R&D Management Conference 2017, 1 - 5 July 2017, Leuven, Belgium

# Evaluating the Quality of Planning in New Product Development Projects


## Marco Antônio Amaral Féris[1], Ofer Zwikael[2]

[1] Cranfield School of Management, Cranfield University, M.Amaral-Feris@cranfield.ac.uk

[2] The Australian National University, ofer.zwikael@anu.edu.au


**The research and development industry shifts significant resources, from physical products to software. This is triggered by the need to stay competitive in a tough market. However, the poor performance of new product development in the field of software development may restrict this trend. Following a research stream that focuses on NPD planning, we introduce the quality of planning evaluation model (QPEM) and a knowledge base for improving the quality of planning evaluation. QPEM suggests planning quality should be evaluated using two distinct and complementary approaches of top-down and bottom-up for enhancing the accuracy of planning: a) an established measure that assesses 16 planning products and b) a novel measure that assesses 55 factors that affect project performance. This second measure uses cognitive maps, which is a methodology based on expert knowledge that graphically describes the behaviour of a system, and represents the project manager's know-how and**

**characteristics, technological expertise, top management support, enterprise environmental factors, and the quality of methods and tools in a form that corresponds closely with humans' perceptions. The alignment between these two approaches is demonstrated through multiple case studies.**

## 1. Introduction

With the aim to stay competitive in tough markets, the research and development (R&D) industry is predicted to shift significant resources from physical products to software development (SD) in the coming years. The R&D spending in software and services grew from 54% to 59% between 2010 and 2015 and the expected growth for 2020 is 63% (PwC's Strategy&, 2016). However, the performance of NPD in the SD field is usually low (Van Oorschot et al., 2010; Stockstrom and Herstatt, 2008).

To overcome this problem and be ready for the challenges ahead, researchers have identified improving the quality of planning as a key area for enhancing performance (Stockstrom and Herstatt, 2008; Verworn et al., 2008; Salomo et al., 2007). Planning aims to ensure that the solutions designed are mature enough to conduct the project through the next phases and achieve the desired goals (Salomo et al., 2007). This is the project phase before the funder makes the major investment, where the level of effort steadily increases and the level of uncertainty remains high (Hird et al., 2016), but tends to decrease towards the end of the phase. The costs of changes are typically low, but costs that influence the final characteristics of the project's product begin to rise. Proper planning (Serrador and Turner, 2015) should reduce the inherent high levels of uncertainty and complexity of NDP projects (Hird et al., 2016), such as requirement (Van Oorschot et al., 2010) and goal changes (Salomo et al., 2007).

This study introduces a model to evaluate the quality of planning (QPEM) of NPD in the field of SD projects and a knowledge base that supports QPEM in improving the quality of planning evaluation. QPEM has two complementary approaches (top-down and bottom-up) for enhancing the accuracy of planning (Jørgensen, 2004b), including planning quality of the manager (QPM), an established measure that assesses 16 core planning products from planning processes (Zwikael and Globerson, 2004), and quality of planning through cognitive maps (QCM), a novel measure that assesses 55 factors that affect the same planning processes.

Design science research (DSR) was selected as a research method, because of its strength in solving a real problem using applied research (Hevner et al., 2004), and the design science research process (DSRP) model (Peffers et al., 2007) was adopted to conducting this DSR study.

This paper proceeds as follows: Section 2 shows significant issues on existing approaches for evaluating the quality of planning. Section 3 discusses the research approach, Section 4 describes the design and development of QPEM, while Section 5 presents a knowledge base that supports QPEM in improving the quality of planning evaluation. The alignment between the top-down and bottom-up approaches is presented in Section 6, and Section 7 summarises the findings, discusses the implications for research and practitioners, and limitations of this study, and outlines further research.

## 2. Issues on existing approaches for evaluating the quality of planning

Despite researchers' continuous efforts to measure the quality of planning of NPD in the field of SD projects, the literature shows significant issues on existing approaches for evaluating the quality of planning. For example, Henttonen et al. (2016) showed that NPD performance indicators depend on the type of innovation project and identified 11 (out 20) indicators related to process and implementation. However, these indicators do not measure in depth the quality of planning.

Checklists are possibly the easiest tool for analysing the quality of planning. Among other tools, they can be used to identify risks, check whether the project can move to the next phase (Keil et al., 2008), and ensure that the project is compliance with the organisation's policies. However, because checklists depend on experts' knowledge, while good checklists can help in risk identification, bad ones can identify non-existent risks (Keil et al., 2008).

In addition, Hird et al. (2016) identified three approaches for forecasting resource planning.

They are: 1) Estimation-based, which involves one or more experts with knowledge in the domain (e.g. Delphi). However, the quality of estimation-based approaches depends on the level of knowledge and engagement of the experts; 2) Theory-based, which involves existing models from the literature (e.g. constructive cost model–COCOMO). However, as it has fixed attributes and there is no one-size fits-all attributes for NPD projects, the importance of this approach has been diminishing; and 3) Historical data-based, which involves the identification of trends from data of past projects (e.g. machine learning techniques). However, this approach requires vast quantities of data to provide quality information.

