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THE INFLUENCE OF MONITORING AND CONTROL ON PROJECT MANAGEMENT SUCCESS

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ABSTRACT

This article analyzes monitoring and control techniques and tools and their influence on project management and performance. It researches the current literature, the Bodies of Knowledge approach and the managers' perspective. The article studies the impact of the use of methodologies, techniques and tools on the outcomes of various projects carried out recently by a sample of interviewees.

Through interpretive work the view of the Bodies of Knowledge is reviewed and synthesized. Information from project managers in various sectors is collected in order to analyze the correlation between variables that determine the application of monitoring and control methodologies, techniques and/or tools and variables that determine the success criteria in projects.

The impact of the adoption of techniques and tools was evident on project performance. There was a positive influence of the use of techniques and tools on the results. It was found that some sectors do not use enough methodologies, techniques and tools. The empirical study proved the importance of using these tools as a success factor in project management and performance.

We aim to contribute with an actual approach of the use of techniques and tools in project monitoring and control processes, thus promoting the implementation of both traditional and new tools. The importance of project management is presented in order to increase the interest of researchers in it as a knowledge field applicable to various sectors.

The methodology used to prepare the study is useful in project management contexts and provides a procedure that allows an adequate analysis, data processing and results presentation, both interpretively and graphically.

Keywords: Monitoring and control, project management

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1. INTRODUCTION

The process of monitoring and control (M&C) of projects is a topic of common interest in project management. The purpose of its implementation is to achieve the objectives of the project, causing the least possible difficulty. It is based on observation, systematic measurement of performance, identifying variances, and adoption of corrective / preventive actions as well as changes management. Proposals from professional associations and standard organizations in project management agree that the process of M&C contributes to the minimization of the deviations during execution and to the achievement of better results. This demonstrates the importance of this process in the application of subject, and in the development of studies on techniques, tools and new contributions.

The studies of M&C project management have been motivated by the impact that the process has on their success. In a literature review conducted by Rozones et al (2006), the importance of process control throughout the lifecycle of projects is highlighted and the lack of appropriate methodologies despite the evolution of discipline. Rozones et al emphasizes that many of the causes of project failures can be attributed to the lack of planning and monitoring, highlighting importance of control in the achievement of the aims and improvement the project performance. He classifies them as one-dimensional and multidimensional control systems. One-dimensional systems are not integrated variables, this being their main disadvantage. They are used for specific issues due to their easy usability. Multidimensional systems include the integration of variables.

M&C is especially important in some sectors, for example, studies demonstrate the practical implications in the international development, aid, and disaster recovery, where an effective control process can get the correct implementation of a project (Steinfort, 2010; Steinfort and Walker, 2011). Although the aid sector and international cooperation has not been regarded as a traditional area of intervention of the project management (Ahsan and Gunawan, 2010; P. Crawford and Bryce, 2003; Ika et al., 2010), and the available literature is little and too recent (Steinfort, 2010), thus justifying the contributions that focus on improving processes and monitoring and control applications such projects. In this paper assumed as particular research topic the approach on the consequences of observing techniques, performance measurement and control that are fundamental for self-management methodology and project management, as well as search and choice of factors relevant to the plan, to help simplify tasks and achieve better results in the practice of the project managers (Cicmil et al., 2006; Hodgson and Cicmil, 2006).

Research contributions have set trends for the M&C process, generating the development of methods, techniques, tools, or modifications of the traditional models. Earned value management, for example, is the method most often used in measuring multidimensional systems. It is perhaps the most applied for the M&C. There are a number of publications on the results and modifications of this technique, which reflect the ease of its application, interpretation and implementation. Anbari (2003), suggests that EVM can be used in various types and classes of projects in public and private sectors. Kim et al (2003) confirms the acceptance of earned value in monitoring processes, despite their disadvantages of excluding other aspects such as, among others, quality, technology or design.

