An empirical study on the use of project management tools and techniques across project life-cycle and their impact on project success

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Even though project management tools and techniques (PMTT) have been commonly used by project managers, research on PMTT still has not been adequately investigated as to whether its use contributes to the success of a project. The lack of such knowledge leads to the use of PMTT because of popularity rather than any known benefits. To respond to this issue, the authors conducted a large-sample study based on a survey and statistical analyses to investigate the use of PMTT. Evidence emerged that some PMTT should be used in a certain phase of a project and such uses contribute to project success.

Introduction

Project management has been around for decades and has gained its reputation in recent years as a management practice that helps an organisation achieve its business results. Project management helps an organisation reduce product development time to market, utilise limited resources, handle technological complexity, respond to stakeholder satisfaction and increase global market competition (Cleland, 1998). Even with its significance in business practices, research on project management is still relatively young and lacks theoretical bases and concepts (Shenhar, 2001). To lead a project successfully, a project manager has to become adept at initiating, planning, executing, monitoring and controlling and closing (PMI, 2008). To do so, project managers typically use several tools and techniques to help them orchestrate activities along a project life cycle. This seems to be the correct approach since several studies have suggested that the proper use of project management tools and techniques impacts the success of a project (Might and Fischer, 1985; Pinto and Slevin, 1988; Cash and Fox, 1992; Hatfield, 1995; Thamhain, 1996; Coombs, McMeekin *et al.*, 1998; Milosevic, Inman *et al.*, 2001). On the contrary, the inappropriate use of tools and techniques can also be counterproductive to project management outcomes (Nicholas, 1990; Cash and Fox, 1992; Hatfield, 1995; Thamhain, 1996; Kerzner, 2000). In practice, there are many project management tools and techniques (PMTT) available to project managers and project team members. The questions are: 'what are the appropriate PMTT to use that will lead to better project performance and when should a project manager or a team member use such tools and techniques?'. While PMTT literature suggests the use of some tools and techniques, propositions were based on experience or the conceptual beliefs of the authors rather than on solid empirical research. In addition, while the literature focuses mostly on the use of certain tools and techniques, it fails to empirically confirm the impact of the use of PMTT on project success. To address these issues, the authors here conducted empirical research to investigate the use of PMTT. The research question is: 'In a specific phase of a project life cycle, which project management tools and techniques are used and whether or not such uses impact the success of a project?'. The answer to this question helps provide empirical evidence to support a contingency approach on the use of PMTT. Based on a survey from over 400 project managers, the research results indicate that while many PMTT are used in a specific phase, only some of them enhance the success of the project.

Literature review

Project management tools and techniques

In the literature, PMTT have been discussed mostly in project management books, both for academic and practical purposes. In terms of the definition, some authors perceived PMTT as software for project management (Fox, Murray *et al.*, 2003), while others view them as systematic procedures or practices that project managers use for producing specific project management deliverables (Milosevic, 2003). This study subscribes to the latter definition of PMTT. Since it is mostly in book form, generally, the literature on PMTT discusses the processes of how to use PMTT and to a certain extent, the benefits of using PMTT to produce the project management deliverables for each project management activity. The same discussion is also found in some journal articles. For example, Balcombe and Smith (1999) discuss the use of Monte Carlo analysis for project risk analysis. Rad (1999) discusses the use of Work Breakdown Structure. Earned Value Management is a topic of discussion for many authors (Brandon Jr., 1998; Fleming and Koppelman, 2002; Kauffmann and Keating *et al.*, 2002).

Project Management Institute (PMI) has suggested nine knowledge areas in project management (PMI, 2005; PMI, 2008); see Table 1 below. In project integration management, the literature suggests the use of PMTT such as project selection methods and project charter (Kliem and Ludin, 1999; Newell, 2002; Milosevic, 2003). Work Breakdown Structure (WBS), scope statement and quality function deployment, etc. should be used for scope management (Simons and Lucarelli, 1998; Kliem and Ludin, 1999; Milosevic, 2003). For project cost management, several authors suggest the use of cost estimating techniques and Earned Value Management (Fleming and Koppelman, 1994; Brandon Jr., 1998; Kliem and Ludin, 1999; Fleming and Koppelman, 2000; Newell, 2002; Milosevic, 2003). In quality management, a project manager has the options of benefit/cost analysis, flowcharting, cause-and-effect diagrams, cost of quality, Pareto diagrams, and control charts (Kliem and Ludin, 1999; Newell, 2002; Milosevic, 2003). CPM, PERT, GERT, Gantt charts, simulation, Monte Carlo analysis, buffer management, schedule crashing, milestone charts, etc. (Jones, 1988; Balcombe and Smith, 1999; Kliem and Ludin, 1999; Newell, 2002; Milosevic, 2003) are the PMTT suggested for time management. Risk matrix, Monte Carlo analysis, decision tree analysis, check list, SWOT analysis and Delphi are some examples of PMTT available for project risk management (Balcombe and Smith, 1999; Kliem and Ludin, 1999; Newell, 2002; Milosevic, 2003). PMTT such as stakeholder analysis and responsibility matrix can be used for human resource management and communications management (Kliem and Ludin, 1999; Newell, 2002; Milosevic, 2003). Make-or-buy analysis and contract type selection are the options of PMTT for procurement management (Newell, 2002). Table 1 below illustrates some examples of PMTT present in the literature, organised using project management knowledge areas (PMI, 2005; PMI, 2008). Note that some PMTT, e.g. ROI, Payback period, cost/benefit analysis, SWOT analysis, flow charting, cause-and-effect diagram and risk management, are common to both project and general management. Others PMTT such as WBS, Earned Value Management, CPM, PERT and GERT are unique to project management.

Since there are many PMTT available for project managers, the question arises 'How are PMTT actually used in practice?'. Thamhain's study on project managers' familiarity with the use of PMTT indicates that only 28% of PMTT in the study are actually used by project managers and project managers have only 50% basic familiarity with those tools and techniques (Thamhain, 1999). White and Fortune (2002) obtained a similar finding. Besner and Hobbs (2004) found that most of the 72 PMTT in their study were used more often in projects with budgets in excess of $1 million and of more than one year's duration. Table 2 below summarises the studies on the use of PMTT.

Even though these studies identified some patterns in the use of PMTT, they did not clearly suggest which tools and techniques were appropriate to be used at what point in the project life cycle. They also did not directly suggest whether the use of these PMTT had any impact on project success. In addition, in many of these studies, the researchers' focus was only on a small set of PMTT, which does not represent the comprehensive list of PMTT available.

Project success

Without any specific discussion about the PMTT, the literature on project success suggests that the proper use of PMTT impacts the success of a project

Table 1: PMTT and project management knowledge areas

Knowledge areas	PMTT
Integration management	Project selection, return on investment, payback period, project charter
Scope management	WBS, scope statement, quality function deployment, change request, scope change control, product review, performance measurement, lesson learned
Cost management	Cost estimating techniques, earned value management, cost change control system, performance measurement
Quality management	Benefit/cost analysis, flowcharting, cause-and-effect diagram, cost of quality, Pareto diagram, control charts, trend analysis, quality audits, benchmarking, statistical sampling
Time management	CPM, PERT, GERT, Gantt charts, simulation, Monte Carlo analysis, buffer management, schedule crashing, milestone charts, variance analysis
Risk management	Risk matrix, Monte Carlo analysis, decision tree analysis, check list, SWOT analysis, and Delphi, project risk audit, earned value management
Human resource management	Stakeholder analysis, responsibility matrix, team building activities, reward and recognition systems, organisation charts, project team directory
Communications management	Stakeholder analysis, earned value management, information retrieval systems
Procurement management	Make-or-buy analysis, contract type selection, statement of work, contract change control system, source selection, bidder conferences

(Might and Fischer, 1985; Cash and Fox, 1992; Hatfield, 1995; Thamhain, 1996; Milosevic, Inman *et al.*, 2001). To determine the success or failure of a project, many authors proposed different project success dimensions. Recently, the literature on project success focuses on a multi-dimension and multi-criteria approach, referred to as the stakeholder approach. Baccarini (1999) discussed the logical framework method, defining project success as the combination of project management success and product success. He suggested that time-cost-performance can be used as criteria for project management success while the goal and purpose of the projects (e.g. customer satisfaction and profit) should be used to measure product success. Similar findings are found in the studies of Pinto and Slevin (1988), Brown and Eisenahrdt (1995) and Lim and Mohamed (1999). The study of Shenhar *et al.*, (2001) suggested project success dimensions as project efficiency, benefits to customers, benefits to the performing organisation and preparation for the future.