Because of these issues in existing approaches for evaluating the quality of planning, we need a new approach aimed at overcoming the limitations to existing methods. Hence the paper's research question is: "How can the planning quality of NPD in the SD field be better evaluated?"

## 3. Research approach

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, methods, models and theory (Vaishnavi and Kuechler, 2004) and aims to design solutions for real problems (Hevner et al., 2004).

DSR is the research that creates this type of missing knowledge using design primarily as a research method (Vaishnavi and Kuechler, 2004). For carrying out DSR, we selected the DSRP model (Peffers et al., 2007) that is addressed in this study as follows (Amaral Féris, 2017; Amaral Féris et al., 2017):

Step 1– Problem identification and motivation: continue to examine the contribution of planning for enhancing project performance as suggested by Stockstrom and Herstatt (2008).

Step 2– Objectives of a solution: develop a model to evaluate and improve the quality of planning of SD projects (Section 1).

Step 3– Design and development: describe QPEM (Section 4) and two strategies for improving the quality of planning (Section 5).

Step 4– Demonstration: the demonstration of the utility of QPEM, which is the essence of DSR (Hevner et al., 2004), was performed through the alignment between top-down and bottom-up approaches (Section 6).

Step 5– Evaluation: the evaluation of QPEM was performed through correlation analysis (Section 6).

Step 6– Communication: this study is part of an ongoing research project aimed at enhancing project performance, regardless of the type of SD project. We analysed the effectiveness of QPLAN (a decision support tool that implements QPEM in practice) in 11 organisations (Amaral Féris, 2017) and showed that QPLAN reduced the psychological biases that prevent managers from making correct planning decisions (Amaral Féris et al., 2017). In this paper, we focus on QPEM and organisations that develop new products.

## 4. Evaluating the quality of planning

QPEM evaluates the quality of planning through two distinct and complementary approaches (top-down and bottom-up) for enhancing the accuracy of planning (Jørgensen, 2004b). Moreover, the contrast of both approaches allows the project manager to identify the strengths and weaknesses of planning and thus, focus on the most important planning issues. QPEM's output is a quantitative objective indicator (Chiesa and Frattini, 2007) that represents the quality of planning (QIPlan). QIPlan is calculated from the average of QPM and QCM and ranges from 0.0 (lowest) to 1.0 (highest) (Amaral Féris, 2017; Amaral Féris et al., 2017).

### *4.1. Evaluating the quality of planning through the top-down approach*

The evaluation of the quality of planning through the top-down approach is made by QPM, an established 16-item scale developed by Zwikael and Globerson (2004) that captures post-decision project planning (Salomo et al., 2007). At the end of the planning, the project manager evaluates 16 core planning products from 16 planning processes using a 5-point Likert scale. The quality of planning of each planning product is then converted according to a quantitative subjective indicator (Chiesa and Frattini, 2007) that ranges from 0.0 (lowest) to 1.0 (highest) (Amaral Féris, 2017; Amaral Féris et al., 2017).

### *4.2. Evaluating the quality of planning through the bottom-up approach*

The evaluation of the quality of planning through the bottom-up approach is made by QCM, a novel scale based on cognitive maps. The concept of cognitive mapping was introduced by the American psychologist Edward Tolman, while studying decision making in "rats and men" (Tolman, 1948). During his experiment using mazes, he observed that rats learnt signals from this environment and built a mental representation of the maze (i.e. a cognitive map) to find food (i.e. achieve their goals). Among other contributions, Tolman paved the way for the Nobel Prize work of Kahneman in 2002 (Welsh, 2016) and the dual process theory (Kahneman, 2011), which impacted on the quality of decisions taken during the planning phase (Amaral Féris et al., 2017).

Cognitive maps are based on expert knowledge (Stach et al., 2005), and describe graphically the behaviour of a system in a form that corresponds closely with humans' perceptions (Rodriguez-Repiso et al., 2007). This methodology is used in numerous areas for solving problems, such as political (Axelrod, 1976), strategic management (Huff, 1990), medicine, information systems and supervisory systems (Stach et al., 2005). Cognitive maps are an effective tool to analyse the development process of NPD products (Carbonara and Scozzi, 2006). In planning, cognitive maps are used for modelling success factors (Salmeron, 2009), supporting risk analysis (Ngai et al., 2004) and decision-making systems (Sharif et al., 2010).

There are three elements in a cognitive map: a) nodes, for identifying the most relevant factors in the system; b) edges, for representing the causal-effect relationships (positive or negative) between factors (Rodriguez-Repiso et al., 2007); and c) weights, for indicating the intensity of these relationships (Stach et al., 2005) (Figure 1).