In other studies/researches, progressive changes have been made to the EVM in order to improve its implementation. This is the case of Lipke et al (2009), who proposed a method of forecasting final cost and duration of the project, by varying the method to analyze the performance of the calendar (Earned Schedule). Vandevoorde and Vanhoucke (2006) compared the classic indicators of the earned value with a new performance indicator called "earned schedule". They concluded that the use of the modification/change depends on the needs of project managers, and that similar results could be produced for monitoring in early and middle stages. Plaza and Turetken (2009), have designed a spreadsheet as a new version of EVM called EVM/LC. The authors have proposed the tool, looking for a better estimation of the duration and control of projects. Rozenes and others (2004), proposed a multidimensional system to quantify the deviations from the planning phase to implementation phase, which includes aspects such as quality, which cannot be analyzed through other techniques.

Another technique transferred from the area of management into organizations, which has been applied in the M&C project, is the balanced scorecard (BSC). Its function is to detect changes in the market to give rise to organizational changes, and its application in project management allows evaluating the integration of three perspectives: customer, internal processes and learning, and growth. Norrie and Walker (2004) describes the use of the balanced scorecard as a tool for improving the effectiveness of project management, and proposes its use as an extension of the current practices of strategic measurement and improving operational performance of project teams.

The critical chain methodology (CC), which applies the theory of constraints (TOC), is a technique used in organizations operating in multi-projects; it is a method for planning, programming and controlling that recognizes the relationship between activities and resource constraints. This technique is applied for monitoring the progress of projects, the deviations, the schedule and for assisting in correct decision-making (Cohen et al., 2004). The study by Cohen and others has shown that there are advantages in its application. However, provided that it conforms with the needs of the project, it can also be implemented with others tools. Besides the above, traditional techniques such as the Gantt Chart, Program Evaluation and Review Technique (PERT) and Critical Path Method (CPM) are still being studied. Their adaptation to information technology tools have corrected their limitations and promoted a new generation of applications.

Finally, considering that we are trying to analyze the impact of the adoption of methods, techniques and tools of M&C on performance in project management, we have analyzed the criteria normally used to assess such performance. As in other management disciplines that use performance measurement, a discussion has been established in the field of project management on performance assessment and its impact on the project success (Bryde, 2005). Performance assessment is based on the measurement and monitoring of the performance criteria of the projects (Barclay and Osei-Bryson, 2010) and has traditionally been associated with the variables of time, cost and quality (Pillai, Joshi and Rao, 2002; Wi and Jung, 2010).

Although there is divergence of views on what constitutes a "successful project" (Prabhakar, 2008), different authors distinguish between project success, as measured by the achievement of objectives on the final product; and project management success, measured usually in terms of time, cost and quality (Baccarini, 1999; de Wit, 1988). In this regard, Cooke-Davies (2002) states that we should differentiate between success criteria (measures the project will be judged by) and success factors (inputs to the management supporting the success). Project performance is measured by metrics (Luu, Kim and Huynh, 2008; Marques, Gourc and Lauras, 2010), and the process is about setting goals, about the choice of an improvement strategy through success factors, and measurement to establish the difference between what is planned and the results (Toor and Ogunlana, 2008, 2010).

Some studies show that it is impossible to generate a universal list of criteria, since they vary from one project to another (Jha and Iyer, 2007, Marques et al., 2010). Others propose adopting new dimensions that broaden the vision, such as management process quality and meeting stakeholders' expectations (Van Der Westhuizen and Fitzgerald, 2005). In general, most current methods are based on the so-called iron triangle (cost, time and quality) (Wi and Jung, 2010); and other categories are added to this. Other researchers propose traditional categories or some additional (Almahmoud, Doloi and Panuwatwanich, 2012; Cho, Hong and Hyun, 2009, Jha and Iyer, 2007; Ling, 2004; Sohail and Baldwin, 2004). Other proposals suggest categories different from traditional (Cheung et al., 2004; Lauras, and Gourc Marques, 2010; Toor and Ogunlana, 2010). For the preparation of this paper we have used the three traditional categories plus three others taken from the literature described in this section.

The research analyzes and describes the current status of the topic under study, including journal literature, standards and Bodies of Knowledge. An empirical study is carried out to understand the project managers' perspective and adoption of methods, techniques and tools of M&C. The purpose of the empirical phase is to analyze the impact of use of tools and techniques on projects performance.