In sum, the stakeholder approach includes internal and external criteria as the dimensions of project success. Although there is no mutual agreement on what should be used as the dimensions of project success, the pattern of success dimensions from the literature can be categorised into three major groups: internal factors (time, cost and performance), customer-related

Table 2: The studies on the use of PMTT

Authors	Research description	No. of PMTT studied	Research method
Thamhain (1999)	Identify PMTT by popularity	38	Survey 180 projects, 294 professionals; observation; and retrospective interviewing
Fox and Spence (1998)	Study on the identification of tools used, level of use, types of uses, satisfaction with the tools employed, level of training received, and adequacy of the tool's use	Not precisely defined (Software tools)	Survey 159 project managers
Besner and Hobbs (2004)	Identify how PMTT are used differently in different project situations	72	Survey 753 project managers
Coombs, *et al.*, (1998)	Benchmarking the project management practices in R&D projects	Not precisely defined	Interview 11 business units
White and Fortune (2002)	Identify the tools and techniques that are actually used by project managers and report limitations or drawbacks of using those tools and techniques	44	Survey 236 projects
Raz and Michael (2001)	Identify which risk management tools are widely used, associated with successful project in general, and associated with effective project risk management	38	Survey 84 project managers

factors (satisfaction, actual utilisation and benefits) and organisational-related factors (financial, market, benefits). These groups are aligned with the new research agenda on a value-creation aspect of projects (Winter, Andersen *et al.*, 2006). The authors utilised these three groups of success dimensions in this study.

Project life cycle

The project life cycle provides the basic framework for managing the projects (Cleland and Kocaoglu, 1981; Adams and Caldentey, 1997; PMI, 2008). Understanding project life cycles benefits research in project management; as noted by Slevin and Pinto (1987), 'the concept of a project life cycle provides a useful framework for looking at project dynamic overtime.' Within its life cycle, a project is typically divided into phases where extra control is needed to effectively manage the completion of a major deliverable. Depending on the management and control needs of an organisation, the uniqueness of the industry, the nature of projects, and its areas of applications; the names and numbers of phases in project life cycles vary (Adams and Barndt, 1983; Snyder and Fox, 1985; Adams and Caldentey, 1997; Belanger, 1997; Phillips, 1999; 2000; Bonnal and Gourc, 2002; Gray and Larson, 2008; PMI, 2008). The phases can be sequential, overlapping, or spiral. While the sequential and overlapping models are common to most projects, the spiral model is widely used in software development and information system projects (Snyder and Fox, 1985; Belanger, 1997). Even though there are many project life cycle models with various phase names and numbers of phases, the most common life cycle is the one with four distinct phases: conceptual, planning, execution and termination (Gray and Larson, 2008; PMI, 2008). Since it is widely used and listed in PMBOK (PMI, 2000; PMI, 2005; PMI, 2008), the authors utilised this life cycle model in this study.

Research description

The objective of this research is to investigate the use of PMTT. The research question is: in a specific phase of a project life cycle, which project management tools and techniques are used and whether or not such uses impact the success of a project.

Research hypothesis: the uses of PMTT with respect to phases and project performance

Based on the definitions of PMTT, 'systematic procedures or practices that project managers use for producing specific project management deliverables' it is rather obvious that project managers will use different PMTT to produce different deliverables. Since specific deliverables will be produced in each phase, different PMTT should therefore be used in association with the project phases. To further explain, during the conceptual phase, project managers are required to develop, e.g. the preliminary scope definition. Possibly, the PMTT that is used to develop such a deliverable is a preliminary scope statement. When the project goes further along to the planning phase, the main deliverables of this phase are, for example, detailed scope, project schedule and budget. To develop such deliverables, PMTT such as WBS, hierarchical schedule and analogous budget estimation may be used. In the execution phase, Earned Value Management, cost baseline, schedule crashing may be the major PMTT employed. Lessons learned and performance report may be used in the termination phase. If PMTT are used to develop project management deliverables for each phase, such uses should have a positive impact on the success of the project. For instance, the use of WBS in the planning phase as part of defining scope and developing the project plan should contribute to a better project performance. With this observation, it is stated that:

> **Hypothesis: There are statistically significant correlations between the use of PMTT in association with each phase of the project life cycle and the project success**

The literature, though, states that the use of PMTT impacts the success of the project and many studies investigate the use of PMTT regardless of any specific context. The results from the testing of this hypothesis will reveal PMTT that, when used, would lead to a better project performance.

Research method

This research was conducted using survey research methods. In particular, a questionnaire was developed for data gathering and some statistical methods were used for data analysis. A panel of experts was formed to assist in questionnaire development and to validate the research results.

Research participants and survey method

To test the aforementioned hypothesis, a survey was carried out to gather the research evidence. Based on approximately 160,000 active members of Project Management Institute (PMI) in 2005, 4000 project managers from PMI directory were randomly selected (computer generated) to participate in this study. At the time of this study, those project managers had at least two years of experience and resided in the USA (sampling frame). Mail and internet data collection were used as the means of the survey. Out of 4000 targets, 412 usable responses were received. The demographic information of the data is as follows:

- Industry: The top five industries are information technology (16.79%), financial services (12.65%), telecommunication (8.76%), healthcare (6.81%) and manufacturing (6.57%). Even though construction (4.38%) and defence (3.41%) industries represent a significant proportion of PMI membership, they ranked eighth and ninth in this study.
- Project size: For the projects studied, 37% of them had a budget below $740,000, 32% of them had a budget from $740,001 to $3,000,000 and 31% of them had a budget over $3,000,000.
- Project duration: For the projects that were studied, 21% of them had a duration up to six months, 32% of them had a duration from seven months to one year, 18% of them had a duration from one year to 1.5 years, and 29% of them had a duration longer than 1.5 years.

Questionnaire

A questionnaire was developed to gather the research data. First, the respondents supplied personal information, such as years of experience. Then respondents were asked to think about one project that was recently completed and answer the questions in the next three groups. The first group was the general project information such as size, duration, strategic focus and type. The second group was the project success. Respondents were asked if they agree with the statements such as 'This project came in on time or faster, the project met all specification requirements, and the project created financial benefit for your organisation'. A 5-point Likert scale (1 strongly disagree, 5 strongly agree) was provided for rating. The last group was the information regarding the frequency of use of each PMTT in each phase of the project life cycle, rated by a 6-point Likert scale (0 means not applicable and 5 means more frequently used). In other words, for each PMTT, respondents were asked to rate how often they used PMTT in each specific phase. An example of the questions includes: 'How often do you use an analogous estimate in (1) the conceptual phase (2) planning phase (3) execution phase and (4) termination phase?'

Statistical analyses

Two multivariate statistical methods were used for hypothesis testing. First, Analysis of Variance (ANOVA), T-test and a post hoc test using Tukey's honestly significant difference (HSD) were used to test whether or not there are statistically significant differences in the use of PMTT across phases. If it is found that the uses of PMTT are not significantly different across phases, pursuing the hypothesis testing is irrelevant. Once it was found that the uses of PMTT were significant across phases, Stepwise regression analyses were performed to test the hypothesis. The dependent variables were the project success measures. The independent variables were the frequency uses of PMTT in each phase. Project phases were the moderating variables.