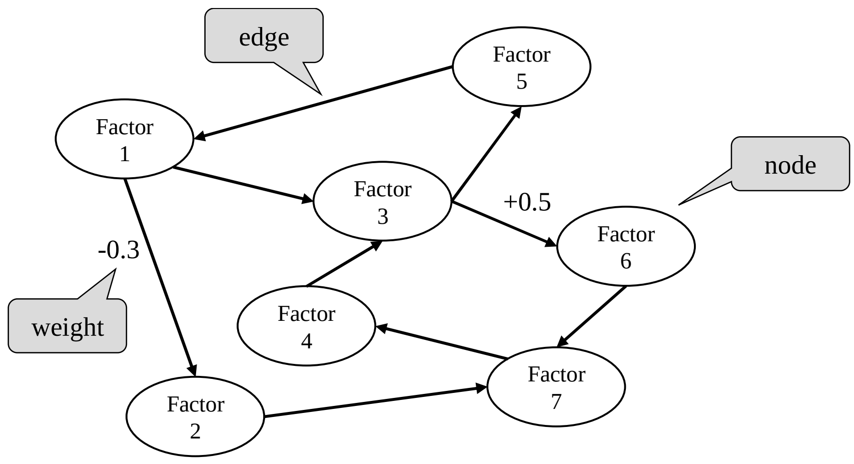


Figure 1: The three elements of a cognitive map (adapted from Stach et al., 2005)

In total, QCM has 21 cognitive maps and 55 factors, comprising 16 cognitive maps representing the same 16 core planning processes used by QPM, and five for enhancing the evaluation made by them (Amaral Féris, 2017; Amaral Féris et al., 2017). All factors were grouped by similarities into the 21 cognitive maps. For example, the “Plan Risk Management” cognitive map has nine factors: “maturity of an organisation’s processes for assigning ownership of risks”, “multi-vendor complicated dependencies”, “risk level”, “secure project funding”, “team members with great motivation”, “alternative solutions planned”, “acceptance of possible failure planned”, “occurrence of breakthrough” and “up-front risk analysis done”. Figure 2 shows the 21 QCM cognitive maps and highlights this example.


Figure 2: The 21 QCM cognitive maps and the example highlighted (adapted from Amaral Féris et al., 2017)

QCM captures two types of planning activity: pre-decision business planning and post-decision project planning (Salomo et al., 2007). At the beginning of planning (pre-decision business planning), the project manager evaluates 23 factors for an understanding of the business case, the enterprise environmental factors that affect quality of planning, the infrastructure that surrounds the project and the risk level (Appendix A). At the end of planning (post-decision project planning), the project manager evaluates 32 factors related to the development process (Appendix B). This second set of factors also serves as a checklist that he or she may use to improve the project plan. For example, "the project plan has small releases planned" and "the project plan has slack incorporated" (questions related to factors #9 and #10 in Appendix B). As QPM, all answers are measured on a five-point Likert scale that is converted into a quantitative subjective indicator that ranges from 0.0 (lowest) to 1.0 (highest).

*4.3. Focusing on the most important planning issues*

The contrast of QCM and QPM evaluations allows the project manager to identify the strengths and weaknesses of planning and thus focus on the most important planning issues. Examples: a) The evaluation of “plan communications” made by QPM is 0.9 and QCM is 0.8. This means that the indicators provided by them are high and the project manager does not need to improve them. b) The evaluation of “develop human resource plan” made by QPM is 0.8 and QCM is 0.3. This means that there is a significant difference between them and the project manager should identify the reasons for such discrepancy (e.g. check whether the answers provided were overestimated or underestimated). c) The evaluation of “plan risk management” made by QPM is 0.3 and QCM is 0.4. This means the indicators provided by them are low and the project manager does need to improve the risk management plan for reducing project risks.

## 5. Improving the quality of planning evaluation

We developed a knowledge base built for registering the experience acquired by the organisation in developing projects for improving the quality of planning evaluation systematically and gradually. Based on NPD (Goffin and Koners, 2011), information systems (Jørgensen and Gruschke, 2009; Boh et al., 2007) and operations management literature (Anand et al., 2010), this knowledge base serves as a reference for the project manager to check whether the evaluations provided by QPEM are being overestimated or underestimated.

In addition, the knowledge base provides a quantitative objective indicator (Chiesa and Frattini, 2007) to represent the quality of project planning (QIPlanOrg). QIPlanOrg is calculated from the average of the QIPlan of past projects developed by the organisation.

The effectiveness of the knowledge base in improving the quality of planning evaluation depends on the number of projects registered in this knowledge base. Answers provided by the project manager at the beginning of planning and end of planning that were inputs for QPEM evaluate the quality of planning, QPEM indicators (QIPlan, QPM and QCM), and the identification of enhancement opportunities at the end of project are then registered in the data base. Then, in the second project developed by the organisation, the project manager can consult data from the first project. In the third project, the project manager can consult data from the first and the second projects, and so on, i.e. the knowledge base builds a profile of the organisation step-by-step that can be used by the project manager as a reference to analyse the quality of planning. The more projects developed by the organisation, the more accurate the reference provided by the knowledge base.