The question proposed to define the hypothesis in the research is: How can the adoption of techniques and tools be a key factor in project management performance and success?. With this study we aim to provide a contextual framework for applying project management's tools, developed through the analysis of literature and an empirical study. We also seek to confirm the relation between the adoption of these tools and project performance, establishing the variables that affect the results both positively and negatively.

2. Standards and Project Management Methodologies

The bodies of knowledge of project management are developed by organizations, agencies (public or private), professionals and researchers to define and validate the conceptual domain and competencies required for performing adequately in the area. The BOKs contain the most important knowledge (Rozenes et al., 2006), and besides being a guideline, have methods, techniques, tools and skills for their practitioners (White and Fortune, 2002). The fulfillment of the standards is voluntary (Hiyassat, 2000), and its adoption in organizations has increased.

Ahlemann and others (2009), confirm the existence of a large number of standards for project management, issued by organizations, standardization companies and associations in the world. They have common content and principles, and one of the effects of standardization is the creation and maintenance of a market for tools to support the project management practices (Garcia, 2005). Milosevic and Patanakul (2005) argues that increasing the level of standardization in some factors may lead to greater success in managing projects.

The standards should be regarded as an instrument for facilitating the efficient and effective use of resources, since the latter are mobilized through projects in organizations and establish a competitive advantage (Bredillet, 2003). According to Crawford (2004), widely distributed standards have been essential for the growing interest in project management, but it can also be seen as limiting its development and influence. Wirth and Tryloff (1995) compared some bodies of knowledge and standards, and suggested the development of a common international document based on the alternatives available.

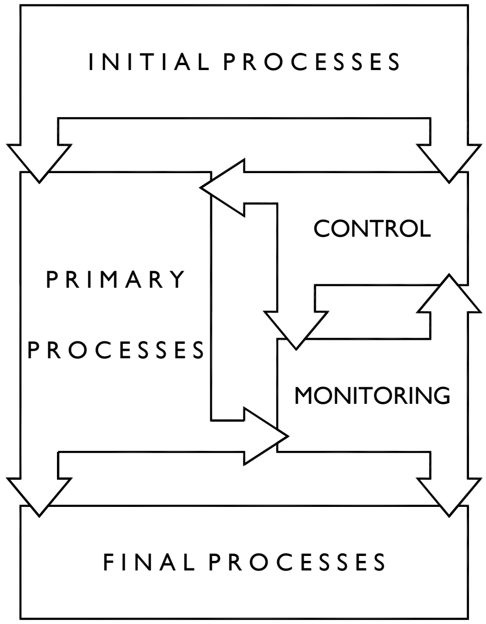


Figure 1. The project management process.

M&C is a project management process commonly referred to by all the BOKs, according to which it represents one of the central and most important processes within their standards. Figure 1 shows a general understanding on the importance of M&C within the processes typically referred to in the standards of project management.

The following sections present the compilation of the approach for realizing the process of M&C projects for each of the bodies of knowledge and internationals standards.

2.1. Project Management Body of Knowledge (PMBOK)

The PMBOK is a standard of the Project Management Institute (PMI) which describes methods, processes, techniques and tools applicable to the management of projects (Pant and Baroudi, 2008). The proposal included in the PMBOK are recognized and accepted worldwide (Barad and Tzvi., 2000; Milosevic and Patanakul, 2005) (Shi, 2011), and its content has been implemented in many sectors (McHugh and Hogan, 2011).

The monitoring and control is an essential process in its approach. This process aims to monitor performance, measure and regulate it in a systematic way to identify changes in planning (Project Management Institute, 2008).

