Project Management Success

Project management success is calculated from Efficiency, a measure defined and validated by Lechler and Dvir (2010), which values range from 0.0 to 1.0 (see Appendix B for the details about the items used to calculate it). The scale's alpha coefficient was 1.00.

Efficiency, the extent to which time and cost planned have been met (Scott-Young and Samson, 2008; Malach-Pines et al., 2008; Zwikael and Sadeh, 2007), is measured in a 5-point Likert scale that is converted to a value that ranges from 0.0 to 1.0 (Chapter 4, Table 4.2). This is calculated from the average of two items (schedule and budget efficiencies, which are described in Appendix B). The scale's alpha coefficient was .912.

Project Ownership Success

Project ownership success is calculated from the average of three success measures defined and validated by Lechler and Dvir (2010), which values range from 0.0 to 1.0. They are: Effectiveness, Business Results, and Customer Satisfaction (see Appendix B for details about the items used to calculate them). The scale's alpha coefficient was .948.

Effectiveness, the extent of benefits that the project brought to its client (Malach-Pines et al., 2008; Scott-Young and Samson, 2008; Zwikael and Sadeh, 2007), is measured in a 5-point Likert scale that is converted to a value that ranges from 0.0 to 1.0 (Chapter 4, Table 4.2). This is calculated from the average of 6-item (effectiveness related to technical specification, client performance, project is used, affect clients, decision / performance, and positive effect, which are described in Appendix B). The scale's alpha coefficient was .996.

Customer Satisfaction, the extent of satisfaction with the benefits provided by the project and how it was conducted (Malach-Pines et al., 2008; Scott-Young and Samson, 2008; Zwikael and Sadeh, 2007), is measured in a 5-point Likert scale that is converted to a value that ranges from 0.0 to 1.0 (Chapter 4, Table 4.2). This is calculated from the average of 2-item (customer satisfaction related to the evaluation of the funders satisfaction with the process and results, which are described in Appendix B). The scale's alpha coefficient was .983.

Business Results, the perceived value of the project (Malach-Pines et al., 2008; Dvir, et al., 2003; Shenhar and Dvir, 2007), is measured in a 5-point Likert scale (that is converted to a value that ranges from 0.0 to 1.0 (Chapter 4, Table 4.2). This is calculated from the average of 2-item (business results related to the evaluation of economic success and general results achieved by the project, which are described in Appendix B). The scale's alpha coefficient was .980.

Demographic Control

There are four demographic control variables to test the effect of them on project success: gender (Jiang et al., 2004; Kang et al., 2006; Liang et al., 2007), age (Kang et al., 2006; Liang et al., 2007), work experience (Jiang et al., 2004), and project manager experience (Zwikael et al., 2014).

6.3.4.4 Data Analysis

Correlation and regression analysis were performed for testing the research model. Partial correlations were performed for testing the effect of demographic control variables.

6.3.4.5 Results

Table 6.7 presents the means, standard deviations, correlations, and reliabilities of the study variables for descriptive purposes. Quality of planning is significantly correlated with project management success (0.518), including QPM (0.468) and

QCM (0.547) measures, and project ownership success (0.651), including QPM (0. 626) and QCM (0. 627) measures.

Table 6.7: Means, standard deviations, reliabilities, and correlations

		M	SD	1	1a	1b	2	2a	3	3a	3b	3c
1	Quality of Planning	0.614	0.138	(0.872)								
1a	QPM	0.671	0.173	.976**	(0.938)							
1b	QCM	0.558	0.113	.942**	.846**	(0.909)						
2	Project Project Management Success	0.547	0.267	.518**	.468**	.547**	(1.000)					
3	Project Ownership Success	0.715	0.222	.651**	.626**	.627**	0.312	0.320	(0.948)			
3a	Effectiveness	0.735	0.193	.628**	.609**	.597**	.337*	.337*	.973**	(0.966)		
3b	Customer Satisfaction	0.693	0.315	.667**	.657**	.618**	0.278	0.278	.937**	.867**	(0.983)	
3c	Business Results	0.717	0.205	.498**	.450**	.525**	0.293	0.294	.892**	.888**	.690**	(0.980)

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

Table 6.8 presents the regression analysis conducted to test the main effect of quality of planning in project management success. Significance coefficient value for quality of planning suggests that a higher level of quality of planning is associated with enhancement in project management success (R = 0.537, R Square = 0.288, F Change = 2.428, Beta = 0.530, p-value<0.01). This supports H_1 as expected. In addition, the analysis was made with four control variables, including gender, age, work experience, and project manager (PM) experience. However, results also suggest that these control variables do not influence project management success (0.102, 0.192, -0.100, and 0.011, respectively).

Table 6.8: Regression—project management success

Control Variables	Beta	T	p-value
Quality of Planning	0.530**	3.337	0.002
Gender	0.102	0.649	0.522
Age	0.192	0.456	0.652
Work Experience	-0.100	-0.230	0.820
PM Experience	0.011	0.049	0.961

*** $p<0.001$

Likewise, table 6.9 presents the regression analysis conducted to test the main effect of quality of planning in project ownership success. Significance coefficient value for quality of planning suggests that a higher level of quality of planning is associated with enhancement in project ownership success (R = 0.672, R Square = 0.451, F Change = 4.937, Beta = 0.667, p-value<0.01). This supports H_2 as expected. In addition, the analysis was made with four control variables, including gender, age, work experience, and project manager (PM) experience. However, results also suggest that these control variables do not influence project ownership success (0.027, 0.118, -0.282, and 0.018, respectively).

Table 6.9: Regression—project ownership success

Control Variables	Beta	T	p-value
Quality of Planning	0.667**	4.779	0.000
Gender	0.027	0.194	0.848
Age	0.118	0.317	0.753
Work Experience	-0.282	-0.740	0.465
PM Experience	0.018	0.094	0.926

*** $p<0.001$

6.3.4.6 Discussion

The motivation for this test was to further explore the contradictory results that appear in the literature regarding the effectiveness of planning on project success, because of specific characteristics of software projects, such as high level of complexity, volatility of requirements and intangibility of products. Correlation and regression analysis were performed for testing the research model, which was based on the model developed by Zwikael and Sadeh (2007) and success measures defined by Lechler and Dvir (2010). In this research, results supported H_1 and H_2, i.e., a higher level of quality of planning is associated with enhancement in project management success and project ownership success, but gender, age, work experience, and project management experience do not influence it.

6.3.5 Step 2d—Amount of Alignment between QPM and QCM

6.3.5.1 Hypotheses Development

This step tested the amount of alignment (Salkind, 2009) between QPM and QCM, the two QPLAN independent scales that evaluate the quality of planning, to allow calculating the average between two measures that use similar data range. It starts by testing the correlation among them, followed by the identification of the difference between them, which serves to adjust the threshold used to classify quality indices in high, medium and low zones.

The correlation test between QPM and QCM is made through two competing hypotheses, where H_3 assumes a positive correlation, whereas the null hypothesis (H_{03}) assumes no significant cause and effect relationship exists. The expectation is to confirm H_3, due to both top–down and bottom–up approaches are valid and complementary strategies to be used during the planning (Jørgensen, 2004).

H_3—There is a positive correlation between QPM and QCM

H_{03}—There is no correlation between QPM and QCM

The identification of which measure (QPM or QCM) provides more optimistic evaluations is made through other two competing hypotheses, where H_4 assumes that QPM will have higher values than QCM, whereas the null hypothesis (H_{04}) assumes the opposite. The expectation is to confirm H_4, because although the top–down approach (adopted by QPM) provided reasonably accurate estimates with less effort (Jørgensen, 2004), it is less accurate (Connolly and Dean, 1997) than the bottom–up approach (adopted by QCM).

H_4—QPM will have higher values than QCM

H_{04}—QPM will have lower values than QCM

6.3.5.2 Sample and Procedure

The sample was comprised of 64 projects out of 66 projects collected from the QPLAN knowledge base. Two projects were not considered in the sample due to they had not completed the planning. The procedure was described in Section 6.3.3.2.

6.3.5.3 Measures

The QPM index has an established 16-item scale (described in Appendix B), validated and utilised extensively in the literature (e.g., Zwikael and Globerson, 2004, 2006; Masters and Frazier, 2007; Zwikael and Sadeh, 2007; Papke-Shields et al., 2010; Zwikael and Ahn, 2011; Barry and Uys, 2011; Rees-Caldwell and Pennington, 2013; Zwikael et al., 2014), through a weighted linear combination of the quality of 16 planning products (Chapter 2; Section 2.3.4.2). These items were evaluated through questionnaire 2, measured in a 5-point Likert scale, and converted to a value that ranges from 0.0 to 1.0 (Chapter 4, Table 4.1). Likewise, it was found 3.9 per cent of missing data, which captured through two addition answer's options ('Irrelevant' and 'Do not know') in the questionnaires. Answers with missing data were removed from the calculation of the QPM index. The scale's alpha coefficient was .946.

The QCM index has a 55-factor scale, where 23 factors (out of 55 – Section 4.4.2; Table B.1) were evaluated in the beginning of planning through questionnaire 1

(Appendix B, Table B.1) and 32 factors (out of 55 – Section 4.4.2; Table B.2) were evaluated at the end of planning though questionnaire 3 (Appendix B, Table B.2). These 55 factors were measured in a 5-point Likert scale, and converted to a value that ranges from 0.0 to 1.0 (Chapter 4, Table 4.2), and calculated according to the model presented in Figure 4.4 (Chapter 4). Likewise, it was found 3.8 per cent of missing data, which were not considered in the calculation of the QCM index. The scale's alpha coefficient was .931.

6.3.5.4 Data Analysis

To test the hypotheses, a correlation was conducted to examine the relationship between QPM and QCM (H_3) and a mean comparison (paired-samples t test) was conducted to find out whether the scales provide different values (H_4).

It should be noted that means and standard deviations are different than analysis made in Step 2c, due to sample in this step being higher (64 projects that had completed the planning, instead the 36 projects that have ended).

6.3.5.5 Results

Table 6.10 presents the paired sample t test of means compared. There is a positive and significant correlation between QPM and QCM (R = 0.858, R Square=0.735, p-value<0.01) which supports H_3 as expected. In addition, it was identified that the evaluation made by QPM is more optimistic (it has higher values) than the evaluation made by QCM evaluation in 22 per cent.

Table 6.10: Paired sample t test of means compared

	Dif %	Dif Mean	Std. Deviation	T	df	Sig. (2-tailed)
QPM QCM	22%	0.120	0.100	9.634	63	0.000

6.3.5.6 Discussion

Results from this evaluation step showed that both H_3 and H_4 are supported, i.e. there is a positive correlation between QPM and QCM, and QPM has higher values than QCM.