## 6. Alignment between top-down (QPM) and bottom-up (QCM) approaches

### *6.1 Hypothesis development*

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 by examining a project from a broad viewpoint to provide the effort estimations (top-down) or by estimating them individually and then calculating the sum of all the activities (bottom-up) (Shepperd and Cartwright, 2001). In the top-down approach, the time required to estimate the effort is lower compared to the bottom-up and it does not require as much technical expertise. However, the quality of the project's estimation depends on data from past projects, from memory or from project documentation (Jørgensen, 2004a). Conversely, the bottom-up approach leads to understanding the project requirements in detail and this knowledge will be useful during the project execution but the quality of the activities' estimations depends on the knowledge of the experts (Jørgensen, 2004b).

We argue that top-down (QPM) and bottom-up (QCM) approaches are valid and complementary for evaluating the quality of planning of SD projects (Jørgensen, 2004b):

$H_1$*: There is a positive correlation between QPM and QCM.*

*6.2. Sample and procedures*

A total of 66 projects of NPD (39) and improvements in existing products (25) projects were collected in this study, but two projects were not considered in this test because they had not completed the planning. Participants consisted of 48 project managers and six supervisors from 12 organisations. These organisations are of different sizes, process maturity levels, types of industry and countries. Table 1 shows the sample profile in this test.

Table 1. Sample profile

| Project Type | Organisation | Industry Type | Australia | Brazil | US | Israel | Germany | Italy | Total |
|---|---|---|---|---|---|---|---|---|---|
| NPD | A | Automation | | 7 | | | | | 7 |
| | B | R&D | | 10 | 1 | | | | 11 |
| | C | Defence | | 18 | | 2 | 1 | | 21 |
| Improvements in existing products | D | IT | | 9 | 1 | | | 3 | 13 |
| | E | Education | 6 | | | | | | 6 |
| | F | Pharmaceutical | | 1 | | | | | 1 |
| | G | Logistics | | 4 | | | | | 4 |
| | H | Banking | | 1 | | | | | 1 |
| | | Total | 6 | 50 | 2 | 2 | 1 | 3 | 64 |

At the beginning of the planning, project managers were asked to identify the project (e.g. project name), classify the project's characteristics for defining a proper management approach (Shenhar and Dvir, 2007), evaluate the initial conditions of planning (e.g. "This project has clear and realistic objectives") and fill the demographic information sheet (e.g. project management approach, work experience). At the end of the planning, project managers were asked to evaluate its quality (e.g. "The project plan is able to deliver the scope with the quality required on time"). At the end of the project, supervisors were asked to evaluate its success (according to Lechler and Dvir's, 2010 dimensions) and project managers were asked to identify enhancement opportunities (e.g. "What should be done differently next time?").

The measures used in this test were QPM and QCM (Sections 4.1-4.2). A correlation analysis was conducted to examine the relationship between QPM and QCM (H1).

### *6.3. Results and discussion*

The positive and significant correlation between QPM and QCM (R=0.858, R Square=0.735, p-value<0.01) provides support for H1, i.e. top-down and bottom-up approaches are valid and complementary for evaluating the quality of the planning of SD projects.

## 7. Conclusions

Motivated by the shift of significant resources from physical products to software in the R&D industry and the low performance of SD, we introduced an innovative model to evaluate the quality of planning of SD projects (QPEM) and a knowledge base for improving the quality of planning evaluation. To develop QPEM, we first examined the relevant literature related to planning quality evaluation of NPD in the SD field. Then, we selected DSR (Hevner et al., 2004) as a research approach and DSRP to conduct this study (Peffers et al., 2007), because this model provides a mental model for the research output. The demonstration of the utility of QPEM, which is the essence of DSR (Hevner et al., 2004), was performed in multiple case studies in organisations that developed SD projects, which were chosen for strengthening the results from an in-depth examination of each case within the business environment (Yin, 2003).

As a result, the research question could be answered. The quality of planning of SD can be better evaluated through QPEM, because the design of this model addresses several best practices from the literature and industry for evaluating the quality of planning.

Notwithstanding, the limited number of projects does not allow full validation. One may argue that QPEM may not be as effective under different types of management approaches. For example, an organisation that adopts a sequential approach for an NPD in the SD field that follows the DO-178C (Moy et al., 2013) may find QPEM more effective than those using a flexible approach (e.g. Scaled Agile Framework–SAFe). Therefore, future work is planned to collect more data and analyse the effectiveness of QPEM in different management approaches.

## References


Amaral Féris, M.A. 2017. "QPLAN: A Tool for Enhancing Software Development Project Performance with Customer Involvement." In: *Handbook of Research on Strategic Alliances and Value Co-Creation in the Service Industry*, edited by S. Rozenes and Y. Cohen, 259-283. Hershey: IGI Global.

Amaral Féris, M.A., Zwikael, O. and Gregor, S. 2017. "QPLAN: Decision Support for Evaluating Planning Quality in Software Development Projects". *Decision Support Systems* 96: 92-102.

Anand, G., Ward, P.T. and Tatikonda, M.V. 2010. "Role of explicit and tacit knowledge in Six Sigma projects: An empirical examination of differential project success." *Journal of Operations Management* 28 (4):303–315.