Expert panel

A panel of experts was formed, consisting of five individuals from academia, consulting and industry who have knowledge about PMTT. The panel assisted in the selection of PMTT, questionnaire development and validation of the research results. Later in the Results and Discussion section, quotes from experts are used to justify the research results.

Variables for hypothesis testing

The three groups of variables for hypothesis testing in this study were PMTT, project phases and project success dimensions.

PMTT

Based on the literature, e.g. (PMI, 2000; Milosevic, 2003; PMI, 2005), the authors compiled a list of 56 PMTT and presented the list to the panel of experts. Using 1-to-5 Likert scale (1 means rarely used and 5 means frequently used), the experts rated (based on their perception) the frequency of the use of each PMTT by project managers in industries. The result was compiled and presented back to the panel for evaluation. Based on the rating of each PMTT, the panel suggested a list of 39 PMTT to be used in the survey. The list includes top 37 PMTT that had the rating higher than 2.75. Even though Monte Carlo Analysis and Earned Value Management had low ratings, with their potential benefit to project management, the panel suggested adding them to the list (see Table 3 below).

Project phase

Four generic phases in the project life cycle were the focus of this study. They are the conceptual, planning, execution, and termination phases. These four

Table 3: PMTT and their ratings from the expert panel

39 PMTT included in the survey		
T01 Analogous estimate (4.5)	T14 Earned Value Management, EVM (2.0)	T27 Project change request (3.75)
T02 Bar chart (4.75)	T15 Flowchart (3.25)	T28 Project charter (3.5)
T03 Bottom-up estimate (4.5)	T16 Focus group (3.0)	T29 Responsibility matrix (3.75)
T04 Brainstorming (3.75)	T17 Hierarchical schedule (3.75)	T30 Risk response plan (2.75)
T05 Cause and effect diagram (2.75)	T18 Lessons learned (4.25)	T31 Schedule crashing (2.75)
T06 Chart of accounts (3.5)	T19 Milestone analysis (3.5)	T32 Scope statement (3.5)
T07 Checklist (4.25)	T20 Milestone chart (4.25)	T33 Skill inventory (3.0)
T08 Communication plan (2.75)	T21 Milestone prediction chart (2.75)	T34 Slip chart (2.75)
T09 Contingency plan (3.0)	T22 Monte Carlo analysis (1.75)	T35 Stakeholder analysis (3.25)
T10 Cost baseline (3.5)	T23 Pareto Diagram (3.0)	T36 Stakeholder matrix (2.75)
T11 Critical Path Method CPM (3.5)	T24 Performance Measurement Baseline, PMB (4.0)	T37 Time-scaled Arrow Diagram, TAD (3.0)
T12 Customer roadmap (2.75)	T25 Performance report (4.5)	T38 Top-down estimate (3.75)
T13 Customer visits (3.5)	T26 Project change log (4.0)	T39 Work Breakdown Structure, WBS (3.5)
17 PMTT not included in the survey		
Affinity diagram (2.5) Analytic hierarchy process (2.25) Assumption analysis (2.25) Change co-ordination matrix (2.25) Commitment scorecard (2.0) Control charts (2.25)	Cost planning map (1.75) Critical chain scheduling (2.0) Decision tree analysis (2.0) Jogging line (2.0) Life cycle costing (2.5) Line of balance (1.5)	Parametric estimation (1.75) PERT (2.0) Project SWOT analysis (1.75) Quality function deployment (1.25) Sample selection (1.75)

generic phases are common to the mainstream project management literature and practice (Adams and Barndt, 1983; PMI, 2000; Milosevic, 2003; PMI, 2005; PMI, 2008).

Project success measures

Four groups of success measures are used in this study. The first group contains the internal criteria – time, cost and specification (three success measures). The second group consists of two success measures associated with the customer satisfaction. Two success measures related to the business aspects are in the third group. One success measure assessing the overall project success is in the last group. These four groups of success measures were derived using the stakeholder approach, representing both internal and external perspectives (Shenhar and Dvir, 2001), and aligning with the new research agenda on a value-creation aspect of projects (Winter and Andersen, 2006). Table 4 below summarises eight project success measures used in this study.

Table 4: Project success measured used in this study

Success dimension	Success measures	Notation
Internal criteria	– Project came in on time or faster – Project came in under budget or on budget – Project met all specification requirements	S1 S2 S3
Customer	– The outcomes of the project were used by its intended customers – The intended customers of the project were satisfied with the outcomes of this project	S4 S5
Business	– Project created financial benefit for your organisation – Project increased market competitiveness for your organisation	S6 S7
Overall	– Overall, this project can be considered a successful project	S8

Results and discussion

The use of PMTT across different phases of project life cycle

Since the hypothesis focuses on the use of PMTT on a specific phase contributing to the project performance, prior to testing this hypothesis, the authors tested whether or not the uses of PMTT are significantly different across phases. To do so, the analysis of variance (ANOVA) was performed. The results from hypothesis testing indicate that there are statistically significant differences in the use of PMTT across project phases. In other word, a specific PMTT is used in a specific phase. In addition, the results from Tukey's HSD tests show that many PMTT are significantly used in more than one phase but none of them are significantly used throughout all the four phases of the project life cycle. See Appendix A for more details.

The use of PMTT in different phases of project life cycle and project success

Stepwise regression analyses were performed to test the hypothesis. To do so, the authors selected the frequently used PMTT in each phase (the procedure for determining the frequently used PMTT is presented in Appendix B below). For the conceptual phase, ten frequently used PMTT were selected. They are analogous estimate, bar chart, brainstorming, checklist, communication plan, customer visit, project charter, scope statement, stakeholder analysis and WBS. For the later phases, 23, 23 and 14 frequently used PMTT were selected for the planning, execution and termination phases respectively (see Table 5 below).

With the list of PMTT (independent variables), stepwise regression analyses were performed to test the statistically significant contribution of these PMTT to project success. The analysis was conducted one phase at a time. In each phase, regression analysis was performed on each success measure (dependent variable). Table 6 below summarises the results from stepwise regression analysis (see the regression models in Appendix C below).

Table 5: Frequently used PMTT across project phases

Conceptual phase	Planning phase	Execution phase	Termination phase
T01 Analogous estimate T02 Bar chart T04 Brainstorming T07 Checklist T08 Communication plan T13 Customer visits T28 Project charter T32 Scope statement T35 Stakeholder analysis T39 Work Breakdown Structure (WBS)	T01 Analogous estimate T02 Bar chart T03 Bottom-up estimate T04 Brainstorming T07 Checklist T08 Communication plan T09 Contingency plan T10 Cost baseline T11 Critical Path Method (CPM) T13 Customer visits T15 Flowchart T17 Hierarchical schedule T19 Milestone analysis T20 Milestone chart T25 Performance report T26 Project change log T27 Project change request T28 Project charter T29 Responsibility matrix T30 Risk response plan T32 Scope statement T35 Stakeholder analysis T39 Work Breakdown Structure (WBS)	T02 Bar chart T03 Bottom-up estimate T04 Brainstorming T07 Checklist T08 Communication plan T09 Contingency plan T10 Cost baseline T11 Critical Path Method (CPM) T13 Customer visits T15 Flowchart T17 Hierarchical schedule T18 Lessons learned T19 Milestone analysis T20 Milestone chart T24 Performance measurement baseline T25 Performance report T26 Project change log T27 Project change request T29 Responsibility matrix T30 Risk response plan T31 Schedule crashing T32 Scope statement T39 Work Breakdown Structure (WBS)	T02 Bar chart T07 Checklist T08 Communication plan T10 Cost baseline T13 Customer visits T18 Lessons learned T19 Milestone analysis T20 Milestone chart T25 Performance report T26 Project change log T27 Project change request T29 Responsibility matrix T32 Scope statement T39 Work Breakdown Structure (WBS)