In addition, results showed that the current thresholds used to classify quality indices in zones provided unbalanced results. For instance, 64 per cent of indices calculated by QPM are in the high zone, but only 19 per cent are from QCM.

In order to provide balanced results, new thresholds were defined: in the QPM, the high zone threshold moved up from 0.7 to 0.8 but in QCM it moved down from 0.7 to 0.6 and the low-zone moved up from 0.3 to 0.4. See in Table 6.11 the new thresholds that provided more balanced results.

Table 6.11: Percentage of projects before and after defining new thresholds

Zone	QPM	QCM
High	63.8%	19.7%
Medium	17.5%	70.9%
Low	18.7%	9.4%

Zone	QPM	QCM
High	21.6%	40.7%
Medium	59.7%	36.8%
Low	18.7%	22.5%

QPLAN from version 2.0 addressed this issue. It serves to provide better project reports that help project managers focus on planning processes that needs more attention in planning.

6.3.6 Step 2e—Long-term effect of QPLAN in Enhancing the Quality of Planning Over Time

6.3.6.1 Hypothesis Development

This step tested the long-term effect of QPLAN in enhancing the quality of planning over time (Breyfogle, 2003). It serves to demonstrate the utility of QPLAN (Hevner et al., 2004) through graphs showing the enhancement of the quality of planning of software projects developed by organisations that use QPLAN.

For testing the long-term effect of QPLAN in enhancing the quality of planning over time, two opposing hypotheses were raised: H5 assumes that a higher level of quality of planning is associated with improvement in the quality of planning of software projects over time, whereas the null hypothesis (H_{05}) assumes the opposite.

> *H_5—The use of QPLAN by organisations is associated with improvement in the quality of planning of software projects over time*
>
> *H_{05}—The use of QPLAN by organisations is not associated with improvement in the quality of planning of software projects over time*

The expectation is to confirm H5, due to QPLAN has several features developed to improve the quality of planning: (1) quality of planning evaluation, which allow identify whether the quality of project planning is according to organisation's expectations (Chapter 5, Section 5.3.1); (2) identification of project characteristics, which allows plan the project according to its characteristics (Chapter 5, Section 5.3.2); (3) identification of the strengths and weakness of planning, which allows the project manager improve the quality of planning through the focus on most important issues (Chapter 5, Section 5.3.3); the use of lessons learnt, whose learning may contribute to avoiding potential problems in future projects (Chapter 5, Section 5.3.4); and (5) a knowledge base, which provide data from past projects that serve as a reference for the planning of current projects (Chapter 5, Section 5.3.5).

6.3.6.2 Sample and Procedure

The sample was comprised of 49 projects (out of 66 projects collected) from the QPLAN knowledge base, from five organisations (out of twelve) that provided at least five projects for this study ('AN', 'AL', 'DL', 'PH', and 'EL'). Although these five organisations provided a total of 54 projects (out of 66 projects collected), the first project of each one was not considered, due to it is required at least one project already developed by the organisation to serve as a reference to the current project.

6.3.6.3 Measures

The measure is made through the *Organisation Planning Quality Index* (QIPlanOrg), which is calculated from the average of the *Planning Quality Index* (QIPlan) of projects developed by the organisation after having concluded a new project.

6.3.6.4 Data Analysis

The data analysis was made through a trend analysis, by assessing the efficiency of observed QPLAN process (Stojanov et al., 2013). Likewise, a regression analysis was performed for testing the research model.

6.3.6.5 Results

Figure 6.5 presents a graphic for each organisation that received outputs from QPLAN during September 2011 and May 2012. QIPlanOrg is plotted in a solid line and its trend is plotted in a dotted line.

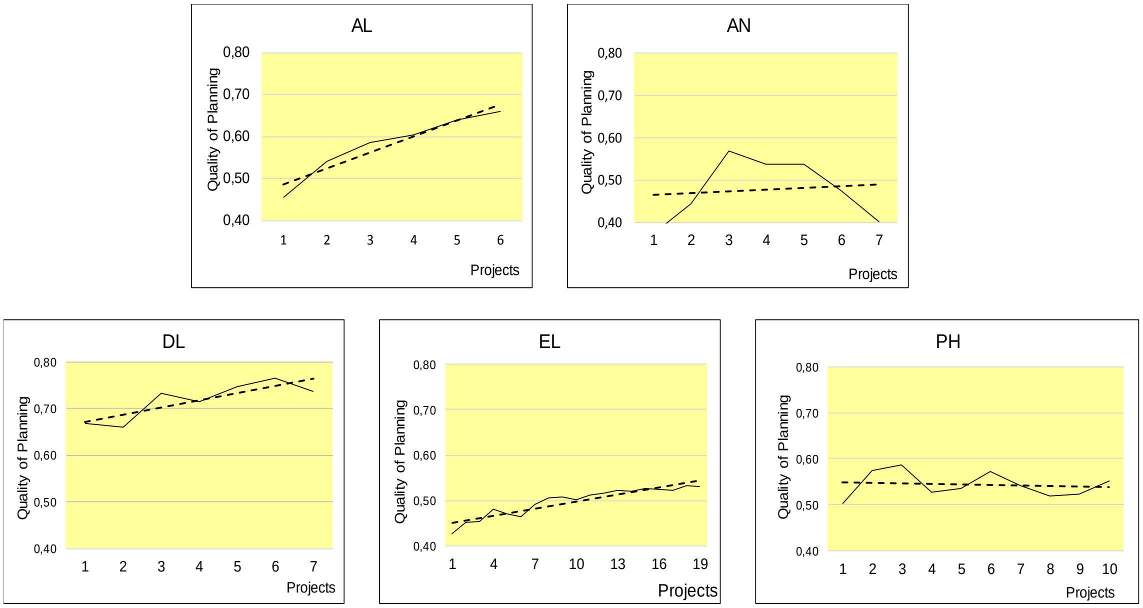

Figure 6.5: Long-term effect of QPLAN
in enhancing the quality of planning over time

Table 6.12 presents the regression analysis conducted to test the main effect of the long-term effect of QPLAN in enhancing the quality of planning over time. Results suggest that slopes are positive but not significant.

Table 6.12: Regression—quality of planning over time

Control Variables	N	Beta	T	p-value
AN	7	0.121	0.272	0.797
AL	6	0.962**	7.060	0.002
DL	7	0.847*	3.560	0.016
PH	10	-0,166	-0,476	0.647
EL	19	0.928***	10.265	0.000

* p<0.05; ** p<0.01; *** p<0.001 (2-tailed)

6.3.6.6 Discussion

The motivation for this test was to further explore the long-term effect of QPLAN in enhancing the quality of planning over time for demonstrating the utility of QPLAN in organisations that have adopted this tool. The data analysis was made through a trend analysis and a regression analysis was performed for testing the research model. Results suggest that slopes are positive and significant in three out five organisations. They are more significant in organisations that have high and medium software process maturity (AL, DL, EL), rather than organisations with low maturity (AN, PH).

6.3.7 Step 2f—Discuss QPLAN with Project Managers—a Qualitative Study

6.3.7.1 The Goal

This step discussed QPLAN with project managers to check whether it was perceived the added-value provided by this tool. It serves to contribute to implement software development improvement programs in organisations (Gopal et al., 2002), and to demonstrate the utility of QPLAN, which is the essence of design science research (Hevner et al., 2004).

6.3.7.2 Sample and Procedure

The sample was comprised of 50 feedback items provided in English and Portuguese (that were translated to English), from June 2010 to September 2012. Participants consist of 20 project managers (out of 48) that provided feedback about QPLAN.

6.3.7.3 Results

During the qualitative analysis of the transcriptions, four major insights emerged. It includes feedback about questionnaires, outputs, and quality of organisation planning projects, as well a discussion about QPLAN applicability with agile projects, as detailed below.

QPLAN Questionnaires

A project manager from ‘DL’ commented that QPLAN questionnaires are generic for software development projects, they are not specific for her organisation (as planned), and cover the most important issues:

> *‘In my opinion the questionnaires weren’t an exact fit to ‘DL’ and they could be more customised to get better answers on our projects—but I guess they have to be somewhat generic to fit projects across all companies/industries, etc. But yes in general I think it covers the most critical aspects of the process.’*

At ‘PH’, a project manager comments that although the questionnaires are extensive, they are suitable for software projects and help the development of better planning:

> *‘A bit long but, if it is too short; you cannot get the desired findings. Questions help to clarify the areas that need to be improved on that project’*

This is the same opinion of a project manager from ‘EL’:

> *‘The questionnaires contain sets of very interesting questions that cover many program’s management aspects that sometimes are not completely understood or considered by the development teams. It leads to very interesting thoughts that sometimes change the perception of how we used to see the program by understanding the different points of view. The planning that seemed to be chaotic by someone who experienced the whole process, started to look not so bad after putting things together.’*

QPLAN Outputs

A project manager from ‘AL’ said that the information provided by the project report provided by QPLAN make sense and portrayed what happened in the project:

> *‘The findings make sense: risks were underestimated, the project delayed and costed more than planned’.*

At ‘DL’, a project manager agreed with that outputs provided by QPLAN made sense and suggested to present QPLAN to a higher hierarchical level:

> *‘The report's findings make much sense. I think it would be cool to present them to my superior. I believe the staff will be interested in seeing the research findings.’*

Finally, a project manager at ‘PH’ was surprised about QPLAN results:

> *‘That is interesting! The results make a lot of sense... Although you are not involved in this project, it seems that you are talking about it.’*

Is QPLAN Suitable for Agile Projects?

A project manager at ‘PH’ raised an interesting question. Because QPLAN is focused in planning, is it suitable for agile projects?

> *‘I'd say that QPLAN for agile projects gets a little complicated, because many of the items asked do not make complete sense.’*

However, although agile projects do not have a formal phase for planning, if the project manager does not plan it appropriately, he or she may have more sprints than necessary, which will generate additional costs and time to deliver the project. A second project manager from the same organisation applied QPLAN for identify issues in his project and recognised that additional sprints performed are caused by poor quality of requirements, which is a planning issue:

'Nailed it! We have many problems with requirements'

6.3.7.4 Discussion

This step discussed QPLAN with 20 project managers that provided feedback. It served to demonstrate the utility of QPLAN, which is the essence of design science research (Hevner et al., 2004).

6.3.9 Discussion

This section examined QPLAN intensively within the business environment through a variety of quantitative and qualitative methods. It started by forming the QPLAN knowledge base from interviews that allowed understand the meaning of success and the common factors that usually lead to project failure (Step 2a), and from questionnaires that allowed collect data from current and past projects developed by the organisations (Step 2b). With the QPLAN knowledge base, it was possible to test the effectiveness of planning on project success (Step 2c), the amount of alignment between QPM and QCM (Step 2d), and the long-term effect of QPLAN in enhancing the quality of planning over time (Step 2e), and discuss QPLAN outputs with project managers (Step 2f).