Axelrod, R. (1976) *Structure of Decision: The Cognitive Maps of Political Elites*. Princeton, New Jersey: Princeton University Press.

Boh, W.F., Slaughter, S.A. and Espinosa, J.A. 2007. "Learning from Experience in Software Development: A Multilevel Analysis." *Management Science* 53 (8):1315-1331.

Boh, W.F. and Wong, S.S. 2013. "Organizational Climate and Perceived Manager Effectiveness: Influencing Perceived Usefulness of Knowledge Sharing Mechanisms." *Journal of the Association for Information Systems* 14 (3):122-152.

Bradford, M. and Florin, J. 2003. "Examining the role of innovation diffusion factors on the implementation success of enterprise resource planning systems." *International Journal of Accounting Information Systems* 4 (3):205–225.

Butler, T. and Fitzgerald, B. 1999. "Unpacking the systems development process - an empirical application of the CSF concept in a research context." *Journal of Strategic Information Systems* 8 (4):351–371.

Carbonara, N. and Scozzi, B. 2006. "Cognitive maps to analyze new product development processes: A case study." *Technovation* 26 (11):1233–1243.

Chiesa, V. and Frattini, F. 2007. "Exploring the differences in performance measurement between research and development: evidence from a multiple case study." *R&D Management* 37

(4):283-301.

Chow, T. and Cao, D. 2008. “A survey study of critical success factors in agile software projects.” *Journal of Systems and Software* 81 (6):961–971.

Dvir, D. and Lechler, T. 2004. “Plans are nothing, changing plans is everything: the impact of changes on project success.” *Research Policy* 33 (1):1-15.

Fairley, R.E. and Willshire, M.J. 2003. “Why the Vasa sank - 10 problems and some antidotes for software projects.” *IEEE Software* 20 (2):18-25.

Fortune, J. and White, D. 2006. “Framing of project critical success factors by a systems model.” *International Journal of Project Management* 24 (1):53–65.

Goffin, K. and Koners, U. 2011. “Tacit Knowledge, Lessons Learnt, and New Product Development.” *Journal of Product Innovation Management* 28 (2):300-318.

Henttonen, K., Ojanen, V. and Puumalainen, K. 2016. “Searching for appropriate performance measures for innovation and development projects.” *R&D Management* 46 (5):914-927.

Hevner, A.R.H., March, S.T., Park, J. and Ram, S. 2004. “Design Science in Information Systems Research.” *MIS Quarterly* 28 (1):75-105.

Hird, A., Mendibil, K., Duffy, A. and Whitfield, R.I. 2016. “New product development resource forecasting.” *R&D Management* 46 (5):857–871.

Huff, A.S. 1990. *Mapping Strategic Thought*. New York: Wiley.

Jørgensen. M. 2004a. “A review of studies on expert estimation of software development effort.” *Journal of Systems and Software* 70 (1-2):37–60.

Jørgensen, M. 2004b. “Top–down and bottom–up expert estimation of software development effort.” *Information and Software Technology* 46 (1):3–16.

Jørgensen, M. and Gruschke, T.M. 2009. “The Impact of Lessons-Learned Sessions on Effort Estimation and Uncertainty Assessments.” *IEEE Transactions on Software Engineering* 35 (3):368-383.

Kahneman, D. 2011. *Thinking, Fast and Slow*, 1st ed. New York: Farrar, Straus and Giroux.

Keil, M., Li, L., Mathiassen, L. and Zheng, G. 2008. “The influence of checklists and roles on software practitioner risk perception and decision-making." *Journal of Systems and Software* 81 (6):908–919.

Lechler, T.G. and Dvir, D. 2010. "An Alternative Taxonomy of Project Management Structures: Linking Project Management Structures and Project Success." *IEEE Transactions on Engineering Management* 57 (2):198-210.

Loh, T.C. and Koh, S.C.L. 2004. "Critical elements for a successful enterprise resource planning implementation in small- and medium-sized enterprises." *International Journal of Production Research* 42 (17):3433–3455.

Moy, Y., Ledinot, E., Delseny, H., Wiels, V. and Monate, B. 2013. "Testing or Formal Verification: DO-178C Alternatives and Industrial Experience." *IEEE Software* 30 (3):50-57.

Ngai, E.W.T., Cheng, T.C.E. and Ho, S.S.M. 2004. "Critical success factors of web-based supply-chain management systems - an exploratory study." *Production Planning and Control* 15 (6):622–630.

Peffers, K., Tuunamen, T., Rotenberger, M.A. and Chatterjee, S. 2007. "A Design Science Research Methodology for Information Systems Research." *Journal of Management Information Systems* 24 (3):45-77.

Pinto, J.K. and Slevin, D.P. 1986. "The Project Implementation Profile: New Tool for Project Managers." *Project Management Journal* 17 (4):57-65.