Table 6: PMTT that contribute to project success measures across project phases

Conceptual phase	Planning phase	Execution phase	Termination phase
T01 Analogous estimate (S7) T07 Checklist (-S8) T08 Communication plan (S8)	T01 Analogous estimate (S7) T02 Bar chart (-S2) T03 Bottom-up estimate (-S2) T09 Contingency plan (S8) T10 Cost baseline (S2) T11 Critical Path Method (CPM) (S1, S2, S3) T17 Hierarchical schedule (S4, S5, S8)	T02 Bar chart (-S2) T07 Checklist (S4) T08 Communication plan (S3, S5) T09 Contingency plan (S1, S2, S8) T10 Cost baseline (S2) T17 Hierarchical schedule (S5, S8) T19 Milestone analysis (S1) T27 Project change request (-S3) T31 Schedule crashing (-S1, -S2, -S8) T32 Scope statement (-S5,-S8)	T10 Cost baseline (S2) T18 Lessons learned (S6) T19 Milestone analysis (S8) T27 Project change request (-S2, -S3, -S6, -S8) T39 Work Breakdown Structure (WBS) (S3)

The results indicate that there are statistically significant correlations between the use of PMTT and different project success measures in different phases of the project life cycle. In other words, PMTT that are the contributors to project success measures are contingent upon project phases. For example, in the planning phase, cost baseline and CPM significantly contribute to the project success based on cost (S2), while the use of bottom-up estimate and bar chart is counterproductive (show a negative value with S2). The use of CPM significantly contributes to time (S1), cost (S2), and quality (S3) success measures and the use of hierarchical schedule contributes to the customer satisfaction (S4 and S5) and overall success (S8).

The conceptual phase

In the conceptual phase, out of the selected ten PMTT, analogous estimate and communication plan were found to be the only two positive contributors to project success measures; however, several PMTT are used in this phase. It is typical that at the early stage of the project life cycle, a detailed definition of the project is not yet clear. To be successful in the later phases, the project manager needs to gather more project information. The use of communication plan may very well serve this purpose and therefore contribute to the overall project success (S8). With limited information and under-developed project definition, analogous estimate may be the only method assisting the project manager in meaningful budget development, leading to an increase in market competitiveness of the product (S7). One unexpected finding is that the use of checklist is counterproductive to the overall project success (S8). However, the authors agree with this finding. Typically, checklist is used when performing projects with detailed activities to keep account of all the activities. During the conceptual phase, very few detailed activities are required or available. The frequent use of checklist in this phase, therefore, shows the negative impact on project success. This interpretation is supported by the panel of experts. For instance, one of the experts noted: 'I am thinking that the reason these are correlated (negatively) is because the conceptualisation phase of projects cannot be or is not 'prescriptive' in nature. Thus a checklist doesn't add value.'

The planning phase

In the planning phase, PMTT that significantly contribute to project success measures are those that serve the purposes of developing detailed scopes, schedules or budgets. CPM and hierarchical schedule seem to be the significant contributors to project success because both of them positively correlate with three success measures. CPM contributes toward the internal dimension of project success (S1, S2, and S3), while hierarchical schedule contributes toward the customer dimension (S4 & S5) and overall project success (S8).

Typically, CPM is a PMTT for time management, which is also a basis for cost management. It is therefore not surprising that CPM contributes to the time (S1) and cost (S2) success dimensions. The authors also agree that the use of hierarchical schedule could lead to success with respect to the customer dimension. Hierarchical schedule suggests different levels of project schedule with different uses. The high level schedule is typically used for communication with the customers while the lower levels are used within the project team. If the high level schedule is developed based on the deliverable-oriented WBS, it tends to be more customer-focused. This may provide a reason why hierarchical schedule contributes to customer satisfaction. Besides CPM and hierarchical schedule, the use of cost baseline, analogous estimate and contingency plan contributes to the project success. The frequent use of cost baseline significantly contributes to the project success in terms of cost (S2), while the use of contingency plan contributes to the overall project success (S8). Analogous estimate contributes to the increase in market competitiveness (S7). The counter-intuitive findings are that both bar chart and bottom-up estimate are negatively associated with success in terms of meeting the budget requirement (-S2). These findings contradict the assumption that using bar chart or bottom-up estimate should improve the success of projects. In general, bar chart is used for scheduling purposes. It indicates when each project activity should be performed. A typical bar chart does not show the dependencies among activities. Without such dependency information, resource allocation may be inappropriate. This in turn has some impact on the project cost.

For the negative contribution of the bottom-up estimate to the project success measure, a likely explanation is that performing bottom-up estimate is costly and may produce a faulty estimate. This is especially true when all required tasks are not included in the preliminary estimates or when several changes in project scope are anticipated. One expert in the panel commented that: 'Bottom-up estimate should be the most accurate method, although it is more costly. If good skills are used to do the estimate, then the estimate should bring success. Since your survey responses indicate lower success rates, I have to assume the preliminary estimating is poorly done and does not consider these hidden tasks.' A comment from another expert is: 'The only problems you would find with bottom-up estimate are projects that have work based on assumptions (e.g. new product development projects) that all the tasks cannot be determined until the first phase is complete. You cannot perform a bottom-up estimate on that which you do not know.'

The execution phase

During the execution phase, PMTT that support monitoring and control activities are significantly correlated with project success measures, as depicted by Table 6 above. It was found that contingency plan has a positive impact on three project success measures (S1, S2 and S8). It may be that by preparing a contingency plan for projects, the project managers can handle the anticipated changes that may occur in the later stages of the project life cycle better than when there is no contingency plan, especially the changes regarding project schedule and cost. It was found also that communication plan contributes to the success measure S3 (specification) and S5 (customer satisfaction). The use of communication plan can benefit the project managers by helping them communicate with the clients, understand their needs, or identify the causes of the problems for monitoring and control of projects for achieving customer satisfaction. Hierarchical schedule contributes to two project success measures (S5 and S8). Its use can help in communicating different levels of project details to different stakeholders of projects. Thus, the stakeholders understand their roles during the execution phase of projects. The use of checklist also contributes to the success in terms of the use of project product by its intended customers (S4).

The results also show that schedule crashing (-S1, -S2, and -S8), project change request (-S3) and project scope statement (-S5, and -S8) are the negative contributors to project success. Normally, project managers should not expedite the project activities if it is not necessary. Hence, when the project managers need to perform schedule crashing, it is because projects have already suffered from major delays. The authors perceived that schedule crashing was not the cause of the lower success rate *per se*. Its use may be associated with the delays and the lack of success because it is a recovery PMTT, used to bring projects back on course when damage has already occurred. The frequent use of project change request and project scope statement is an indicator of how often changes appear in projects. Thus, the more frequently it is used, the more changes projects have. The use of such PMTT themselves may not inhibit project success. The frequent use of such PMTT indicates several changes in projects, which are counterproductive to the project performance. The frequent use of project scope statement may also indicate that the project team just had a good grasp on the project scope at the execution phase. This means that the project had an ill-defined scope in the earlier phases, which in itself could lead to the poor project performance. One expert commented: ‘The scope should not be changed unless a strict change control process is agreed to by all concerned parties. If that means changing the scope statement, then all work and monies invested afterwards should be toward that restated goal. If there are many changes, then project performance certainly would be worse because before you can get somewhere, you have to know where you are going.’