Eight of the nine knowledge areas interact with the process of M&C, which gives one an idea of the significance of its inclusion in project management and the number of elements that are proposed for use in its application. Moreover, a set of techniques and tools are listed, which can be arranged to benefit the outcome of management activities in this process

Table 1. Techniques / tools for monitoring and controlling in projects PMBOK

Technique/Tool
Expert judgment
Change control meetings
Inspection and audits
Variance analysis
Performance reviews
Project management software
Resource leveling
What-if scenario analysis
Adjusting leads and lags
Schedule compression
Scheduling tool
Earned value management
Forecasting
To-complete performance index
Cause and effect diagrams
Control charts
Flowcharting
Histogram
Pareto chart
Run chart
Scatter diagram
Statistical sampling
Approved change requests review
Communication methods
Reporting systems
Risk reassessment
Risk audits
Technical performance measurement
Reserve analysis
Status meetings
Contract change control system
Procurement performance reviews
Performance reporting
Payments systems
Claims administration
Records management system

According to the PMBOK, the central integration activity in the process of M&C sets monitoring variables into seven areas: work, scope, schedule, cost, quality, risk and procurement project. Once the information is gathered from the above areas, it is compared with the management plan. Furthermore, the project status is communicated through performance reports and change requirements (corrective / preventive actions and defect repair) and is created so that it can be incorporated into the project.

The approach of the standard for the M&C primarily focuses on checking obtained deliverables (scope), dates achieved (schedule) and percentage of completed work (cost), whose parameters should be monitored using performance indicators (KPI). The technique suggested by the PMBOK for this activity is the earned value management (EVM), which is the standard PMI and has been developed as a complement to the PMBOK (Project Management Institute, 2005). EVM indicators provide information on variation in cost and time, and allow to estimate the conclusion/end of the project, which are precisely the essential data in the monitoring approach.

Table 1 has been compiled with techniques and / or tools that could be applied to M&C process according to the PMI. The PMI includes a large group of techniques (qualitative and quantitative) that may be applicable in the process of M&C project. The technique most recommended for the M&C is the Earned value analysis and its use can be supplemented with other techniques such as work to complete performance index, variance analysis, performance reporting, trend analysis, project status meetings, reporting system and project management software.

2.2. Association for Project Management Body of Knowledge (APMBOK)

The body of knowledge from the Association for Project Management (APM) is used as a normative standard of project management. The BOK defines the issues in which APM believes that the professionals of project management should be well informed (Morris et al., 2006; 2000; Willis, 1995), as well as knowledge required for the successful management of projects in various sectors.

In the APM, each group is divided into components to form a structure with a total of 52 parts (Anderson and Merna, 2003; Association for Project Management, 2006). The APM model has a structure similar to the scheme of stages of strategic management, in which the plan conception comes from the direction of the organization, and is implanted through an action plan with activities and projects. Thus, the emphasis in the process of M&C in APM can be seen mostly in the elements called "strategy execution" and "technical", since in the strategic management process is precisely the implementation of the strategy where control and monitoring measures are applied on action plans.

Based on the above, we selected the sections of the model which are related to the M&C project. In section "Executing of the strategy" there is a large number of elements related to the monitoring and control process, such as scope management, scheduling, resource management, budget and costs, and change control. The earned value management technique and reporting information management is also included. It is considered that by definition the process of projects monitoring and control raised by APM is equivalent to the strategic monitoring, since the strategic implementation is carried out mainly through internal projects in organizations.

Likewise, according to APM, verification is based on establishing a work plan, which contains parameters that are initially set as a baseline. Once the actual performance is established with respect to these initial set parameters, the deviations are established and appropriate decisions are taken on this project. Once more, in the process of M&C project

APM model, the ideas promoted by the strategic management theory are replicated, since accordingly the analysis, selection and implementation of the strategy, decisions are implemented through concrete actions. These actions, contained in plans, with deadlines, human, material and financial resources, are projects by definition.

It is considered that the model for project management APMBOK initially covers aspects related to the context of project management, in which strategic approach is evaluated with the opportunity and viability of the project as a business. Therefore, the standard includes aspects prior to the decision to undertake the project (feasibility studies), and subsequent of project management such as managing schedule, budget and changes. The approach to M&C can be found within the topics of strategy execution.