PwC's Strategy& 2016. Companies shifting more R&D spending away from physical products to software and services: 2016 Global Innovation 1000 Study. Accessed 5, 2017. http://www.strategyand.pwc.com/global/home/press/displays/2016-global-innovation1000-study

Raz, T., Shenhar, A.J. and Dvir, D. 2002. "Risk management, project success, and technological uncertainty." *R&D Management* 32 (2):101-109.

Reddy, C.S. and Raju, K. 2009. "An Improved Fuzzy Approach for COCOMO's Effort Estimation using Gaussian Membership Function." *Journal of Software* 4 (5):452-459.

Riek, R.F. 2001. "From experience: Capturing hard-won NPD lessons in checklists." *Journal of*

*Product Innovation Management* 18 (5):301-313.

Rodriguez-Repiso, L. and Setchi, R., Salmeron, J.L. 2007. “Modelling IT projects success: Emerging methodologies reviewed.” *Technovation* 27 (10):582–594.

Salmeron, J.L. 2009. “Augmented fuzzy cognitive maps for modelling LMS critical success factors.” *Knowledge-Based Systems* 22 (4):275–278.

Salomo, S., Weise, J. and Gemünden, H.G. 2007. “NPD Planning Activities and Innovation Performance: The Mediating Role of Process Management and the Moderating Effect of Product Innovativeness.” *Journal of Product Innovation Management* 24 (4):285-302.

Schmidt, R., Lyytinen, K., Keil, M. and Cule, P. 2001. “Identifying software project risks: An international Delphi study.” *Journal of Management Information Systems* 17 (4):5-36.

Serrador, P. and Turner, R. 2015. “What is Enough Planning? Results From a Global Quantitative Study.” *IEEE Transactions on Engineering Management* 62 (4):462-474.

Sharif, A.M., Irani, Z. and Weerakkoddy, V. 2010. “Evaluating and modelling constructs for e-government decision making.” *The Journal of the Operational Research Society, supl. Part Special Issue: Operational Research in Project* 61 (6):929-952.

Shenhar, A. and Dvir, D. 2007. *Reinventing project management: the diamond approach to successful growth and innovation.* Boston: Harvard Business School Press.

Shepperd, M. and Cartwright, M. 2001. “Predicting with sparse data.” *IEEE Transactions on Software Engineering* 27 (11):987-998.

Siebdrat, F., Hoegl, M. and Ernst, H. 2014. “Subjective Distance and Team Collaboration in Distributed Teams.” *Journal of Product Innovation Management* 31 (4):765-779.

Simon, H.A. 1996. *The Sciences of the Artificial.* 3rd ed. Cambridge: MIT Press.

Stach, W., Kurgan, L., Pedrycz, W. and Reformat, M. 2005. Genetic learning of fuzzy cognitive maps. *Fuzzy Sets and Systems* 153 (3):371–401.

Stamelos, I., Angelis, L., Morisio, M., Sakellaris, E. and Bleris, G. L. 2003. “Estimating the development cost of custom software.” *Information and Management* 40 (8):729–741

Stockstrom, C. and Herstatt, C. 2008. “Planning and uncertainty in new product development.”

*R&D Management* 38 (5):480-490.

Tolman, E.C. 1948. Cognitive maps in rats and men. *Psychological Review* 55 (4):189-208.

Vaishnavi, V. and Kuechler, W. 2012. *Design Science Research Methods and Patterns: Innovating Information and Communication Technology*. Boston: Auerbach Publications. Taylor and Francis Group.

Van Oorschot, K., Sengupta, K., Akkermans, H. and Van Wassenhove, L. 2010.” Get Fat Fast Surviving Stage-Gate® in NPD.” *Journal of Product Innovation Management* 27 (6):828-839.

Verworn, B., Herstatt, C. and Nagahira, A. 2008. “The fuzzy front end of Japanese new product development projects: impact on success and differences between incremental and radical projects.” *R&D Management* 38 (1):1-19.

Welsh, J.R. 2016. *Empowerment of the Weak: A Path Towards Freedom and Chaos*. Aurora: WaveCloud Corporation.

Willcocks, L. and Griffiths, C. 1994. “Predicting risk of failure in large-scale Information Technology projects.” *Technological Forecasting and Social Change* 47 (2):205-228.

Wohlin, C. and Andrews, A.A. 2001. “Assessing Project Success Using Subjective Evaluation Factors.” *Software Quality Journal* 9 (1):43-70.

Yin, R.K. 2003. *Case Study Research - Design and Methods*. 3rd ed. Thousand Oaks CA: Sage Publications Inc.

Zwikael, O. 2008. “Top management involvement in PM - exclusive support practices for different project scenarios.” *International Journal of Managing Projects in Business* 1 (3):387-403.

Zwikael, O. and Globerson S. 2004. “Evaluating the quality of project planning: a model and field results.” *International Journal of Production Research* 42 (8):1545–1556.

Zwikael, O., Pathak, R.D., Singh, G. and Ahmed, S. 2014. “The moderating effect of risk on the relationship between planning and success.” *International Journal of Project Management* 32 (3):435-441.