The termination phase

In the termination phase; cost baseline, WBS, lessons learned and milestone analysis show significant contribution to project success measures (S2, S3, S6 and S8 respectively). The uses of cost baseline, WBS and milestone analysis are to check the outcomes and to report the final status of the projects based on previous budget, scope, or schedule that were set at the prior phases. Their uses therefore contribute to success in terms of cost (S2), specification requirements (S3) and overall success (S8). The use of lessons learned facilitated the learning and knowledge dissemination. The records of what went right, what went wrong and the analysis and response to them will benefit future projects. It is therefore sensible that the authors found the contribution of lessons learned to the financial benefits to the organisation (S6). On the other hand, project change request is a standout PMTT, which is negatively correlated with four success measures (-S2, -S3, -S6, and -S8). If project managers need to request changes in the last phase, it is a sign of poor project scope management. However, it does not mean that the request for changes is the reason to blame as project managers probably view it. As discussed earlier, the change request is a consequence of the problem. It does reveal the consequences of ill-defined project scopes or frequent changes in the scopes.

PMTT that are used and should be used across project phase

The previous sections presented and discussed the results both from descriptive statistics and hypothesis testing. When comparing the results from Tables 5 and 6, a discrepancy was found in the use of PMTT. The results from Table 5 (also data in Appendix A) indicate the frequent use of certain PMTT. When compared with the results in Table 6 (also Appendix C), only some frequently used PMTT lead to project success. This indicates a crucial issue that in practice, project managers still use PMTT without an understanding of the impact of PMTT on the success of their projects. In other words, project managers still use PMTT by habit or by their popularity, instead of choosing and using PMTT because of their known benefits to the project. Some PMTT, such as bar chart, are used widely because they are common to the community, even though they may not contribute to the success of a project. However, project managers may not be the only ones to blame. The project managers' choice of PMTT may be dictated by the standard process in their organisation. In addition, the research on the benefits or disadvantages of PMTT contributing to the project outcomes is still limited. As a result, such benefits or disadvantages are not widely known. This confirms the significant contributions of this research to the project management community.

Managerial implications

Project managers are required to have many skills in order to manage projects successfully. Among those skills is the capability to utilise PMTT to greatest effect. Since each phase of the project life cycle has its own characteristics, the project managers should use the PMTT appropriately in order to deliver the outcomes required for each phase. The effective use of PMTT also means that the project managers do not only use the PMTT that are commonly known or frequently used by others, but also the ones that contribute to the success of their project. During the conceptual phase, the main deliverables and activities are to develop preliminary project scopes, which are not yet developed in detail. Among other frequently used PMTT, project managers should consider using analogous estimate and communication plan, which were found by the authors to make meaningful contribution to project success. Checklist should be used with caution in this phase. During the planning phase, project managers are required to develop a detailed project scope, which includes cost estimation, time estimation, resource assignment, procurement plan, etc. PMTT such as analogous estimate, contingency plan, cost baseline, Critical Path Method and hierarchical schedule are recommended. The use of bar chart and bottom-up-estimate proves to be counterproductive to the planning of the project cost, which may lead to the poor monitoring and control in the later phases.

In the execution phase, adding to the list from the previous phase, milestone analysis is a PMTT that helps project managers successfully monitor project time status. The use of checklist to check the level of customer satisfaction is

Table 7: Recommended list of PMTT

PMTT	Impact on project success		Description
	When used in	**Type of impact**	
Analogous estimate	• Conceptual phase • Planning phase	• **+ S7 Market competitiveness**	Because the details of projects tasks are not yet available in these phases, analogous estimate is appropriate for preliminary estimation of project cost using the previous project data as the information source for estimation.
Checklist	• Execution phase • Conceptual phase	• **+ S4 Use of product** • **– S8 Overall success**	Project managers should exercise caution when using checklist during the conceptualization phase. The purpose of this PMTT is to list all required items to ascertain that they are performed. During the conceptual phase where only preliminary scope available, checklist does not add value to the projects because all the required items are not yet fully developed. However, it is appropriate for later stages of the project.
Communication plan	• Conceptual phase • Execution phase	• **+ S8 Overall success** • **+ S3 Specification requirements** • **+ S5 Customer satisfaction**	Communication plan is also important to project performance. It is used for determining the communication channel among all stakeholders regarding who will need what information and when. The use of this PMTT then benefits all stakeholders because it helps managing the flow of information.
Contingency plan	• Planning phase • Execution phase	• **+ S8 Overall success** • **+ S1 Time** • **+ S2 Budget**	Contingency plan is found to be beneficial to project success across several contextual factors. Hence, project managers should consider developing contingency plan for any projects they manage starting from the conceptual phase, where projects do not yet consume resources, and reviewing the contingency plan during subsequent phases.
Cost baseline	• Planning phase • Execution phase • Termination phase	• **+ S2 Budget**	Project managers should consider developing cost baseline during the planning phase and use it to measure and monitor cost performance of projects at the later phases. The use of this PMTT can benefit the performance of project by keeping the projects under budget. However, it can be a costly process to organisations.
Critical path method	• Planning phase	• **+ S1 Time** • **+ S2 Budget** • **+ S3 Specification requirements**	Project managers can use CPM to identify the sequence of activities that are critical to a project schedule. The use of this PMTT helps the managers concentrate on the activities on the critical path and can complete projects within the given time and budget.
Hierarchical schedule	• Planning phase • Execution phase	• **+ S4 Use of product** • **+ S5 Customer satisfaction** • **+ S8 Overall success**	Hierarchical schedule can be used for communicating different detailed levels of project schedule with different stakeholders. For example, the clients will receive a less detailed schedule to track the progress of projects, while the team members need a full detailed schedule in order to perform project tasks.
Lessons learned	• Termination phase	• **+ S6 Financial benefits**	Developing lessons learned from projects can financially benefit the organisations when similar projects are conducted in the future. Project managers can use the information from lessons learned to avoid similar errors as in previous projects.
Milestone analysis	• Execution phase • Termination phase	• **+ S1 Time** • **+ S8 Overall success**	Milestone analysis is used to compare planned cost and schedule performance with actual performance. During the execution phase, using this PMTT can help project managers complete projects within planned schedule.
Work Breakdown Structure	• Termination phase	• **+ S3 Specification requirements**	WBS organises and defines the total scope of the project by subdividing the project work into smaller, more manageable piece of work, with each descending level of the WBS representing an increasingly detailed definition of the project work. During the termination phase, the use of WBS help ensure that all project work have been done and that the project meets all requirements

also recommended. In this phase, the use of project change request, schedule crashing and project scope statement indicates that the project has some problems. Appropriate actions should be taken otherwise the project may be less than successful in time, cost, customer satisfaction and overall success measures. For project closure at the termination phase, the use of cost baseline, lessons learned, milestone analysis, and WBS helps. In this phase, the change in project scope indicates less than effective project planning, monitoring, and control. The use of project change request is therefore counterproductive to the project outcomes. To help practitioners take away the results of this research, the authors have summarised a recommended list of PMTT based on the results of this study. Table 7 shows the recommended list, in which items are listed by the PMTT name, their use, their impact on the success measures, and some explanation.

Conclusion

This research identifies two significant findings which are unique contributions to the literature in terms of the contingent use of PMTT across the project life cycle phases. First, it confirms that the use of PMTT is contingent upon the phases of the project life cycle. In general, the characteristics and required deliverables of each phase influence the activities necessary in the phase, which in turn influence which PMTT will be employed. This study, therefore, extends the literature by identifying and presenting the score of PMTT used in each phase of the project life cycle based on the empirical study of a large sampling population across different industries and types of projects and situations. Second, this study denotes the PMTT that contribute to project success measures in each phase of the project life cycle. Thus, in order to manage projects successfully, project managers may consider utilising the PMTT that match the characteristics of phases and that are significant contributors to success measures in each phase of the project life cycle.