Table 2. Techniques / Tools S&C in projects APM

Technique/Tool
Key performance indicators
Quality management
WBS (Work Breakdown Structure)
OBS (Organizational Breakdown Structure)
CBS (Cost Breakdown Structure)
Earned value management
Gantt Charts
Milestone Charts
PERT
CPM
Precedence diagram
Cash flow
Trend analysis – predictions

It is considered that the APM body of knowledge presents two technical approaches used in the process of M&C: application of traditional techniques (PERT, CPM, precedence, Gantt) and performance-related techniques.

For these latter the earned value management (WBS, OBS, CBS), indicators, trend analysis, predictions and cash flow are incorporated.

The APM techniques may be seen in table 2, which has been summarised and compiled from reports of the APM standard.

2.3. International Competence Baseline (ICB)

ICB is the skills standard outlined by the International Project Management Association (IPMA), an organization of professionals in the management of projects (Söderlund, 2004), ensuring consistent processes in project management (International Project Management Association, 2006).

The model's structure is organized into elements called competencies, which are organized into three groups: technical, behavioural and context. The competence sets represent all elements necessary for proper project management (Anderson and Merna, 2003). According to the ICB (International Project Management Association, 2006), a competence is a collection of knowledge, personal attitudes, skills and relevant experience needed for successful project management.

In the body of knowledge of the IPMA three sets of techniques suggested for the M&C may be identified, The first, relates to the handling of managers and teams (responsibility matrix, groups, decision making and continuous improvement), the second refers to the planning and preliminary organization of good control (critical path, planning time, budgets, scenarios), and the third, the techniques that can be incorporated with the earned value (cost control, reporting, auditing, performance, budget control).

Table 3. Techniques / Tools S&C in projects ICB

Technique/Tool	
	Decision models
	Responsibility matrix
	Deliverable design and control methods
	Critical path planning
	Time contingency ‘buffers’ or ‘float’
	Time planning methods and time control methods
	Cost control methods
	Earned value
	Project reporting system
	Financial audits
	Control cycles
	Change management
	Continuous improvement
	Scenario planning
	Key performance index
	Budget planning and budget control

Although this classification is not explicit in the standard ICB, it is considered to be a classification very appropriate for the application of the process, since it is complemented by three key aspects: team responsible for the M&C process, M&C planning and performance verification.

The techniques that have been collected may be seen in table No. 3, whose structure has been compiled from information included in the ICB. It is considered that the proposal of ICB presents specific actions related to the process of M&C projects, which can be applied easily if implemented through specific methodologies on specific types of projects. Similarly, the inclusion of specific aspects of project managers’ behaviour makes the proposal unique and ensures that the processes are supported by personal skills and implementation of techniques.

2.4. International Standard Organization 10006 (ISO 10006)

The version of standard ISO 10006:2003 has been published by the International Organization for Standardization and provides guidelines for quality management in projects (West, 2002), and recommendations for successful management processes of these (Rutešić et al., 2005). The document has been prepared based on the 1994 version of ISO 9001 and does not constitute a guide to the global project management (Anderson and Merna, 2003), but provides at least a starting point for meeting management requirements and can be very helpful for people involved in such activities (West, 2002). At present the new version is being developed and has not yet been published.

We analyzed the sections of the standard that suggest one or further processes related to implementation of control activities in the project. The selected sections are: management responsibility, resource management, product realization and measurement, analysis and improvement. According to the standard, measuring performance should be based on the management plan and verification of the state indicators of project progress (The International Organization Standardization, 2003). It also states that performance reports and corrective actions are the instruments of control of project management.

The ISO 10006 standard includes the essential elements of control of the projects illustrated by the referred "iron triangle" (time, cost and scope), plus other additional important elements such as contracts, communications and information. Although the description of the application precludes drawing many practical details, we distinguish other elements of measurement, process analysis and improvement as related to the continuous improvement of the organization which runs the project.