## Appendix A. Quality of planning evaluation by QCM (first set of factors)

| Factors | References | Cognitive Maps | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 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 Human Resource Plan | Acquire Project Team | Plan Communications | Plan Risk Management | Plan Procurements | Project Manager Characteristics | Technological Expertise | Top Management Support | Enterprise Environmental Factors | Quality of Methods and Tools |
| 1. Sound basis for project | Fortune and White, 2006 | X | | | | | | | | | | | | | | | | | | | | |
| 2. Clear realistic objectives | Riek, 2001; Fortune and White, 2006 | | X | | | | | | | | | | | | | | | | | | | |
| 3. Time pressure on the project | Wohlin and Andrews, 2001 | | | | | | | | X | | | | | | | | | | | | X | |
| 4. Cooperation between project team members | Siebdrat et al., 2014 | | | | | | | | | | | | | | X | | | | | | X | |
| 5. Cooperation between the project team and other project teams | Siebdrat et al., 2014 | | | | | | | | | | | | | | X | | | | | | X | |
| 6. High value on face-to-face communication | Chow and Cao, 2008 | | | | | | | | | | | | | | X | | | | | | X | |
| 7. Maturity of an organisation's processes for assigning ownership of risks | Raz et al., 2002 | | | | | | | | | | | | | | | X | | | | | X | |
| 8. Appropriate project management assigned | Fortune and White, 2006 | | | | | | | | | | | | | | | | | | | X | | |
| 9. Involvement of the project management in the initiation | Fortune and White, 2006 | | | | | | | | | | | | | | | | | | | X | | |
| 10. Confidence of top management support | Zwikael, 2008 | | | | | | | | | | | | | | | | | | | X | | |
| 11. An entrepreneurial climate for product innovation | Boh and Wong, 2013 | | | | | | | | | | | | | | | | | | | | X | |
| 12. Organisational culture too political | Chow and Cao, 2008 | | | | | | | | | | | | | | | | | | | | X | |
| 13. Turbulent environment | Willcocks and Griffiths, 1994 | | | | | | | | | | | | | | | | | | | | X | |
| 14. High turnover rate | Wohlin and Andrews, 2001 | | | | | | | | | | | | | | | | | | | | X | |
| 15. Learning from past experience | Goffin and Koners, 2011 | X | | | | | | | | | | | | | | | | | | | | X |
| 16. Experience with similar projects | Willcocks and Griffiths, 1994; Dvir and Lechler, 2004 | | | | | | | | | | | | | | | | | | | | | X |
| 17. Familiar technology | Fortune and White, 2006 | | | | | | | | | | | | | | | | | | X | | | |
| 18. Multi-vendor complicated dependencies | Schmidt et al., 2001 | | | | | X | | | | | | | | | | X | X | | | | | |

| Factors | References | Cognitive Maps | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 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 Human Resource Plan | Acquire Project Team | Plan Communications | Plan Risk Management | Plan Procurements | Project Manager Characteristics | Technological Expertise | Top Management Support | Enterprise Environmental Factors | Quality of Methods and Tools |
| 19. Existence of project tools | Zwikael and Globerson, 2004 | | | | | | | | | | X | | | | | | | | | | | X |
| 20. Quality of requirement methodology | Wohlin and Andrews, 2001 | | | | | | | | | | | X | | | | | | | | | | X |
| 21. Quality of test methodology | Wohlin and Andrews, 2001 | | | | | | | | | | | X | | | | | | | | | | X |
| 22. Quality of configuration management system | Wohlin and Andrews, 2001 | | | | | | | | | | | X | | | | | | | | | | X |
| 23. Risk level | Zwikael et al., 2014 | | | | | | | | | | | | | | | X | | | | | | |

**Appendix B. Quality of planning evaluation by QCM (second set of factors)**

| Factors | References | Cognitive maps | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 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 Human Resource Plan | Acquire Project Team | Plan Communications | Plan Risk Management | Plan Procurements | Project Manager Characteristics | Technological Expertise | Top Management Support | Enterprise Environmental Factors | Quality of Methods and Tools |
| 1. Sufficient input in the planning | Pinto and Slevin,1986 | X | | | | | | | | | | | | | | | | | | | | |
| 2. Use of prototypes to refine requirements | Butler and Fitzgerald, 1999 | | | X | | | | | | | | | | | | | | | | | | |
| 3. Compatibility with other systems | Bradford and Florin, 2003 | | X | | | | | | | | | | | | | | | | | | | |
| 4. Performance required | Fairley and Willshire, 2003 | | X | | | | | | | | | | | | | | | | X | | | |
| 5. Reliability required | Reddy and Raju, 2009; Ngai et al., 2004 | | X | | | | | | | | | | | | | | | | X | | | |
| 6. Database size | Reddy and Raju, 2009 | | X | | | | | | | | | | | | | | | | X | | | |
| 7. Delivering most important features first | Chow and Cao, 2008 | | | | | X | | | | | | | | | | | | | | | | |