6.4 Chapter Summary

This chapter demonstrated the evaluation performed for QPEM and QPLAN. It described the tests of accuracy and reliability of the algorithms that calculate quality indices, tests of functionality, and completeness of QPLAN Tool. These tests assure that QPLAN implementation works as expected. Likewise, it described the intensive investigation within the business environment (Hevner et al., 2004) of QPEM and QPLAN through multiple cases studies and a variety of quantitative and qualitative methods. Results showed that QPEM quality indices and QPLAN questionnaires, reports, and approach are adequate for enhancing the success rate of software development projects. This served to demonstrate the utility of both artefacts, which is the essence of design science research (Hevner et al., 2004). In summary, the examination of the QPLAN implementation and within the business environment demonstrated that this is an accurate and reliable tool that enhances the success rate of software development projects.

Chapter 7: Conclusion

7.1 Introduction

After reviewing the relevant literature related to the positive effect of project planning on project success, this study has identified that current models, methods and tools available in the literature for evaluating the quality of project planning have limitations. For example, the PMPQ model was not designed specifically for software development projects, and the quality of checklists depends on how they are produced. In addition, this study sought to address a problem that has plagued the software industry for years—the low success rate of software development projects.

Following the research stream that showed the positive effect of planning on enhancing project success, and motivated by the significance of the software industry in the modern world, two research questions were formulated to guide this work:

> *RQ1: Does improvement in the quality of planning of software development projects enhance project success rate of these projects?*
>
> *RQ2: How can the quality of planning of software development projects be better evaluated and improved?*

To answer these questions, three objectives were outlined, which aimed to contribute to both the project management literature and the software industry: (1) the examination of the influence of the quality of planning on project success in different types of software projects, organisations, industries and countries; (2) the development and validation of QPEM, a model that can evaluate the quality of project planning of software development projects; and (3) the development and validation of QPLAN, a tool that can enhance project success.

To address these questions and achieve the research objectives, this research first examined the project management literature that deals with the planning for understanding how to take advantages from its genuine uncertainty. DSR was selected as a research method because this research is applied research aimed at solving a real problem (Hevner et al., 2004) in the field of ISs (Baskerville, 2008). This study used the DSRP model that has six steps. The first two steps aim to identify the problem and the motivation to conduct the research, and to identify the objectives of a solution. The third step focuses on the description of the design and development of the artefacts. The remaining three steps from the DSRP model deal with the demonstration of artefacts' utility, their evaluation and the communication of the research to academics and practitioners. The data collection process resulted in a sample of 66 projects from 12 organisations located in six countries (Australia, Brazil, the US, Israel, Germany and Italy) that belong to eight types of industries (Automation, IT, Education, R&D, Defence, Pharmaceutical, Logistics and Banking). The sample was provided by 48 project managers that answered questionnaires at the beginning of the planning, at the end of the planning and at the end of the project. The data collected represented a significant and rich sample of software development projects that were analysed though a variety of quantitative and qualitative methods.

As a result, the research questions could be answered. For the first one, the answer is yes (i.e., it confirms that a higher level of quality of planning is associated with an increase on project management success and project ownership success in relation to software development projects). This is supported by the results provided from the test of the effectiveness of quality of planning on project success.

For the second research question, the answer is that the effectiveness of the quality of planning of software development projects can be evaluated and project success can be enhanced through the use of QPLAN. This is supported by the results provided from the test of the long-term effect of QPLAN in enhancing the quality of planning over time and the feedbacks provided by practitioners.

It should be noted that the QPLAN tool was not delivered to practitioners. Instead, questionnaires' data provided by practitioners were inputted in QPLAN knowledge base by the researcher, which delivered the QPLAN's outputs (project and organisation reports) back to them. This procedure was adopted in order to protect QPLAN against piracy.

7.2 Summary of the Study

This thesis was organised according to the DSR publication schema proposed by Gregor and Hevner (2013). Summary results of each chapter are described below.

Chapter 1 dealt with the problem identification and motivation and objectives of a solution, which are the first and second steps of the DSRP model.

Chapter 2 reviewed the relevant literature related to project success and project planning focused on software projects. It presented different concepts of project success, and an intensive investigation of the planning, including its characteristics, project management approaches for dealing with planning, and methods used to evaluate its quality. Moreover, it outlined the debate in the literature about the effectiveness of quality of planning on project success. This motivated the development of a new model for evaluating the quality of planning of software development projects (QPEM) and hypotheses were raised to test it.

Chapter 3 outlined DSR as a research method, and the DSRP model as a process model (Peffers et al., 2006) adopted in this thesis. It provided an overview of DSR and the justification for using it as research method for supporting the design and development of the QPEM model and QPLAN tool. Likewise, this study was positioned in terms of philosophical grounding, level of artefact abstraction, type of knowledge contribution, and type of theory provided. At the end, it was described the use of the DSRP model for developing, evaluating and presenting this study.

Chapter 4 described the design and development of QPEM model. It discussed the use of two complementary measures for enhancing the accuracy on planning, and presented the two measures used by QPEM for evaluating the quality of planning. The first measure is QPM and was founded in the project management literature, while the second measure is QCM and was developed in this study. This chapter addressed the second research objective (the development of the QPEM) and the third step of the DSRP model (design and development).

Chapter 5 described the design and development of the QPLAN tool. It provided an overview of this tool, described its design and the approach adopted for enhancing the success rate of software projects. This chapter addressed the third research objective (the development of the QPLAN) and the third step of the DSRP model (design and development).

Chapter 6 outlined the evaluation of the QPEM model and the QPLAN tool. It demonstrated their utility to the software industry, which is the essence of design science research (Hevner et al., 2004), and described the software tests performed in the QPLAN tool. These tests checked the accuracy and reliability of the algorithms that calculate quality indices, and the functionality, completeness and usability of QPLAN. In addition, it was described the intensive investigation made within the business environment through multiple cases studies and the use of a variety of quantitative and qualitative methods to evaluate QPEM and QPLAN. This chapter addressed the first research objective (the examination of the influence of the quality of planning on project success), and conclude that a higher level of quality of planning is associated with enhancement on project success. Likewise, this chapter addressed the fourth, fifth and sixth steps of the DSRP model (demonstration, evaluation and communication).

7.3 Contributions to Theory

Contributions to the theory provided by this thesis result from the novel approach adopted in both QPEM and QPLAN, which integrates concepts and knowledge from the project management (NTCP diamond model, PMPQ model and factors that affect project planning), computer science (cognitive maps and factors that affect software project planning) and international business literature (the expanded Karnaugh map).

The QPEM model is an innovative artefact designed for evaluating the quality of planning of software development projects consistently that overcome the limitations identified on current models and extended the PMPQ model. QPEM combines two distinct measures, with top–down and bottom–up approaches (QPM and QCM), for enhancing the accuracy on planning. In addition, it considers the project manager's know-how (through the 16 core planning processes as QPM), project manager characteristics (the fit between the personality of the project manager and the profile of the project), technological expertise (the knowledge and experience available in the project team), top management support (the level of support from the top management to the project), enterprise environmental factors (any or all environmental factors that affect project success), and quality of methods and tools (the infrastructure that surround or influence a project success). This approach allows mapping the relations between them in a form that corresponds closely to the way humans perceive it (Rodriguez-Repiso et al., 2007a), and identify the different intensities between planning factors, as suggested by Ling et al. (2009).

The QPLAN tool is an innovative artefact for the software industry that enhances project success through an integrated approach: a) the evaluation of the quality of planning of software development projects consistently (the implementation of QPEM in practice); b) the identification of project characteristics, which helps the project manager to define a proper project management approach; c) the identification of strengths and weaknesses of planning, which helps the project manager to focus on the most important issues; d) the identification of what went well and what should be done differently in future projects, which contributes to avoiding potential problems in future projects; and e) the knowledge base with the experience of the organisation in development of software projects, which serves as a reference to the project manager during planning. QPLAN's effectiveness is higher in organisations with a high or medium level of software process maturity.

7.4 Practical Implications

Practical implications provided by QPLAN also resulted from the novel approach adopted in its design of the architecture. As discussed below, QPLAN: (1) helps project managers to better plan through the evaluation and analysis of the quality of planning; (2) enhances project success through the introduction of best practices in the software development planning process; and (3) allows monitoring performance of projects undertaken by the organisation.

7.4.1 Implications of QPLAN to Help Project Managers in Better Planning

QPLAN helps project managers in better planning by providing a powerful set of resources for analysing the quality of planning. First, it identifies the strengths and weakness of planning, which serves to help project managers focus on the most important issues for enhancing the quality of project planning. This is the implementation of the expanded Karnaugh Map in practice. Second, QPLAN provides the project report that has all of project data, suggestions for enhancing planning quality, and performance comparisons and factors evaluation with past projects. Finally, all of the project data can be exported by QPLAN to other tools, such as Microsoft Excel (Collins, 2013) and SPSS (Hair et al., 2010). As a result, the project manager can use additional resources for analysing the quality of planning using functions other than those implemented in QPLAN.

7.4.2 Implications of QPLAN to Enhance Project Success

QPLAN enhances project success by introducing best practices in the software development planning process. First, it allows improvement on the quality of project planning that has a positive effect on project success (Pinto and Slevin, 1987; Zwikael and Globerson, 2004; Fortune and White, 2006; Mendoza et al., 2007). Second, it identifies project characteristics, which help projects managers to define proper planning. This is the implementation of the NTCP diamond model (Shenhar and Dvir, 2007) in practice. Finally, QPLAN implements a mechanism for planning process improvement (Iversen et al., 2004) comprising a lessons-learnt process and a knowledge base for registering the past experience of the organisation.

7.4.3 Implications of QPLAN to Monitor Projects' Performance

QPLAN presents the performance of the projects undertaken by the organisation in the organisation report, which is created from the knowledge base.

In addition, QPLAN improves organisation's planning processes from its own experience in developing projects by identifying the critical success factors that allow planning process improvement based on evidences by promoting lessons learnt for getting the story behind a participant's experiences (Rossman and Rallis, 2003), and by analysing data in other tools, such as Microsoft Excel (Collins, 2013) and SPSS (Hair et al., 2010), which has additional resources for data analysis.

7.5 Limitations

The use of DSR approach along with the prior academic thinking adopted for conducting this study proved to be appropriate for providing the insight sought in the two research questions. This approach supported the development and evaluation of the research contributions to both project management literature and software industry. It should be noted that specific care was taken to strengthen the findings by using a variety of quantitative and qualitative methods. Nonetheless, three major limitation was found in the samples collected during evaluation of QPEM and QPLAN: a) the limited focus on most projects in a single country (76 per cent of the sample), which was caused by the proximity of the researcher's professional network; b) the size of sample for testing the long-term effect of QPLAN in enhancing the quality of planning over time; and c) the short time after project completion to evaluate project ownership success.