Table 4. Techniques / Tools ISO 10006

Technique/tool			
	Work breakdown structure		Quality auditing
	Measurement and control progress		Statistical methods
	Plan for remaining work		Control charts
	Measuring project performance (KPI)		Flowcharting
	The timings of reviews		Brainstorming
	Regular reviews of the project schedule		Pareto chart
	Progress review meetings		Trend analysis
	Inspection and auditings		Contingency plans
	Control of documents and records		Earned value analysis

Table 4 shows the tools and techniques suggested for the M&C process in ISO 10006, whose structure has been developed from its reports. It can be seen that a group of qualitative techniques transferred from the quality management is included, and others related to the measurement of project progress and performance.

2.5. Projects in Controlled Environments (PRINCE2)

Prince2 is a structured method project management, developed by the OGC, Office of Government Commerce UK (McManus and Wood-Harper, 2003).

The use of PRINCE project management has been intensively promoted (L. Crawford et al., 2006), and is recognized internationally as the standard, frequently used in some countries (Fortune et al., 2011), becoming one of the three most frequently requested along with the PMI and APM (Whitty and Maylor, 2009).

The method uses a process approach to guide the flow of project management activities, so that it is possible to distinguish which activities are directed at monitoring processes and / or control of the project. In the distribution it can be observed that one of the principles is the "manage by stages"; one of the thematic approach of "progress" and the processes of monitoring and/or control are managing stage boundaries, controlling a stage and managing product delivery.

Likewise, in PRINCE2, those project management variables which are subject to M&C are: cost, schedule, quality, scope, risk and benefits.

The progress approach according to the method is carried out by measuring the achievement of planned goals and objectives, and involves comparing the progress of the variables to be controlled at specific decision points. The output of the progress measurement provides the completion of corrections and approval of additional working to complete the project.

The project management approach in frequently controlled stages indicates the importance given to aspects of M&C.

This approach provides two types of monitoring progress: events-based approach (late stage, end of year) useful for monitoring purposes, and time-based approach (monthly, periods, etc.) useful in monitoring and presentation report (Office of Government Commerce, 2009).

Management products that are presented as advantageous for establishing and executing progress controls are the project plan, stage plans, exception plan and work packages. It can be seen that dividing activities into stages allows to carry out actions for reviewing and correcting reports in small cycles, which leads to frequent and reviewed feedback during the whole project life cycle.

It is considered that with the distribution of management processes in PRINCE, a project manager can easily identify the activities that relate to monitoring and / or controlling, as well as the sequence for implementation.

The division into management segments with continuous assessment may improve the outcome of the process, since it induces the responsible person to have permanent contact to the milestones and boundaries among each of the stages.

Table 5 presents the techniques and tools for M&C proposed in PRNCE2, whose structure has been compiled from the information included in the standard. These are applied with the topic of progress control, stage control process and stage management boundaries. According to the standard, with progress measurement it is possible to assess the achievement of the plan objectives. It is evident that the earned value technique, as in other bodies of knowledge, is once more recommended. Similarly guidance techniques can be classified into three periods: before the decision to carry out the project (feasibility), planning stage and progress assessment stage, the latter being the main focus of the present research.

Table 5. Techniques PRINCE2

The critical chain technique
Gantt charts
Spread sheets
Product checklist
Critical path diagram
Review lessons
Risk checklists
Risk prompt lists
Brainstorming
Risk breakdown structure
Risk models
Expected monetary value
Milestone chart
S-curve
Earned value management

2.6. Comparing of Standards and Methodologies

It is considered that standards have common contributions, which supports the development of a proposal to integrate the perception of monitoring and control in the subject of project management into a single instrument. As a result of this group Table 6 shows techniques / tools groups for each standard, assigned to variables traditional. Table 6 has been prepared with information, structured and summarized throughout this document, from reports of each of the standards

It is considered that the monitoring and control variables classification performed in accordance with the guidelines of each of the standards, indicates that most of its proposals agree on the importance of applying the monitoring process on the variables representing the axis of the management of a project (scope, time, cost or quality). Likewise, most applicable tools and techniques recommended, focus their application in these variables. Therefore, these techniques support the achievement of the objectives with each management variable, supporting them with their implementation in specific cases.