| Factors | References | Cognitive maps | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 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 Human Resource Plan | Acquire Project Team | Plan Communications | Plan Risk Management | Plan Procurements | Project Manager Characteristics | Technological Expertise | Top Management Support | Enterprise Environmental Factors | Quality of Methods and Tools |
| 8. Realistic schedule planned | Fortune and White, 2006 | | | | | | | | X | | | | | | | | | | | | | |
| 9. Small releases planned | Chow and Cao, 2008 | | | | | | | | X | | | | | | | | | | | | | |
| 10. Slack planned | Pinto and Slevin, 1986 | | | | | | | X | | | | | | | | | | | | | | |
| 11. Overtime planned | Chow and Cao, 2008 | | | | | | | | X | | | | | | | | | | | | | |
| 12. Realistic effort estimates | Jørgensen and Gruschke, 2009 | | | | | | | | | X | | | | | | | | | | | | |
| 13. Secured project funding | Loh and Koh, 2004 | | | | | | | | | | X | | | | | X | | | | X | | |
| 14. Right amount of documentation developed | Chow and Cao, 2008, Fortune and White, 2006 | | | | | | | | | | | X | | | | | | X | | | | |
| 15. Rigour of project management plan review | Wohlin and Andrews, 2001 | | | | | | | | | | | X | | | | | | | | | | |
| 16. Rigour of development review | Wohlin and Andrews, 2001 | | | | | | | | | | | X | | | | | | | | | | |
| 17. Rigour of test planning review | Wohlin and Andrews, 2001 | | | | | | | | | | | X | | | | | | | | | | |
| 18. Appropriate technical training to team | Fortune and White, 2006; Pinto and Slevin, 1986 | | | | | | | | | | | | X | | | | | | | | | |
| 19. Team members with great motivation | Chow and Cao, 2008 | | | | | | | | | | | | X | | | X | | | | | | |
| 20. Well allocated resources | Verworn et al., 2008 | | | | | | | | | | | | | X | | | | X | | | | |
| 21. Sufficient resources | Fortune and White, 2006 | | | | | | | | | | | | | X | | | X | | | X | | |
| 22. Plan for effective communication between team members | Fortune and White, 2006 | | | | | | | | | | | | | | | | | | | | | |
| 23. Plan to involve customer in the project | Chow and Cao, 2008 | | | | | | | | | | | | | | X | | | | | | | |
| 24. Alternative solutions planned | Willcocks and Griffiths, 1994 | | | | X | | | | | | | | | | | X | | | | | | |
| 25. Acceptance of possible failure planned | Fortune and White, 2006 | | | | | | | | | | | | | | | X | | | | | | |
| 26. Occurrence of breakthrough | Dvir and Lechler, 2004 | | | | | | | | | | | | | | | X | | | | | | |
| 27. Well defined roles and responsibilities | Verworn et al., 2008; Schmidt et al., 2001 | | | | | | | | | | | | | | X | | | | | | | |
| 28. Up-front risk analysis done | Raz et al., 2002 | | | | | | | | | | | | | | | X | | | | | | |

| Factors | References | Cognitive maps | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 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 Human Resource Plan | Acquire Project Team | Plan Communications | Plan Risk Management | Plan Procurements | Project Manager Characteristics | Technological Expertise | Top Management Support | Enterprise Environmental Factors | Quality of Methods and Tools |
| 29. Appropriate approach for people management | Riek, 2001; Pinto and Slevin, 1986 | | | | | | | | | | | | X | | | | | X | | | | |
| 30. Tech specifications detailed | Verworn et al., 2008 | | X | | | | | | | | | | | | | | | | X | | | |
| 31. Team members with high competence and expertise | Verworn et al., 2008; Chow and Cao, 2008 | | | | | | | | | | | | | X | | | | | X | | | |
| 32. Contractor to fill gaps in expertise | Loh and Koh, 2004 | | | | | | X | | | | | | | | | | X | | X | | | |

## Appendix C. Identification of enhancement opportunities at the end of project

| # | Questions | References |
|---|---|---|
| 1 | What went well? | Jørgensen and Gruschke, 2009 |
| 2 | What should be done differently next time? | |
| 3 | How new is the product to customers and users? | Shenhar and Dvir, 2007 |
| 4 | How much new technology is used? | |
| 5 | How complex is the system and its subsystems? | |
| 6 | How critical is the time frame? | |
| 7 | Change management was effective | Dvir and Lechler, 2004 |
| 8 | The project had a diverse and synergistic team | Siebdrat et al., 2014 |
| 9 | Team meetings were effective | Chow and Cao, 2008 |
| 10 | Risks were managed in an appropriate way | Raz et al., 2002; Fortune and White, 2006 |
| 11 | It was a high-risk project | Zwikael et al., 2014 |
| 12 | Project was managed in an appropriate way | Shenhar and Dvir, 2007 |
| 13 | How easy was implementation? | Fortune and White, 2006 |
| 14 | The involvement of the top manager benefited the project | Zwikael, 2008 |
| 15 | The collaboration between team members and organisation's departments was high | Siebdrat et al., 2014 |
| 16 | The methodology adopted was appropriate | Wohlin and Andrews, 2001 |