Despite its strengths in terms of the rigorous empirical research methods based on the use of survey and a panel of experts, the potential limitations of this research should be recognised. Firstly, the 39 PMTT in this study do not represent every PMTT available to project managers. Some PMTT such as Probability and Impact Matrix are not on the list. Even though PMTT such as critical chain scheduling and decision tree analysis were on the original list of 56 PMTT, they were dropped from the list when the number of PMTT was reduced to 39. Secondly, the measurement on the use of PMTT is the frequency of use. This measurement does not reflect how well the project managers use these PMTT. However, with the list from the PMI directory, it can be assumed that the project managers who responded to the survey are knowledgeable in the use of PMTT and can use them well. Thirdly, although the PMI member list is a good source for representing project managers and used in many researches (Pinto and Slevin, 1987; Pinto and Mantel, 1990; Pinto and Prescott, 1990; Fox and Spence, 1998; Besner and Hobbs, 2004), this list is not representative of the project manager universe. The research was restricted to project managers residing in the USA. Lastly, the samples here do not represent all ranges or projects. These research findings may only be applicable to such projects with similar demography as of those in the featured samples.

In future research, studies can be conducted to investigate whether or not when a certain PMTT is used another PMTT is more likely to be used and whether or not those PMTT have a combined contribution to project success. This investigation can be performed along the project life cycle. Other research can be conducted to investigate the use of PMTT relating to other situational factors such as project size, project duration, project type and project strategic focus. In other words, instead of analysing the use of PMTT with respect to the phases in the project life cycle, studies can be conducted to analyse their use with regard to the aforementioned situational factors and investigate whether or not such utilisation contributes to the project success. The findings of future studies should therefore help expand the contingency theory in the use of PMTT and suggest the appropriate use of PMTT, regarding certain situations, to practitioners.

Appendix A: The significant uses of PMTT across phases

Results from statistical analysis

Tool No.	Tool names	F	P	Tukey's HSD
T01	Analogous estimate	97.4480	P < 0.01	1–2*
T02	Bar chart	47.6048	P < 0.01	2–3
T03	Bottom-up estimate	58.6912	P < 0.01	2
T04	Brainstorming	149.8279	P < 0.01	1–2
T05	Cause and effect diagram	5.2978	P < 0.01	2–3
T06	Chart of accounts	11.4823	P < 0.01	2–3
T07	Checklist	33.6377	P < 0.01	2–3
T08	Communication plan	29.3486	P < 0.01	2–3
T09	Contingency plan	82.9081	P < 0.01	2–3
T10	Cost baseline	24.2522	P < 0.01	2–3
T11	Critical Path Method (CPM)	80.1877	P < 0.01	2–3
T12	Customer roadmap	8.1563	P < 0.01	1–2–3
T13	Customer visits	14.8656	P < 0.01	1–2–3
T14	Earned Value Management (EVM)	15.6687	P < 0.01	3
T15	Flowchart	40.4486	P < 0.01	2–3
T16	Focus group	22.4685	P < 0.01	1–2
T17	Hierarchical schedule	29.7575	P < 0.01	2–3
T18	Lessons learned	74.5840	P < 0.01	4
T19	Milestone analysis	51.3506	P < 0.01	3
T20	Milestone chart	44.8993	P < 0.01	2–3
T21	Milestone prediction chart	6.2677	P < 0.01	2–3
T22	Monte Carlo analysis	5.8841	P < 0.01	1–2–3
T23	Pareto diagram	3.9544	P < 0.01	3
T24	Performance Measurement Baseline (PMB)	40.7356	P < 0.01	3
T25	Performance report	59.5484	P < 0.01	3
T26	Project change log	81.1605	P < 0.01	3
T27	Project change request	94.4526	P < 0.01	3
T28	Project charter	52.4873	P < 0.01	1–2
T29	Responsibility matrix	44.4888	P < 0.01	2–3
T30	Risk response plan	40.5537	P < 0.01	2–3
T31	Schedule crashing	71.5784	P < 0.01	3
T32	Scope statement	67.2215	P < 0.01	1–2
T33	Skill inventory	37.3889	P < 0.01	2
T34	Slop chart	11.3402	P < 0.01	3
T35	Stakeholder analysis	33.2277	P < 0.01	1–2
T36	Stakeholder matrix	17.2726	P < 0.01	1–2
T37	Time-scaled Arrow Diagram (TAD)	22.2283	P < 0.01	2–3
T38	Top-down estimate	41.5172	P < 0.01	1–2
T39	Work Breakdown Structure (WBS)	65.5806	P < 0.01	2–3

*1: Conceptual phase, 2: Planning phase, 3: Execution phase; 4: Termination phase

How to read this table: T01 Analogous estimate is significantly used (F value of 97.4480 and $p < 0.01$) in Phase 1 (conceptual phase) and Phase 2 (planning phase). T02 Bar chart is significantly used (F value of 47.6048 and $p < 0.01$) in Phase 2 (Planning phase) and Phase 3 (Execution phase). The table below summarises this finding.

Significantly used PMTT in each phase

Conceptual phase	Planning phase	Execution phase	Termination phase
T01 Analogous estimate T04 Brainstorming T12 Customer roadmap T13 Customer visits T16 Focus group T22 Monte Carlo analysis T28 Project charter T32 Scope statement T35 Stakeholder analysis T36 Stakeholder matrix T38 Top-down estimate	T01 Analogous estimate T02 Bar chart T03 Bottom-up estimate T04 Brainstorming T05 Cause and effect diagram T06 Chart of accounts T08 Communication plan T09 Contingency plan T10 Cost baseline T11 Critical Path Method (CPM) T12 Customer roadmap T13 Customer visits T15 Flowchart T16 Focus group T17 Hierarchical schedule T20 Milestone chart T21 Milestone prediction chart T22 Monte Carlo analysis T28 Project charter T29 Responsibility matrix T30 Risk Response plan T32 Scope statement T33 Skill inventory T35 Stakeholder analysis T36 Stakeholder matrix T37 Time-scaled arrow diagram T38 Top-down estimate T39 Work Breakdown Structure (WBS)	T02 Bar chart T05 Cause and effect diagram T06 Chart of accounts T07 Checklist T08 Communication plan T09 Contingency plan T10 Cost baseline T11 Critical Path Method (CPM) T12 Customer roadmap T13 Customer visits T14 Earned Value Management (EVM) T15 Flowchart T17 Hierarchical schedule T19 Milestone analysis T20 Milestone chart T21 Milestone prediction chart T22 Monte Carlo analysis T23 Pareto diagram T24 Performance Measurement Baseline T25 Performance report T26 Project change log T27 Project change request T29 Responsibility matrix T30 Risk response plan T31 Schedule crashing T34 Slip chart T37 Time-scaled arrow diagram T39 Work Breakdown Structure (WBS)	T18 Lessons learned

How to read this table: In the conceptual phases, 11 PMTT are significantly used. They are T01 Analogous estimate, T04 Brainstorming, T12 Customer roadmap, T13 Customer visit, T16 Focus group, T22 Monte Carlo Analysis, T28 Project charter, T32 Scope statement, T35, Stakeholder analysis, T36 Stakeholder matrix, and T38 Top-down estimate. The table also presents the PMTT significantly used in the planning, execution, and termination phases.

Appendix B: Frequently used PMTT– descriptive statistics

To define the frequently used PMTT in each phase, the following process was used:

Step 1: For each phase, the means of the frequency of use of each PMTT are calculated for each PMTT (412 responses), shown as numbers in the table below.

Step 2: The PMTT are then sorted in descending order based on the mean frequency of use in each phase.

Step 3: The difference between the frequency values of the most frequently used PMTT and the second most frequently used PMTT is calculated. This step is repeated until the difference between the last two least frequently used PMTT is found.

Step 4: The cutting point that we used to group PMTT into frequently used group and not-frequently used group is determined by the fulfillment of one of the following conditions:

- The difference between the frequencies of the use of PMTT show a large gap in our opinion.
- The frequency of use of the PMTT should be around 2.5 or above.

See more information in the following table.