In addition, QCM has 55 factors that were organised by similarities in a hierarchical structure of 21 cognitive maps to allow comparisons with QPM. Three cognitive maps have only one factor for each—all of them related to planning processes from time management. The reason for that is to control the size of the questionnaires by reducing the number of factors for measuring time management, as QPM has five planning processes (out of 16) related to time management.

7.6 Future Work

This research lays the foundation for future work in two research streams, including the continuation of the research by collecting more projects data for overcoming the limitations identified in Section 7.5, and the empowerment of QPLAN as a tool for enhancing project success of other types of projects.

7.6.1 Increasing the Sample Size

The first suggestion for future work is to increase the current sample size by collecting more project data from countries other than Brazil, and from other organisations that develop different types of software projects. This will address the limited focus on most projects in a single country, and the limited focus on six programming languages used for developing software projects.

7.6.2 Evaluate Project Ownership Success during Utilisation Phase

The second suggestion is to evaluate project ownership success (effectiveness, customer satisfaction, and business results) during utilisation phase (i.e., after the customer has used the software). This will address the limitation of a short time after project completion to evaluate project ownership success.

7.6.3 QPLAN for Enhancing the Success Rate of Other Types of Projects

The third suggestion is the empowerment of QPLAN as a tool able to enhance the success rate of different project types, such as construction and hardware (Lovelock, 2013) that are characterised by the usually low success rate over time (Zhang and Fan, 2013; Love et al., 2011) by modifying QCM cognitive maps.

QPLAN was designed to enhance the success rate of software development projects based on two grounds. The first is related to QPEM model, and is applicable only to software projects: the evaluation of the quality of planning of software projects. The second is related to the NTCP diamond model, expanded Karnaugh map, lessons learnt and knowledge base, and is applicable to any type of project: the introduction of best practices for enhancing planning process.

Based on this, the QPEM model must be modified, which is the unique component project-specific. QPEM has two measures. QPM evaluates the quality of planning of any type of project through the evaluation of 16 planning products, while QCM evaluates the quality of planning of software projects through the evaluation of 55 factors that affect quality of planning.

As QCM has factors related to any type of project and factors specific for software projects, it is necessary to add sets of specific factors for each type of project.

This requires the investigation of factors in the literature, critical analyses of them, modifications in the QCM cognitive map and the implementation in the QPLAN tool. The evaluation should be done through multiple cases studies and includes Interviews with senior managers, collection of data from current and past projects, test of the effectiveness of quality of planning on project success and the long-term effect of QPLAN in enhancing the quality of planning over time, as well discussion of QPLAN results with project managers. This process may require many iterations before a suitable model is developed (Stach et al., 2005).

The significance to this research is the enhancement of QPEM model for evaluating the quality of planning of different project types, such as construction, hardware, mechanics and space projects. The significance to practice is the enhancement of QPLAN tool for enhancing project success of these others types of projects.

7.6.4 Confirm the Effectiveness of QPLAN in Various Project Contexts

The last suggestion for future work is to confirm the effectiveness of QPLAN in various project contexts, for example when various methodologies such as Six Sigma, Agile, PMBOK and PRINCE2 are adopted implemented.

7.7 Conclusions

Much attention has been directed towards the problem of usually low success rate of software development projects in the IT industry. To overcome these difficulties, researchers continuously aim to enhance project success over time. However, results have been fruitless to date.

Using DSR as a research method, the DSRP model as a process and reviewing the relevant literature related to the planning, this study proposed two innovative artefacts aimed at enhancing software development project success, the QPEM model for evaluating the quality of planning, and the QPLAN tool for enhancing project success.

QPEM is a model that evaluates the quality of project planning of software development projects. Based on cognitive maps (Stach et al., 2005), it represents the project manager’s know-how, project manager characteristics, technological expertise, top management support, enterprise environmental factors, and quality of methods and tools in a form that corresponds closely to the way humans perceive. As a consequence, QPEM is a model easy to be understood by academics from the project management area, and by practitioners from the software industry. Moreover, because of the use of cognitive maps, QPEM can also deal with future changes in technology, even if it does cause a significant change in the current way of software development. In this case, it may well be required to add new proven factors that will affect the quality of planning, remove factors that no longer affect it (Rodriguez-Repiso et al., 2007a), and perform a new evaluation process.

QPLAN is a tool that enhances software development project success, by evaluating the quality of project planning, and by introducing best practices in the planning process, regardless of the project management approach adopted by the organisation. The QPEM model performs the evaluation of the quality of project planning. The introduction of best practices in the planning process is performed by NTCP diamond model that classifies the project according to its characteristics (Shenhar and Dvir, 2007), the expanded Karnaugh map that identifies the strengths and weaknesses (Sedoglavich, 2008) of planning, lessons learnt that identifies a project's good and poor practices, and a knowledge base that registers the experience of projects developed by the organisation. QPLAN is a tool that combines knowledge from the project management, computer science, and international business literatures and brought them to practice.

QPEM and QPLAN artefacts were examined intensively within the business environment through multiple cases studies, and evaluated through a variety of quantitative and qualitative methods. Quantitative results achieved by their evaluations, feedback provided by practitioners and the continuous interests of organisations, which is the essence of design science research (Hevner et al., 2004), allow us to argue that the desired aims of this research were successfully reached.

With these artefacts in place, organisations can now achieve a better success rate in projects through improved knowledge in project management, the adoption of best practices in their processes and their own experience in project development.

APPENDIX A: INFORMATION SHEET, CONSENT FORM, QUESTIONNAIRES AND DEMOGRAPHIC INFORMATION

Information Sheet

Title of Research Study:

Enhancing the Quality of Planning of Software Development Projects

Description of Study: You are invited to participate in a study being undertaken by Mr Marco Féris, A/Prof Ofer Zwikael, Professor Shirley Gregor and Dr Vesna Sedoglavich from the Australian National University, and Dr Liam O’Brien from Geoscience Australia. The objective of this research is to evaluate the quality of software development planning processes in order to increase the likelihood of project success by collecting data from past and current projects. The study has been approved by the Human Research Ethics Committee, the Australian National University, with protocol number 2011/346.

Participation: Participation is completely voluntary, and you may choose to withdraw your participation from the research within three months from participation. If you do withdraw, I will immediately destroy any notes or records I have made of information you have given me. Participation or refusal to participate will not impair any existing relationship between the participants and any other institutions or people involved.

Use of Information: Information from this research may be published in reports, journal articles or in book form, in English or Portuguese. As far as possible, I will protect your privacy and the confidentiality of the information you give me. I will not use your real name or the name of your organisation in notes or publications. I will audio-record interviews and discussions, and take photographs, only with your consent.

Questions and Concerns: If there is anything you want to know more about, or if you have any concerns about any part of this research, please feel free to contact Mr Marco Féris. Alternatively, you may contact A/Prof Ofer Zwikael, Professor Shirley Gregor, Dr Vesna Sedoglavich or Dr Liam O'Brien to discuss any questions or concerns.

Thank you for your participation.

Mr Marco Féris

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Dr Liam O'Brien

Solution Architect, Engagement, Brokerage, Assurance and Architecture Section, ICT Innovation and Services, Geoscience Australia.

Tel: +61 2 6249 9358 **Email**: William.OBrien@ga.gov.au

Or, if you have serious concerns regarding the way the research was conducted, please contact the ANU Human Research Ethics Committee:

Human Ethics Officer, Human Research Ethics Committee, Australian National University (ANU).

Tel: +61 2 612 57945 **Email**: Human.Ethics.Officer@anu.edu.au

Consent Form

Title of Research Study:

Enhancing the Quality of Planning of Software Development Projects

1. I, ____

   (please print), consent to taking part in the study. I have read the information sheet for this study and understand its contents. The objectives of the project have been explained to me and I understand them. My consent is freely given.
2. I understand that if I agree to participate in the research project I will be asked to inform data from past and current projects.
3. I have been advised that my personal information, such as my name and work contact details, will be kept confidential so far as the law allows.
4. I voluntarily consent to participate, but I understand that I may withdraw from the study within three months after participation.

5. ☐ I agree the interview will be recorded.

6. ☐ I agree photos will be taken

Signed ____________________________________ Date ________________

Thank you for your participation.

Questionnaire 1—Initiation

This questionnaire is to be filled out at the beginning of planning by the project manager. The purpose is to evaluate contextual enablement factors; that is, factors that affect the development of the project management plan (i.e., outputs from initiation phase, enterprise environment factors and organisation process assets).

1. Project name:

2. Project description:

3. Project start: ______ (month)
4. Project duration: ______ (months)
5. Programming language: ___________

6. Strategy goal:

☐ Extension (improving, upgrading an existing product)

☐ Strategy (creating strategy position for the business through new products or markets)

☐ Problem solving (acquire or develop a new technology or a new capability)

☐ Maintenance (routine maintenance, fixing regular problems)

☐ Research (study: exploring future ideas, no product in mind)

☐ Do not know

7. Organisation software process maturity:

☐ High (CMMi L3 or higher)

☐ Middle (ISO9001 or CMMi L2)

☐ Low (no ISO9001 certification or CMMi L1)

8. Type of organisation structure:

- ☐ Project-based
- ☐ Matrix
- ☐ Functional

9. How new is the product to customers and users?

- ☐ Derivative (improvement)
- ☐ Platform (new generation in an existing product line)
- ☐ Breakthrough (new-to-the-world product)

10. How much new technology is used?

- ☐ Low-tech (no new technology)
- ☐ Medium-tech (some new technology)
- ☐ High-tech (all or mostly new, but also uses existing technologies)
- ☐ Super high-tech (project will use completely new technologies at initiation)

11. How complex are the system and its subsystems?

☐ Assembly (subsystem—performing a single function)

☐ System (collection of subsystems—performing multiple functions)

☐ Array (widely dispersed collection of systems serving a common mission)

12. How critical is the time frame?

☐ Regular (delays not critical)

☐ Fast/Competitive (time to market is a competitive advantage)

☐ Time-critical (completion time is critical to success, windows of opportunity)

☐ Blitz (crisis project)

For each of the statements below, circle the number that reflects your extent of agreement:

		Strongly agree		*Neutral*		*Strongly disagree*	*Irrelevant*	*Do not Know*
13.	There is an appropriate project charter to allow for development of a high-quality project plan.	5	4	3	2	1	A	B
14.	This project has clear and realistic objectives.	5	4	3	2	1	A	B
15.	The external pressure on the project is high.	5	4	3	2	1	A	B
16.	Organisation culture is cooperative.	5	4	3	2	1	A	B
17.	There are interactive inter-departmental project planning groups.	5	4	3	2	1	A	B
18.	There is an oral culture focusing on face-to-face communication.	5	4	3	2	1	A	B
19.	There is sufficient organisation maturity for assigning ownership of risks.	5	4	3	2	1	A	B