Tool No.	Tool Names	Conceptual	Planning	Execution	Termination
T01	Analogous Estimate	**3.195**	**3.165**	2.242	1.476
T02	Bar chart	**2.953**	**3.697**	**3.589**	**2.424**
T03	Bottom-p Estimate	2.504	**3.370**	**2.889**	1.852
T04	Brainstorming	**3.978**	**3.861**	**3.060**	2.035
T05	Cause and effect diagram	1.277	1.341	1.419	1.071
T06	Chart of accounts	1.846	2.431	2.544	2.123
T07	Checklist	**3.116**	**3.862**	**4.114**	**3.494**
T08	Communication plan	**3.064**	**3.813**	**3.835**	**3.125**
T09	Contingency plan	2.405	**3.418**	**3.538**	2.120
T10	Cost Baseline	2.408	**3.198**	**3.323**	**2.687**
T11	Critical Path Method (CPM)	2.065	**3.252**	**3.446**	2.007
T12	Customer roadmap	2.020	2.101	1.892	1.520
T13	Customer visits	**3.131**	**3.314**	**3.200**	**2.526**
T14	Earned Value Management (EVM)	1.174	1.578	1.978	1.615
T15	Flowchart	2.598	**3.083**	**2.828**	1.836
T16	Focus group	2.235	2.201	1.831	1.373
T17	Hierarchical schedule	1.916	**2.758**	**2.768**	1.894
T18	Lessons learned	2.206	2.452	**2.774**	**3.816**
T19	Milestone analysis	1.902	**2.823**	**3.408**	**2.686**
T20	Milestone chart	2.379	**3.350**	**3.643**	**2.751**
T21	Milestone prediction chart	1.100	1.357	1.536	1.165
T22	Monte Carlo analysis	0.724	0.862	0.771	0.576
T23	Pareto diagram	0.916	1.012	1.153	0.869
T24	Performance measurement baseline	1.600	2.447	**2.960**	2.263
T25	Performance report	2.135	**2.931**	**3.762**	**3.221**
T26	Project change log	1.806	**2.801**	**3.752**	**2.667**
T27	Project change request	1.812	**2.877**	**3.864**	**2.565**
T28	Project charter	**3.403**	**3.226**	2.464	2.015
T29	Responsibility matrix	2.602	**3.545**	**3.403**	**2.388**
T30	Risk response plan	2.034	**2.958**	**2.963**	1.958
T31	Schedule crashing	1.242	1.918	**2.796**	1.521
T32	Scope statement	**3.857**	**4.108**	**3.392**	**2.608**
T33	Skill inventory	2.084	2.553	2.116	1.309
T34	Slip chart	0.692	0.898	1.213	0.965
T35	Stakeholder analysis	**2.868**	**2.958**	2.248	1.890
T36	Stakeholder matrix	2.157	2.333	1.870	1.488
T37	Time-scaled arrow diagram	1.610	2.462	2.481	1.832
T38	Top-down estimate	2.435	2.224	1.651	1.260
T39	Work breakdown structure (WBS)	**2.843**	**4.025**	**3.737**	**2.553**

How to read this table: The table lists the mean values representing the usage of PMTT (1 rarely, 5 very often) in each phase. For example, the mean usage of T01 Analogous estimate is 3.195 in conceptual phase, 3.165 in the planning phase, and 2.242 and 1.476 in the execution and termination phases consecutively. The procedure explained above was performed to identify the frequently used PMTT (independent variables) for stepwise regression analysis. Those PMTT are indicated in this table by their bolded mean values. For example, with its frequent use, T01 Analogous estimate is the independent variable for the stepwise regression analysis in the conceptual and planning phases. T02 Bar chart is the independent variable for the analysis in all four phases. This information is also summarised in Table 5.

Appendix C: Results from regression analyses

Success measures	PMTT	Coeff	Cum adj. R^2	PMTT	Coeff	Cum adj. R^2
	Conceptual phase			**Planning phase**		
S1				T11 CPM	0.1093	0.0093
S2				T10 Cost baseline T03 Bottom-up estimate T11 CPM T02 Bar chart	0.1496 −0.1225 0.1257 −0.1039	0.0156 0.0245 0.0323 0.0399
S3				T11 CPM	0.1620	0.0237
S4				T17 Hierarchical schedule	0.1091	0.0093
S5				T17 Hierarchical schedule	0.1475	0.0192
S6						
S7	T01 Analogous estimate	0.1079	0.0091	T01 Analogous estimate	0.1339	0.0153
S8	T07 Checklist T08 Communication plan	−0.1689 0.1347	0.0104 0.0230	T17 Hierarchical schedule T09 Contingency plan	0.1516 0.1384	0.0311 0.0467
	Execution phase			**Termination phase**		
S1	T31 Schedule crashing T09 Contingency plan T19 Milestone analysis	−0.2037 0.1106 0.1077	0.0187 0.0324 0.0403			
S2	T31 Schedule crashing T09 Contingency plan T10 Cost baseline T02 Bar chart	−0.2230 0.1490 0.1457 −0.1091	0.0253 0.0493 0.0630 0.0720	T10 Cost baseline T27 Project change request	0.1666 −0.1599	0.0077 0.0266
S3	T27 Project change request T08 Communication plan	−0.1405 0.1327	0.0083 0.0221	T27 Project change request T39 WBS	−0.1798 0.1171	0.0144 0.0231
S4	T07 Checklist	0.1272	0.0136			
S5	T17 Hierarchical schedule T32 Scope statement T08 Communication plan	0.1335 −0.1354 0.1150	0.0150 0.0242 0.0336			
S6				T27 Project change request T18 Lessons learned	−0.1311 0.1062	0.0101 0.0186
S7						
S8	T09 Contingency plan T17 Hierarchical schedule T31 Schedule crashing T32 Scope statement	0.1814 0.1524 −0.1193 −0.1090	0.0246 0.0327 0.0442 0.0526	T19 Milestone analysis T27 Project change request	0.1432 −0.1418	0.0077 0.0236

How to read this table: In each phase, several regression analyses were performed with respect to each success measure (dependent variable). For example, in the conceptual phase, an analysis was conducted to test the correlation between 10 PMTT (independent variables) and a success measure S1 project came in on time or faster (dependent variable). Other regression analyses were conducted for other success measures. The analyses were also done for other phases. Different lists of PMTT were used in different phases. Refer to Table 5 for the list of PMTT.

The result shows, for example, that in the conceptual phase, T01 Analogous estimate is the only PMTT that correlates with the success measure S7: project increased market competitiveness for the organisation. The correlation coefficient is 0.1079 and the variance explained is 0.91%. In the execution phase, several PMTT are correlated (negatively and positively) with the success measure S2: project came in under budget or on budget. T31 Schedule crashing and T02 Bar chart show negative correlations (−0.223 and −0.1091 respectively) while T09 Contingency plan and T10 cost baseline show positive correlations (0.1490 and 0.1457 respectively). With Stepwise regression analysis, each PMTT was added into the regression model one at a time. The total variance explained by this regression model is 7.2% after adding T02 Bar chart into the model.

References

Adams, J. R. and Barndt, S. E. (1983), 'Behavioral Implications of the Project Life Cycle', In: *Project Management Handbook*, Cleland, D. I. and King, W. R., New York, NY: Van Nostrand Reinhold, pp. 183–204.

Adams, J. R. and Caldentey, M. E. (1997), *A Project-Management Model. Field Guide to Project Management*, USA: International Thomson Publishing Company, pp. 48–60.

Apm (2000), *Project Management: Body of Knowledge*, Peterborough, UK: G&E 2000 Limited.

Baccarini, D. (1999), 'The Logical Framework Method for Defining Project Success', *Project Management Journal*, Vol. 30, No. 4, pp. 25–32.

Balcombe, K. G. and Smith, L. E. D. (1999), 'Refining the Use of Monte Carlo Techniques for Risk Analysis in Project Planning', *The Journal of Development Studies*, Vol. 36, No. 2, pp. 113–135.

Belanger, T. C. (1997), Choosing a Project Life Cycle. Field Guide to Project Management. D. I. Cleland. USA, International Thomson Publishing Company, pp. 48–60.

Besner, C. and Hobbs, B. (2004), *An Empirical Investigation of Project Management Practice: In Reality, Which Tools do Practitioners Use?*, PMI Research Conference 2004, London, UK.

Bonnal, P. and Gourc, D. *et al.*, (2002), 'The Life Cycle of Technical Projects', *Project Management Journal*, Vol. 33, No. 1, pp. 12–19.

Brandon Jr., D. M. (1998), 'Implementing Earned Value Easily and Effectively', *Project Management Journal*, Vol. 29, No. 2, pp. 11–19.

Brown, S. L. and K. Eisenhardt (1995), 'Product Development: Past Research, Present Findings, and Future Directions', *Academy of Management Review*, Vol. 20, No. 2, pp. 343–378.

Cash, C. and R. Fox (1992), 'Elements of Successful Project Management', *Journal of Systems Management*, pp. 10–12.

Cleland, D. (1998), 'Strategic project management', In: Pinto, J. K., *Project Management Handbook*, San Francisco, CA: Jossey-Bass Publishers, pp. 27–54.

Cleland, D. I. and Kocaoglu, D. F. (1981), *Engineering management*, New York, McGraw-Hill.

Coombs, R. and McMeekin, A. (1998), 'Toward the Development of Benchmarking Tools for R&D Project Management', *R&D Management*, Vol. 28, No. 3, pp. 175–186.

Fleming, Q. W. and Koppelman, J. M. (1994), 'The Essence of Evolution of Earned Value', *Cost Engineering*, Vol. 36, No. 11, pp. 21–27.

Fleming, Q. W. and Koppelman, J. M. (2000), *Earned value project management*, Newton Square, PA: Project Management Institute.

Fleming, Q. W. and Koppelman, J. M. (2002), 'Earned Value Management: Mitigating the Risks Associated with Construction Projects', *Management Services*, March.

Fox, J. and Murray, C. (2003), 'Conducting Research Using Web-Based Questionnaires: Practical, Methodological, and Ethical Considerations', *International Journal of Social Research Methodology*, Vol. 6, No. 2, pp. 167–180.

Fox, T. L. and Spence, J. W. (1998), 'Tools of the Trade: A Survey of Project Management Tools', *Project Management Journal*, Vol. 29, No. 3, pp. 20–27.

Gray, C. F. and Larson, E. W. (2008), *Project Management: The managerial process*, New York: McGraw Hill.

Hatfield, M. (1995), 'Managing to the Corner Cube: Three-Dimensional Management in a Three-Dimensional World', *Project Management Journal*, Vol. 26, pp. 13–20.

Jones, C. V. (1988), 'The Three-Dimensional Gantt Chart', *Operations Research*, Vol. 36, No. 6, pp. 891–903.

Kauffmann, P. and Keating, C. (2002), 'Using Earned Value Methods to Substantiate Change-of-Scope Claims', *Engineering Management Journal*, Vol. 14, No. 1, pp. 13–20.
Kerzner, H. (2000), *Applied Project Management: Best Practices on Implementation*, John Wiley & Sons.
Kliem, R. L. and Ludin, I. S. (1999), *Tools and tips for today's project manager*, Newtown Square, PA: Project Management Institute.
Lim, C. S. and Mohamed, M. Z. (1999), 'Criteria of Project Success: An Exploratory Re-Examination', *International Journal of Project Management*, Vol. 17, No. 4, pp. 243–248.
Might, R. J. and Fischer, W. A. (1985), 'The Role of Structural Factors in Determining Project Management Success', *IEEE Transactions on Engineering Management*, Vol. 32, No. 2, pp. 71–77.
Milosevic, D. (2003), *Project management toolbox: tools and techniques for the practicing project manager*, Hoboken, NJ: John Wiley and Sons.
Milosevic, D. and Inman, L. (2001), 'Impact of Project Management Standardization on Project Effectiveness', *Engineering Management Journal*, Vol. 13, No. 4, pp. 9–16.
Milosevic, D. Z. (2003), *Project Management toolbox*, New York, NY: John Wiley and Sons.
Newell, M. W. (2002), *Preparing for the Project Management Professional (PM) Certification Exam*, New York: AMACOM.
Nicholas, J. M. (1990), *Managing business and engineering projects: concepts and implementation*, Englewood Cliffs, NJ: Prentice Hall.
Phillips, J. B. and Phillips, A. (1999), 'Management of Modular Projects: A Templating Approach', *Project Management Journal*, Vol. 30, No. 4, pp. 33–41.
Pinto, J. K., Mantel, J. and Samuel, J. (1990), 'The Causes of Project Failure', *IEEE Transactions on Engineering Management*, Vol. 37, No. 4, pp. 269–276.
Pinto, J. K. and Prescott, J. E. (1990), 'Planning and Tactical Factors in Project Implementation Process', *Journal of Management Studies*, Vol. 27, No. 3, pp. 305–327.
Pinto, J. K. and Slevin, D. P. (1987), 'Critical Factors in Successful Project Implementation', *IEEE Transactions on Engineering Management*, Vol. 34, No. 1, pp. 22–27.
Pinto, J. K. and Slevin, D. P. (1988), 'Critical Success Factors Across the Project Life Cycle', *Project Management Journal*.
PMI (2000), *Project Management Body of Knowledge* (PMBOK), Project Management Institute.
PMI (2005), *A Guide to the Project Management Body of Knowledge*, Newtown Square, PA: Project Management Institute.
PMI (2008), *A Guide to the Project Management Body of Knowledge*, Newtown Square, PA: Project Management Institute.
Rad, P. F. (1999), 'Advocating a deliverable-oriented work breakdown structure', *Cost Engineering*, Vol. 41, No. 12, p. 35.
Raz, T. and Michael, E. (2001), 'Use and Benefits of Tools for Project Risk Management', *International Journal of Project Management*, Vol. 19, pp. 9–17.
Shenhar, A. J. (2001), 'One Size Does Not Fit All Projects: Exploring Classical Contingency Domains', *Management Science*, Vol. 47, No. 3, pp. 394–414.
Shenhar, A. J. and Dvir, D. (2001), 'Project success: A multidimentional strategic concept', *Long Range Planning*, Vol. 34, pp. 699–725.
Simons, G. R. and Lucarelli, C. M. (1998), 'Work Breakdown Structures', In: Pinto, J. K., *The Project Management Handbook*, San Francisco, CA, Jossey-Bass Inc.
Slevin, D. P. and Pinto, J. K. (1987), 'Balancing Strategy and Tactics in Project Implementation' *Sloan Management Review*, pp. 33–41.
Snyder, C. A. and Fox, J. F. (1985), 'A Dynamic systems Development Life-Cycle Approach: A Project Management Information System', *Journal of Management Information Systems*, Vol. 11, No. 1.
Thamhain, H. J. (1996), 'Managing Self-Directed Teams Toward Innovative Result', *Engineering Management Journal*, Vol. 8, No. 3.
Thamhain, H. J. (1999), *Emerging Project Management Techniques: A Managerial Assessment*, Portland International Conference on Management of Engineering and Technology, Portland, Oergon, USA.
White, D. and Fortune, J. (2002), 'Current Practice in Project Management – An Empirical Study', *International Journal of Project Management*, Vol. 20, pp. 1–11.

Winter, M. and Andersen, E. S. (2006), 'Focusing on business projects as an area for future research: An exploratory discussion of four different perspectives', *International Journal of Project Management*, Vol. 24, Vol. 8, pp. 699–709.

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