For each of the statements below, circle the number that reflects your extent of agreement:

		Strongly agree		*Neutral*		*Strongly disagree*	*Irrelevant*	*Do not Know*
20.	An appropriate skilled project manager is assigned.	5	4	3	2	1	A	B
21.	The project manager was highly involved during project initiation.	5	4	3	2	1	A	B
22.	I expect top management to support the project in case of a crisis.	5	4	3	2	1	A	B
23.	The organisation has a positive culture and climate and encourages the project team to share ideas and take risks.	5	4	3	2	1	A	B
24.	Culture in the organisation is too political.	5	4	3	2	1	A	B
25.	The organisation’s environment is turbulent.	5	4	3	2	1	A	B
26.	Staff turnover rate in the organisation is high.	5	4	3	2	1	A	B

For each of the statements below, circle the number that reflects your extent of agreement:

		Strongly agree		*Neutral*		*Strongly disagree*	*Irrelevant*	*Do not Know*
27.	There are historical data that can be used for the development of the project management plan.	5	4	3	2	1	A	B
28.	The organisation has past experience with similar projects.	5	4	3	2	1	A	B
29.	The technology to be adopted in this project is familiar.	5	4	3	2	1	A	B
30.	This is a multi-vendor project with complicated dependencies.	5	4	3	2	1	A	B
31.	The organisation has project tools to support this project.	5	4	3	2	1	A	B
32.	The quality of requirements methodology is high.	5	4	3	2	1	A	B
33.	The quality of test methodology is high.	5	4	3	2	1	A	B
34.	The configuration management system is useful for this project.	5	4	3	2	1	A	B
35.	This is a high-risk project.	5	4	3	2	1	A	B

Questionnaire 2—Planning Evaluation (Part I)

This questionnaire is to be filled out at the end of planning by the project manager. The purpose is to evaluate the quality of planning products.

For each of the statements below, circle the number that reflects your extent of agreement:

		Strongly agree		*Neutral*		*Strongly disagree*	*Irrelevant*	*Do not Know*
1.	Overall, the project plan has the actions necessary to achieve its objectives.	5	4	3	2	1	A	B
2.	The project plan has well-defined deliverables, assumptions and constraints.	5	4	3	2	1	A	B
3.	The project plan is able to deliver the scope with the quality required without detriments.	5	4	3	2	1	A	B
4.	The project plan has identified specific actions to produce the project deliverables.	5	4	3	2	1	A	B
5.	The project plan has sequenced activities with logic relationships.	5	4	3	2	1	A	B
6.	The project plan has identified resources required to perform each schedule activity.	5	4	3	2	1	A	B
7.	The project plan has reasonable time estimations to perform each schedule activity.	5	4	3	2	1	A	B

For each of the statements below, circle the number that reflects your extent of agreement:

		Strongly agree		*Neutral*		*Strongly disagree*	*Irrelevant*	*Do not Know*
8.	The project plan is able to deliver the scope with the quality required on time.	5	4	3	2	1	A	B
9.	The project plan has reasonable cost estimations to perform each schedule activity.	5	4	3	2	1	A	B
10.	The project is able to deliver the scope with the quality required within budget.	5	4	3	2	1	A	B
11.	The project plan has identified quality requirements to be compliant with the organisation’s policies.	5	4	3	2	1	A	B
12.	The project plan has identified roles and responsibilities.	5	4	3	2	1	A	B
13.	The project has a suitable team to achieve its objectives.	5	4	3	2	1	A	B
14.	The project plan has a suitable approach to communicate with stakeholders.	5	4	3	2	1	A	B
15.	The project plan has identified risks and has mitigation and contingency plans.	5	4	3	2	1	A	B
16.	The project has documented purchasing decisions and identified potential sellers.	5	4	3	2	1	A	B

Questionnaire 3—Planning Evaluation (Part II)

This questionnaire is to be filled out at the end of planning by the project manager. The purpose is to evaluate planning products' enablement factors; that is, factors that affect the quality of the development of planning products, such as risks and decisions made during the planning.

For each of the statements below, circle the number that reflects your extent of agreement:

		Strongly agree		*Neutral*		*Strongly disagree*	*Irrelevant*	*Do not Know*
1.	The project plan had enough input.	5	4	3	2	1	A	B
2.	The project plan includes prototypes to refine requirements.	5	4	3	2	1	A	B
3.	This project must be compatible with other systems.	5	4	3	2	1	A	B
4.	The performance required is reasonable to achieve.	5	4	3	2	1	A	B
5.	The reliability required is reasonable to achieve.	5	4	3	2	1	A	B
6.	The database size is reasonable to manage.	5	4	3	2	1	A	B
7.	The most important features are planned to be delivered first.	5	4	3	2	1	A	B

For each of the statements below, circle the number that reflects your extent of agreement:

		Strongly agree		*Neutral*		*Strongly disagree*	*Irrelevant*	*Do not Know*
8.	The schedule planned is realistic.	5	4	3	2	1	A	B
9.	The project plan has small releases planned.	5	4	3	2	1	A	B
10.	The project plan has slack incorporated.	5	4	3	2	1	A	B
11.	The project plan has overtime incorporated.	5	4	3	2	1	A	B
12.	The effort estimates planned are realistic.	5	4	3	2	1	A	B
13.	The funding for this project will not be cut or altered without consultation.	5	4	3	2	1	A	B
14.	The project plan has the right amount of documentation developed.	5	4	3	2	1	A	B
15.	The project plan was subjected to rigorous review.	5	4	3	2	1	A	B
16.	The software development will be subject to rigorous review.	5	4	3	2	1	A	B
17.	The test planning will be subject to rigorous review.	5	4	3	2	1	A	B

For each of the statements below, circle the number that reflects your extent of agreement:

		Strongly agree		*Neutral*		*Strongly disagree*	*Irrelevant*	*Do not Know*
18.	The team has appropriate technical training to perform this project.	5	4	3	2	1	A	B
19.	Team members have great motivation to work in this project.	5	4	3	2	1	A	B
20.	This project has well-allocated resources.	5	4	3	2	1	A	B
21.	There are sufficient resources to perform this project.	5	4	3	2	1	A	B
22.	There is a plan to promote effective communication between team members.	5	4	3	2	1	A	B
23.	There is a plan to involve the customer in the project.	5	4	3	2	1	A	B
24.	The project plan incorporates alternative solution options.	5	4	3	2	1	A	B
25.	The project plan incorporates acceptance of possible failure.	5	4	3	2	1	A	B
26.	This project is at risk of becoming obsolete due to new technological breakthroughs.	5	4	3	2	1	A	B
27.	This project has well-defined roles and responsibilities.	5	4	3	2	1	A	B

For each of the statements below, circle the number that reflects your extent of agreement:

		Strongly agree		*Neutral*		*Strongly disagree*	*Irrelevant*	*Do not Know*
28.	The project plan has an up-front risk analysis done.	5	4	3	2	1	A	B
29.	The project manager has an appropriate approach to people management.	5	4	3	2	1	A	B
30.	The required technology was adequately documented and detailed.	5	4	3	2	1	A	B
31.	Team members have high competence and expertise to work in this project.	5	4	3	2	1	A	B
32.	This project requires a contractor to fill gaps in expertise and transfer knowledge.	5	4	3	2	1	A	B

Questionnaire 4—Project Evaluation (Part I)

This questionnaire is to be filled out at the end of project by the senior manager. The purpose is to contrast the projects' results with project planning and to allow for improvement for the next project planning.

For each of the statements below, circle the number that reflects your extent of agreement:

		Strongly agree		*Neutral*		*Strongly disagree*	*Irrelevant*	*Do not Know*
1.	The project came in on schedule.	5	4	3	2	1	A	B
2.	The project came in on budget.	5	4	3	2	1	A	B
3.	The project met all of the technical specifications.	5	4	3	2	1	A	B
4.	The results of this project represent an improvement in client performance.	5	4	3	2	1	A	B
5.	This project is used by its intended clients.	5	4	3	2	1	A	B
6.	Important clients, directly affected by the project, make use of it.	5	4	3	2	1	A	B
7.	Clients using this project will experience more effective decision making and/or improved performance.	5	4	3	2	1	A	B

For each of the statements below, circle the number that reflects your extent of agreement:

		Strongly agree		*Neutral*		*Strongly disagree*	*Irrelevant*	*Do not Know*
8.	The project has a positive effect on those who make use of it.	5	4	3	2	1	A	B
9.	The clients (funders) were satisfied with the process by which the project was completed.	5	4	3	2	1	A	B
10.	The clients (funders) were satisfied with the results of the project.	5	4	3	2	1	A	B
11.	The project was an economic success.	5	4	3	2	1	A	B
12.	All things considered, the project was a success.	5	4	3	2	1	A	B

Questionnaire 5—Project Evaluation (Part II)

This questionnaire is to be filled out at the end of project by the project manager. The purpose is to contrast projects results with project planning and to allow for improvement for the next project planning.

1. What went well?

2. What should be done differently next time?

For each of the statements below, circle the number that reflects your extent of agreement:

		Strongly agree		*Neutral*		*Strongly disagree*	*Irrelevant*	*Do not Know*
3.	Change management was effective.	5	4	3	2	1	A	B
4.	The project had a diverse and synergistic team.	5	4	3	2	1	A	B
5.	Team meetings were effective.	5	4	3	2	1	A	B
6.	Risks were managed in an appropriate way.	5	4	3	2	1	A	B
7.	It was a high-risk project.	5	4	3	2	1	A	B
8.	The project was managed in an appropriate way.	5	4	3	2	1	A	B
9.	The project was easy to implement.	5	4	3	2	1	A	B
10.	The involvement of the senior manager benefited the project.	5	4	3	2	1	A	B
11.	The collaboration between team members and the organisation's departments was high.	5	4	3	2	1	A	B
12.	The methodology adopted was appropriate.	5	4	3	2	1	A	B

13. How new is the product to customers and users?

☐ Derivative (improvement)

☐ Platform (new generation in an existing product line)

☐ Breakthrough (new-to-the-world product)

14. How much new technology is used?

☐ Low-tech (no new technology)

☐ Medium-tech (some new technology)

☐ High-tech (all or mostly new, but also uses existing technologies)

☐ Super high-tech (project will use completely new technologies at initiation)

15. How complex is the system and its subsystems?

☐ Assembly (subsystem—performing a single function)

☐ System (collection of subsystems—performing multiple functions)

☐ Array (widely dispersed collection of systems serving a common mission)

16. How critical is the time frame?

☐ Regular (delays not critical)

☐ Fast/Competitive (time to market is a competitive advantage)

☐ Time-critical (completion time is critical to success, windows of opportunity)

☐ Blitz (crisis project)

Demographic Information

The information below is to be filled out at the end of project by the project manager and it will only be used for general information.

1. Are you:

☐ Male ☐ Female

2. Age:

☐ Under 25	☐ 31–35	☐ 46–55
☐ 26–30	☐ 36–45	☐ 56 and above

3. Work experience: ___ years
4. Project management experience: ___ years

5. Please state the methodologies and frameworks adopted in this project by ticking the appropriate box(es):

- ☐ PMI
- ☐ Agile
- ☐ ITIL
- ☐ Scrum
- ☐ PRINCE2
- ☐ eXtreme Programming
- ☐ Spiral
- ☐ Six-Sigma
- ☐ Stage-gate
- ☐ Other (please specify): ________________

6. Number of employees in your organisation: _____

7. Organisation name: _________________________

8. Type of industry:

- ☐ Automation
- ☐ IT
- ☐ Education
- ☐ R&D
- ☐ Government
- ☐ Services
- ☐ Other (please specify): ___________________

APPENDIX B: FACTORS EVALUATED BY QCM

This appendix complements the QPEM model described in Chapter 4 and the questionnaires presented in Appendix A. Appendix B presents factors (nodes) used by QCM cognitive maps that are evaluated (edge's weight) in Questionnaire 1—Initiation, Questionnaire 3—Planning Evaluation (Part II), Questionnaire 4—Project Evaluation (Part I) and Questionnaire 5—Project Evaluation (Part II). These factors are organised in four tables (Tables B.1–B.4), which each have the number of the question used in the questionnaires (Appendix A), factor name, cognitive(s) map(s) that use it, an indication of whether the factor leads to project success ('POS') or failure ('NEG'), whether it is a project- or organisation-level factor, and the reference from the literature. A total of 211 factors from the literature were analysed, and 77 were selected based on the technical expertise of the researcher as a practitioner (Section 4.4.2).

Table B.1: Questionnaire 1—Beginning of Planning (QCM)

# (questionnaire)	Enablement Factor	CM 4.2—Develop PMP	CM 5.2—Define Scope	CM 5.3—Create WBS	CM 6.1—Define Activities	CM 6.2—Sequence Activities	CM 6.3—Estimate Activity Resources	CM 6.4—Estimate Activity Durations	CM 6.5—Develop Schedule	CM 7.1—Estimate Costs	CM 7.2—Determine Budget	CM 8.1—Plan Quality	CM 9.1—Develop HR Plan	CM 9.2—Acquire Project Team	CM 10.2—Plan Communications	CM 11.1—Plan Risk Management	CM 12.1—Plan Procurements	CM PM	CM TechE	CM TopM	CM EnvFa	CM QM&T	Effect on Success	References
13	Sound basis for project	x																					POS	Fortune and White, 2006; Loh and Koh, 2004
14	Clear, realistic objectives		x																				POS	Fortune and White, 2006; Reel, 1999; Johnson et al., 2001
15	Time pressure on the project								x												x		NEG	Wohlin and Andrews, 2001
16	Cooperation between project team members														x						x		POS	Somers and Nelson, 2004;
17	Cooperation between project team and other project teams														x						x		POS	Somers and Nelson, 2004; Zwikael et al., 2005
18	High value on face-to-face communications														x						x		POS	Chow and Cao, 2008
19	Maturity for assigning ownership of risks															x					x		POS	Cooke-Davies, 2002
20	Appropriate PM assigned																			x			POS	Zwikael and Globerson, 2004; Fortune and White, 2006
21	Involvement of the PM in the initiation																			x			POS	Zwikael et al., 2005
22	Confidence of top management support																			x			POS	Fortune and White, 2006; Pinto and Slevin, 1986
23	Climate for product innovation																				x		POS	Cooper and Kleinschmidt, 1995
24	Organisational culture too political																				x		NEG	Chow and Cao, 2008
25	Turbulent environment																				x		NEG	Willcocks and Catherine, 1994; Fortune and White, 2006
26	High turnover rate																x				x		NEG	Wohlin and Andrews, 2001
27	Learning from past experience																					x	POS	Willcocks and Catherine, 1994; Fortune and White, 2006

Table B.1 (continued)

# (questionnaire)	Enablement Factor	CM 4.2—Develop PMP	CM 5.2—Define Scope	CM 5.3—Create WBS	CM 6.1—Define Activities	CM 6.2—Sequence Activities	CM 6.3—Estimate Activity Resources	CM 6.4—Estimate Activity Durations	CM 6.5—Develop Schedule	CM 7.1—Estimate Costs	CM 7.2—Determine Budget	CM 8.1—Plan Quality	CM 9.1—Develop HR Plan	CM 9.2—Acquire Project Team	CM 10.2—Plan Communications	CM 11.1—Plan Risk Management	CM 12.1—Plan Procurements	CM PM	CM TechE	CM TopM	CM EnvFa	CM QM&T	Effect on Success	References
28	Experience with similar projects																					x	POS	Willcocks and Griffiths, 1994; Dvir and Lechler, 2004
29	Familiar technology																		x				POS	Fortune and White, 2006
30	Multi-vendor complicate dependencies															x	x						NEG	Schmidt et al., 2001
31	Existence of project tools																					x	POS	Raymond and Bergeron, 2008, Zwikael, 2008b
32	Quality of requirement methodology																					x	POS	Wohlin and Andrews, 2001
33	Quality of test methodology																					x	POS	Wohlin and Andrews, 2001
34	Quality of configuration management system																					x	POS	Wohlin and Andrews, 2001
35	Risk level	x																					POS	Zwikael and Sadeh, 2007

Table B.2: Questionnaire 3—End of Planning (QCM)

# (questionnaire)	Enablement Factor	CM 4.2—Develop PMP	CM 5.2—Define Scope	CM 5.3—Create WBS	CM 6.1—Define Activities	CM 6.2—Sequence Activities	CM 6.3—Estimate Activity Resources	CM 6.4—Estimate Activity Durations	CM 6.5—Develop Schedule	CM 7.1—Estimate Costs	CM 7.2—Determine Budget	CM 8.1—Plan Quality	CM 9.1—Develop HR Plan	CM 9.2—Acquire Project Team	CM 10.2—Plan Communications	CM 11.1—Plan Risk Management	CM 12.1—Plan Procurements	CM PM	CM TechE	CM TopM	CM EnvFa	CM QM&T	Effect on Success	References
1	Sufficient input in the planning	x																					POS	Pinto and Slevin, 1986
2	Use of prototypes to refine requirements			x																			POS	Butler and Fitzgerald, 1999
3	Compatibility with other systems		x																				POS	Büyüközkan and Ruan, 2008; Bradford and Florin, 2003
4	Performance required		x																x				POS	Fairley and Willshire, 2003
5	Reliability required		x																x				POS	Krishnamoorthy and Douglas, 1995; Lui et al., 2009
6	Database size		x																x				NEG	Krishnamoorthy and Douglas, 1995; Reddy and Raju, 2009
7	Delivering most important features first					x																	POS	Chow and Cao, 2008; Napier et al., 2009
8	Realistic schedule planned								x														POS	Fortune and White, 2006; White, 2002; Dvir et al., 1998
9	Small releases planned								x														POS	Fitzgerald et al., 2006; Chow and Cao, 2008
10	Slack planned							x															POS	Pinto and Slevin, 1986
11	Overtime planned								x														NEG	Chow and Cao, 2008; Linberg, 1999
12	Realistic effort estimates									x									x				POS	Jørgensen and Gruschke, 2009, Napier et al., 2009
13	Secured funding										x					x				x			NEG	Loh and Koh, 2004, Tesch et al., 2007
14	Right amount of documentation											x						x					POS	Chow and Cao, 2008; Fortune and White, 2006
15	Rigor of project management plan review											x											POS	Wohlin and Andrews, 2001; Linberg, 1999
16	Rigor of development review											x											POS	Wohlin and Andrews, 2001; Linberg, 1999

Table B.2 (continued)

# (questionnaire)	Enablement Factor	CM 4.2—Develop PMP	CM 5.2—Define Scope	CM 5.3—Create WBS	CM 6.1—Define Activities	CM 6.2—Sequence Activities	CM 6.3—Estimate Activity Resources	CM 6.4—Estimate Activity Durations	CM 6.5—Develop Schedule	CM 7.1—Estimate Costs	CM 7.2—Determine Budget	CM 8.1—Plan Quality	CM 9.1—Develop HR Plan	CM 9.2—Acquire Project Team	CM 10.2—Plan Communications	CM 11.1—Plan Risk Management	CM 12.1—Plan Procurements	CM PM	CM TechE	CM TopM	CM EnvFa	CM QM&T	Effect on Success	References
17	Rigor of test planning review											x											POS	Wohlin and Andrews, 2001; Linberg, 1999
18	Appropriate technical training to team												x										POS	Fortune and White, 2006; Pinto and Slevin, 1986
19	Team members with great motivation												x										POS	Willcocks and Griffiths, 1994; Linberg, 1999
20	Well-allocated resources													x				x					POS	Loh and Koh, 2004, Fortune and White, 2006
21	Sufficient resources													x			x			x			POS	Loh and Koh, 2004, Pinto and Slevin, 1986
22	Plan for effective communication between team members														x								POS	White, 2002; Fortune and White, 2006
23	Plan to involve customer in the project														x								POS	Chow and Cao, 2008; Fortune and White, 2006
24	Alternative solutions planned				x											x							POS	Albias and Wortmann, 2012; Bannerman, 2008
25	acceptance of possible failure planned															x							POS	Fortune and White, 2006
26	Occurrence of breakthrough															x							NEG	Dvir and Lechler, 2004; Reel, 1999
27	Well-defined roles and responsibilities														x								POS	Schmidt et al., 2001
28	Up-front risk analysis done															x							POS	Chow and Cao, 2008; Bannerman, 2008
29	Appropriate approach for people management												x					x					POS	Pinto and Slevin, 1986
30	Technical specifications detailed																		x				NEG	Fairley and Willshire, 2003; Pinto and Slevin, 1986
31	Team members with competence and expertise																		x				POS	Chow and Cao, 2008
32	Contractor to fill gaps in expertise						x										x		x				POS	Bradley, 2008; Loh and Koh, 2004

Table B.3: Questionnaire 4—End of Project (QCM)

# (questionnaire)	Enablement Factor	CM 4.2—Develop PMP	CM 5.2—Define Scope	CM 5.3—Create WBS	CM 6.1—Define Activities	CM 6.2—Sequence Activities	CM 6.3—Estimate Activity Resources	CM 6.4—Estimate Activity Durations	CM 6.5—Develop Schedule	CM 7.1—Estimate Costs	CM 7.2—Determine Budget	CM 8.1—Plan Quality	CM 9.1—Develop HR Plan	CM 9.2—Acquire Project Team	CM 10.2—Plan Communications	CM 11.1—Plan Risk Management	CM 12.1—Plan Procurements	CM PM	CM TechE	CM TopM	CM EnvFa	CM QM&T	Effect on Success	References
1	Efficiency (schedule)								x														NA	Lechler and Dvir, 2010
2	Efficiency (budget)										x												POS	
3	Effectiveness (tech specification)			x															x				NA	
4	Effectiveness (client performance)																			x			NA	
5	Effectiveness (project is used)																						NA	
6	Effectiveness (affect clients)																						NA	
7	Effectiveness (decision/perform)																			x			NA	
8	Effectiveness (positive effect)																						NA	
9	Customer satisfaction (with process)											x											NA	
10	Customer satisfaction																			x			NA	
11	Business results (economic success)										x												NA	
12	Business results	x																					NA	

Table B.4: Questionnaire 5—End of Project (QCM)

# (questionnaire)	Enablement Factor	CM 4.2—Develop PMP	CM 5.2—Define Scope	CM 5.3—Create WBS	CM 6.1—Define Activities	CM 6.2—Sequence Activities	CM 6.3—Estimate Activity Resources	CM 6.4—Estimate Activity Durations	CM 6.5—Develop Schedule	CM 7.1—Estimate Costs	CM 7.2—Determine Budget	CM 8.1—Plan Quality	CM 9.1—Develop HR Plan	CM 9.2—Acquire Project Team	CM 10.2—Plan Communications	CM 11.1—Plan Risk Management	CM 12.1—Plan Procurements	CM PM	CM TechE	CM TopM	CM EnvFa	CM QM&T	Effect on Success	References
3	Effective change management											x											POS	Nah and Delgado, 2006, Somers and Nelson, 2004
4	Diverse and synergistic team													x			x						POS	Linberg, 1999
5	Effective meetings														x			x					POS	Dawson and Owens, 2008
6	Risks managed in an appropriate form															x		x					POS	Cooke-Davies, 2002; Zwikael and Sadeh, 2007
7	Risk level	x																					POS	Zwikael and Sadeh, 2007
8	Competent project manager																	x					POS	Fortune and White, 2006; Pinto and Slevin, 1986
9	Recognising complexity			x															x				POS	Fortune and White, 2006; Willcocks and Griffiths, 1994
10	Involvement of the senior manager																			x			POS	Fortune and White, 2006; Pinto and Slevin, 1986
11	Commitment to the collaboration														x		x						POS	Lam and Chin, 2005; Linberg, 1999
12	Appropriate methodology																	x				x	POS	Bannerman, 2008; Wohlin and Andrews, 2001

APPENDIX C: SCENARIOS FOR TESTING QCM PLANNING QUALITY INDICES

This appendix complements Chapter 4, which describes the formula used to calculate planning quality indices, and Section 6.2.2, which describes the tests performed to check the accuracy and reliability of the algorithm that implements the formula in QPEM (Section 4.4.3) used in the QPEM cognitive maps (Sections 4.4.3–4.4.23).

C.1 Sample and Procedure

The sample comprises five scenarios for testing the algorithms that calculate quality indices by QCM from the simulation of users' answers in questionnaires Q1, Q3, Q4 and Q5 in a fictitious project. They are:

- QCM Test Scenario 1—All of questionnaires' answers as 'Strongly agree'
- QCM Test Scenario 2—All of questionnaires' answers as 'Agree'
- QCM Test Scenario 3—All of questionnaires' answers as 'Neutral'
- QCM Test Scenario 4—All of questionnaires' answers as 'Disagree'
- QCM Test Scenario 5—All of questionnaires' answers as 'Strongly disagree'

In Tables C.1–C.5, the first three columns show the section in Chapter 4 that deals with the cognitive map, its name and the weights calculated by QPEM at the end of the planning. The formula for calculating QCM is the average of the quality of planning of the 16 planning products (see Table 2.1); that is, the average of the weights of the 16 cognitive maps (see Sections 4.4.3–4.4.18). Next, there are 10 columns for the cognitive map’s nodes (Sections 4.4.3–4.4.23). These columns show the weight (Table 4.2) associated with the simulated answer (SA=‘Strongly agree’, A=‘Agree’, N=‘Neutral’, D=‘Disagree’ and SD=‘Strongly disagree’). Moreover, these tables have the Quality of Organisation Planning (QIOrg), which is the average of past projects developed by the organisation.

C.2 Data Analysis

Table C.1: QCM Test Scenario 1—Answers as ‘Strongly agree’

Section	Cognitive Map	Weight	Node 1	Node 2	Node 3	Node 4	Node 5	Node 6	Node 7	Node 8	Node 9	Node 10
4.4.3	Develop Project Management Plan	0.77	QIOrg	Top M	Env Fa	QM &T	PM	SA	SA	SA	SA	
			0.00	0.83	0.50	0.86	1.00	1.00	1.00	1.00	1.00	
4.4.4	Define Scope	1.00	TechE	SA		SA	SA	SA	SA	SA		
			1.00	1.00		1.00	1.00	1.00	1.00	1.00		
4.4.5	Create Work Breakdown Structure	1.00	TechE		SA						SA	SA
			1.00		1.00						1.00	1.00
4.4.6	Define Activities	1.00								SA	0.00	
										1.00	0.00	
4.4.7	Sequence Activities	0.50		SA	SA							
				0.00	1.00							
4.4.8	Estimate Activity Resources	1.00									SA	
											1.00	
4.4.9	Estimate Activity Duration	1.00						SA				
								1.00				
4.4.10	Develop Schedule	0.50	SA			SA	SA		SA			SA
			0.00			1.00	1.00		0.00			1.00
4.4.11	Estimate Costs	1.00	TechE	SA								
			1.00	1.00								
4.4.12	Determine Budget	1.00	TechE		SA	SA	SA	SA				
			1.00		1.00	1.00	1.00	1.00				
4.4.13	Plan Quality	1.00	SA	SA	SA	SA	SA	SA	SA	SA	SA	
			1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
4.4.14	Develop Human Resource Plan	1.00	SA	SA			SA					
			1.00	1.00			1.00					
4.4.15	Acquire Project Team	1.00			SA	SA		SA	SA			
					1.00	1.00		1.00	1.00			
4.4.16	Plan Communication s	1.00	SA	SA	SA	SA	SA	SA	SA	SA		
			1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00		
4.4.17	Plan Risk Management	0.67	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA
			1.00	0.00	0.00	1.00	1.00	1.00	1.00	0.00	1.00	1.00
4.4.18	Plan Procurements	0.67	SA	SA	SA	SA	SA					
			0.00	1.00	1.00	1.00	1.00					
4.4.19	Project Manager Characteristics (PM)	1.00	SA	SA	SA	SA	SA	SA	SA			
			1.00	1.00	1.00	1.00	1.00	1.00	1.00			
4.4.20	Technological Expertise (TechE)	1.00	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA
			1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
4.4.21	Top Management Support (TopM)	0.83	QIOrg	SA	SA	SA	SA	SA	SA	SA	SA	SA
			0.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
4.4.22	Enterprise Environmental Factors (EnvFa)	0.50	QIOrg	SA	SA	SA	SA	SA	SA	SA	SA	SA
			0.00	0.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00	0.00
4.4.23	Quality of Methods and Tools (QM&T)	0.86	QIOrg	SA	SA	SA	SA	SA	SA	SA		
			0.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00		

QCM = 0.88

Table C.2: QCM Test Scenario 2—Answers as ‘Agree’

Section	Cognitive Map	Weight	Node 1	Node 2	Node 3	Node 4	Node 5	Node 6	Node 7	Node 8	Node 9	Node 10
4.4.3	Develop Project Management Plan	0.65	QIOrg	Top M	Env Fa	QM &T	PM	A	A	A	A	
			0.94	0.66	0.55	0.65	0.60	0.60	0.60	0.60	0.60	
4.4.4	Define Scope	0.60	TechE	A		A	A	A	A	A		
			0.60	0.60		0.60	0.60	0.60	0.60	0.60		
4.4.5	Create Work Breakdown Structure	0.60	TechE		A						A	A
			0.60		0.60						0.60	0.60
4.4.6	Define Activities	0.60								A	0.00	
										0.60	0.00	
4.4.7	Sequence Activities	0.50		A	A							
				0.40	0.60							
4.4.8	Estimate Activity Resources	0.60									A	
											0.60	
4.4.9	Estimate Activity Duration	0.60						A				
								0.60				
4.4.10	Develop Schedule	0.50	A			A	A		A			A
			0.40			0.60	0.60		0.40			0.60
4.4.11	Estimate Costs	0.60	TechE	A								
			0.60	0.60								
4.4.12	Determine Budget	0.60	TechE		A	A	A	A				
			0.60		0.60	0.60	0.60	0.60				
4.4.13	Plan Quality	0.60	A	A	A	A	A	A	A	A	A	
			0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	
4.4.14	Develop Human Resource Plan	0.60	A	A			A					
			0.60	0.60			0.60					
4.4.15	Acquire Project Team	0.60			A	A		A	A			
					0.60	0.60		0.60	0.60			
4.4.16	Plan Communications	0.60	A	A	A	A	A	A	A	A		
			0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60		
4.4.17	Plan Risk Management	0.53	A	A	A	A	A	A	A	A	A	A
			0.60	0.40	0.40	0.60	0.60	0.60	0.60	0.40	0.60	0.60
4.4.18	Plan Procurements	0.53	A	A	A	A	A					
			0.40	0.60	0.60	0.60	0.60					
4.4.19	Project Manager Characteristics (PM)	0.60	A	A	A	A	A	A	A			
			0.60	0.60	0.60	0.60	0.60	0.60	0.60			
4.4.20	Technological Expertise (TechE)	0.60	A	A	A	A	A	A	A	A	A	A
			0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60
4.4.21	Top Management Support (TopM)	0.66	QIOrg	A	A	A	A	A	A	A	A	A
			0.94	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60
4.4.22	Enterprise Environmental Factors (EnvFa)	0.55	QIOrg	A	A	A	A	A	A	A	A	A
			0.94	0.40	0.60	0.60	0.60	0.60	0.60	0.40	0.40	0.40
4.4.23	Quality of Methods and Tools (QM&T)	0.65	QIOrg	A	A	A	A	A	A	A		
			0.94	0.60	0.60	0.60	0.60	0.60	0.60	0.60		

QCM = 0.58

Table C.3: QCM Test Scenario 3—Answers as ‘Neutral’

Section	Cognitive Map	Weight	Node 1	Node 2	Node 3	Node 4	Node 5	Node 6	Node 7	Node 8	Node 9	Node 10
4.4.3	Develop Project Management Plan	0.56	QIOrg	Top M	Env Fa	QM &T	PM	N	N	N	N	
			0.82	0.55	0.53	0.55	0.50	0.50	0.50	0.50	0.50	
4.4.4	Define Scope	0.50	TechE	N		N	N	N	N	N		
			0.50	0.50		0.50	0.50	0.50	0.50	0.50		
4.4.5	Create Work Breakdown Structure	0.50	TechE		N						N	N
			0.50		0.50						0.50	0.50
4.4.6	Define Activities	0.50								N	0.00	
										0.50	0.00	
4.4.7	Sequence Activities	0.50		N	N							
				0.50	0.50							
4.4.8	Estimate Activity Resources	0.50									N	
											0.50	
4.4.9	Estimate Activity Duration	0.50						N				
								0.50				
4.4.10	Develop Schedule	0.50	N			N	N		N			N
			0.50			0.50	0.50		0.50			0.50
4.4.11	Estimate Costs	0.50	TechE	N								
			0.50	0.50								
4.4.12	Determine Budget	0.50	TechE		N	N	N	N				
			0.50		0.50	0.50	0.50	0.50				
4.4.13	Plan Quality	0.50	N	N	N	N	N	N	N	N	N	
			0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	
4.4.14	Develop Human Resource Plan	0.50	N	N			N					
			0.50	0.50			0.50					
4.4.15	Acquire Project Team	0.50			N	N		N	N			
					0.50	0.50		0.50	0.50			
4.4.16	Plan Communication s	0.50	N	N	N	N	N	N	N	N		
			0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50		
4.4.17	Plan Risk Management	0.50	N	N	N	N	N	N	N	N	N	N
			0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
4.4.18	Plan Procurements	0.50	N	N	N	N	N					
			0.50	0.50	0.50	0.50	0.50					
4.4.19	Project Manager Characteristics (PM)	0.50	N	N	N	N	N	N	N			
			0.50	0.50	0.50	0.50	0.50	0.50	0.50			
4.4.20	Technological Expertise (TechE)	0.50	N	N	N	N	N	N	N	N	N	N
			0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
4.4.21	Top Management Support (TopM)	0.55	QIOrg	N	N	N	N	N	N	N	N	N
			0.82	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
4.4.22	Enterprise Environmental Factors (EnvFa)	0.53	QIOrg	N	N	N	N	N	N	N	N	N
			0.82	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
4.4.23	Quality of Methods and Tools (QM&T)	0.55	QIOrg	N	N	N	N	N	N	N		
			0.82	0.50	0.50	0.50	0.50	0.50	0.50	0.50		

QCM = 0.50

Table C.4: QCM Test Scenario 4—Answers as 'Disagree'

Section	Cognitive Map	Weight	Node 1	Node 2	Node 3	Node 4	Node 5	Node 6	Node 7	Node 8	Node 9	Node 10
4.4.3	Develop Project Management Plan	0.47	QIOrg	Top M	Env Fa	QM &T	PM	D	D	D	D	
			0.71	0.45	0.56	0.44	0.40	0.40	0.40	0.40	0.40	
4.4.4	Define Scope	0.40	TechE	D		D	D	D	D	D		
			0.40	0.40		0.40	0.40	0.40	0.40	0.40		
4.4.5	Create Work Breakdown Structure	0.40	TechE		D						D	D
			0.40		0.40						0.40	0.40
4.4.6	Define Activities	0.40								D	0.00	
										0.40	0.00	
4.4.7	Sequence Activities	0.56		D	D							
				0.71	0.40							
4.4.8	Estimate Activity Resources	0.40									D	
											0.40	
4.4.9	Estimate Activity Duration	0.40						D				
								0.40				
4.4.10	Develop Schedule	0.56	D			D	D		D			D
			0.71			0.40	0.40		0.71			0.40
4.4.11	Estimate Costs	0.40	TechE	D								
			0.40	0.40								
4.4.12	Determine Budget	0.40	TechE		D	D	D	D				
			0.40		0.40	0.40	0.40	0.40				
4.4.13	Plan Quality	0.40	D	D	D	D	D	D	D	D	D	
			0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	
4.4.14	Develop Human Resource Plan	0.40	D	D			D					
			0.40	0.40			0.40					
4.4.15	Acquire Project Team	0.40			D	D		D	D			
					0.40	0.40		0.40	0.40			
4.4.16	Plan Communication s	0.40	D	D	D	D	D	D	D	D		
			0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40		
4.4.17	Plan Risk Management	0.50	D	D	D	D	D	D	D	D	D	D
			0.40	0.71	0.71	0.40	0.40	0.40	0.40	0.71	0.40	0.40
4.4.18	Plan Procurements	0.50	D	D	D	D	D					
			0.71	0.40	0.40	0.40	0.40					
4.4.19	Project Manager Characteristics (PM)	0.40	D	D	D	D	D	D	D			
			0.40	0.40	0.40	0.40	0.40	0.40	0.40			
4.4.20	Technological Expertise (TechE)	0.40	D	D	D	D	D	D	D	D	D	D
			0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
4.4.21	Top Management Support (TopM)	0.45	QIOrg	D	D	D	D	D	D	D	D	D
			0.71	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
4.4.22	Enterprise Environmental Factors (EnvFa)	0.56	QIOrg	D	D	D	D	D	D	D	D	D
			0.71	0.71	0.40	0.40	0.40	0.40	0.40	0.71	0.71	0.71
4.4.23	Quality of Methods and Tools (QM&T)	0.44	QIOrg	D	D	D	D	D	D	D		
			0.71	0.40	0.40	0.40	0.40	0.40	0.40	0.40		

QCM = 0.44

Table C.5: QCM Test Scenario 5—Answers as 'Strongly disagree'

Section	Cognitive Map	Weight	Node 1	Node 2	Node 3	Node 4	Node 5	Node 6	Node 7	Node 8	Node 9	Node 10
4.4.3	Develop Project Management Plan	0.16	QIOrg	Top M	Env Fa	QM &T	PM	SD	SD	SD	SD	
			0.62	0.10	0.46	0.09	0.00	0.00	0.00	0.00	0.00	
4.4.4	Define Scope	0.00	TechE	SD		SD	SD	SD	SD	SD		
			0.00	0.00		0.00	0.00	0.00	0.00	0.00		
4.4.5	Create Work Breakdown Structure	0.00	TechE		SD						SD	SD
			0.00		0.00						0.00	0.00
4.4.6	Define Activities	0.00								SD	0.00	
										0.00	0.00	
4.4.7	Sequence Activities	0.50		SD	SD							
				1.00	0.00							
4.4.8	Estimate Activity Resources	0.00									SD	
											0.00	
4.4.9	Estimate Activity Duration	0.00						SD				
								0.00				
4.4.10	Develop Schedule	0.50	SD			SD	SD		SD			SD
			1.00			0.00	0.00		1.00			0.00
4.4.11	Estimate Costs	0.00	TechE	SD								
			0.00	0.00								
4.4.12	Determine Budget	0.00	TechE		SD	SD	SD	SD				
			0.00		0.00	0.00	0.00	0.00				
4.4.13	Plan Quality	0.00	SD	SD	SD	SD	SD	SD	SD	SD	SD	
			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
4.4.14	Develop Human Resource Plan	0.00	SD	SD			SD					
			0.00	0.00			0.00					
4.4.15	Acquire Project Team	0.00			SD	SD		SD	SD			
					0.00	0.00		0.00	0.00			
4.4.16	Plan Communications	0.00	SD	SD	SD	SD	SD	SD	SD	SD		
			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
4.4.17	Plan Risk Management	0.33	SD	SD	SD	SD	SD	SD	SD	SD	SD	SD
			0.00	1.00	1.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00
4.4.18	Plan Procurements	0.33	SD	SD	SD	SD	SD					
			1.00	0.00	0.00	0.00	0.00					
4.4.19	Project Manager Characteristics (PM)	0.00	SD	SD	SD	SD	SD	SD	SD			
			0.00	0.00	0.00	0.00	0.00	0.00	0.00			
4.4.20	Technological Expertise (TechE)	0.00	SD	SD	SD	SD	SD	SD	SD	SD	SD	SD
			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.4.21	Top Management Support (TopM)	0.10	QIOrg	SD	SD	SD	SD	SD	SD	SD	SD	SD
			0.62	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.4.22	Enterprise Environmental Factors (EnvFa)	0.46	QIOrg	SD	SD	SD	SD	SD	SD	SD	SD	SD
			0.62	1.00	0.00	0.00	0.00	0.00	0.00	1.00	1.00	1.00
4.4.23	Quality of Methods and Tools (QM&T)	0.09	QIOrg	SD	SD	SD	SD	SD	SD	SD		
			0.62	0.00	0.00	0.00	0.00	0.00	0.00	0.00		

QCM = 0.11

C.3 Results and Discussion

The results show that the QPEM algorithm that calculates the quality indices is providing the expected results (calculated manually according to the formula described in Section 4.4.3). Table C.6 presents a summary of the expect results (Tables C.1–C.5) compared to the outputs provided by QPEM. The first two columns have the table number and the test scenario. Next are the quality indices for the QPM, QCM, Quality of Planning and Quality of Organisation Planning.

Table C.6: Expected results compared to QPEM outputs

		Expected Results				Actual Results			
Table	Scenario	QPM	QCM	Quality of Planning	Quality of Organisation Planning	QPM	QCM	Quality of Planning	Quality of Organisation Planning
C.1	SA	1.00	0.88	0.94	0.00	1.00	0.88	0.94	0.00
C.2	A	0.80	0.58	0.69	0.94	0.80	0.58	0.69	0.94
C.3	N	0.50	0.50	0.50	0.82	0.50	0.50	0.50	0.82
C.4	D	0.30	0.44	0.37	0.71	0.30	0.42	0.36	0.71
C.5	SD	0.00	0.11	0.06	0.63	0.00	0.11	0.06	0.62

A mean comparison (paired-samples t test) was conducted to determine the differences between the Expected Results and the Actual Results (Table C.7). It was found that the difference in the results is not statistically significant. This means that the algorithms that calculate the quality indices are providing the expected results.

Table C.7: Paired sample t-test of means compared

	Dif %	Dif Mean	Std. Deviation	T	df	Sig. (2-tailed)
Differences between the Expected Results and the Actual Results	0.371%	0.002	0.005	1.710	19	0.104

In conclusion, the White Box Testing (Section 6.2.2) demonstrated that the algorithms that calculate the QPEM quality indices provide accurate and reliable results.

APPENDIX D: QPLAN

The QPLAN software tool is confidential.

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