Despite this, gaps can be seen in representation and applications; techniques for monitoring and control of other variables that are not part of the axis of project management, but they support their successful development, such as risk, communications, purchasing, documentation, among others. In such cases, recommended techniques and / or tools are scarce, with little applicability, and without contributions to the standards, which in turn represents a future line of research for the subject.

Table 6. Techniques/tool for control of projects into project management standards

TECHNIQUE/TOOL ON MONITORING AND CONTROL					
Variables	PMI	APM	ICB	ISO	PRINCE2
Scope	Inspection, Variance analysis			Measurement and control progress	
Time	Performance reviews, Variance analysis, Project management software, Resource leveling, What-if scenario analysis, Adjusting leads and lags, Schedule compression, Scheduling tool	WBS (Work Breakdown Structure), OBS (Organizational Breakdown Structure), Gantt Charts, Milestone Charts, PERT, CPM, Precedence diagram,	Responsibility matrix, Critical path planning, Time contingency 'buffers' or 'float', Time planning methods and time control methods	The timings of reviews, Work breakdown structure	Activity-on-node technique, The critical chain technique, Gantt charts, Spreadsheets, Critical path diagram, Milestone chart, Estimating techniques, Product checklist
Costs	Earned value management, Forecasting, To-complete performance index, Performance reviews, Variance analysis, trend analysis, Project management software	Earned value management, CBS (Cost Breakdown Structure), Cash flow, Trend analysis – predictions, Key performance indicators	Cost control methods, Earned value, Budget planning and budget control, Key performance index, Project reporting system	Earned value analysis, Flowcharting, Measuring project performance (KPI), Plan for remaining work	
Quality	Cause and effect diagrams, Control charts, Flowcharting, Histogram, Pareto chart, Run chart, Scatter diagram, Statistical sampling, Inspection, Approved change requests review	Quality management		Pareto chart, Control charts, Trend analysis, Statistical methods, Inspection and auditings, Quality auditing	Pareto analysis
Risk	Risk reassessment, Risk audits, Variance and trend analysis, Technical performance measurement, Reserve analysis, Status meetings			Regular reviews of the project schedule, Progress review meetings	Risk checklists, Risk prompt lists, Risk models, Risk breakdown structure
Communications and procurements	Forecasting methods, Communication methods, Reporting systems. Contract change control system, Procurement performance reviews, Inspections and audits, Payments systems, Claims administration, Records management system			Control of documents and records	

3. RESEARCH METHODS

For the study we used qualitative and quantitative strategies in order to determine the use of monitoring and control techniques and tools, and to evaluate the relation between their use and project success. The preliminary step was conducting a review and interpretive work (analytical-descriptive) of the literature and bodies of knowledge. Once the review was completed, we designed a questionnaire, structured in three parts, which aimed to collect empirical data about the managers interviewed, the use of techniques and tools, and their relationship with performance measured by success criteria in projects.

The first part of the questionnaire had three open questions, the rest of the questions were closed. The first part, with ten questions, gathered general information on the managers interviewed. The second part had three questions that gathered information on methodologies, techniques and tools in order to assess the level of their use. Finally, data was collected on the frequency of application and submission of progress reports according to the size of the project, procedures, use of indicators and variable measurement during monitoring and control reports. Results were presented individually, indicating the ones with the highest use of techniques and tools and seeking the relation that may exist between their use and project performance. The third and last part of the questionnaire consisted of three questions that explored the final performance of a project carried out by the manager interviewed and that had recently been completed.

To this end, and based on the literature review, we chose six performance criteria that are considered relevant in determining success (time, cost, quality, activities, scope and stakeholders' satisfaction). The variables that determine performance were linked with the results on the use of techniques and tools, assessing whether there was any correlation.

People with experience in the area were selected to avoid crowding the questionnaire and to clarify the language used in questions and thus improve the understanding of the statements contained therein. A questionnaire was sent to project managers registered in a database of a public university. The information obtained from 280 questionnaires was analyzed and described.

The application of techniques and tools was analyzed, describing their adoption in general and determining which had greater applicability. Finally, through a correlation analysis, the influence of the adoption of techniques and tools on project results was established; variables with the greatest correlation were shown and results discussed.

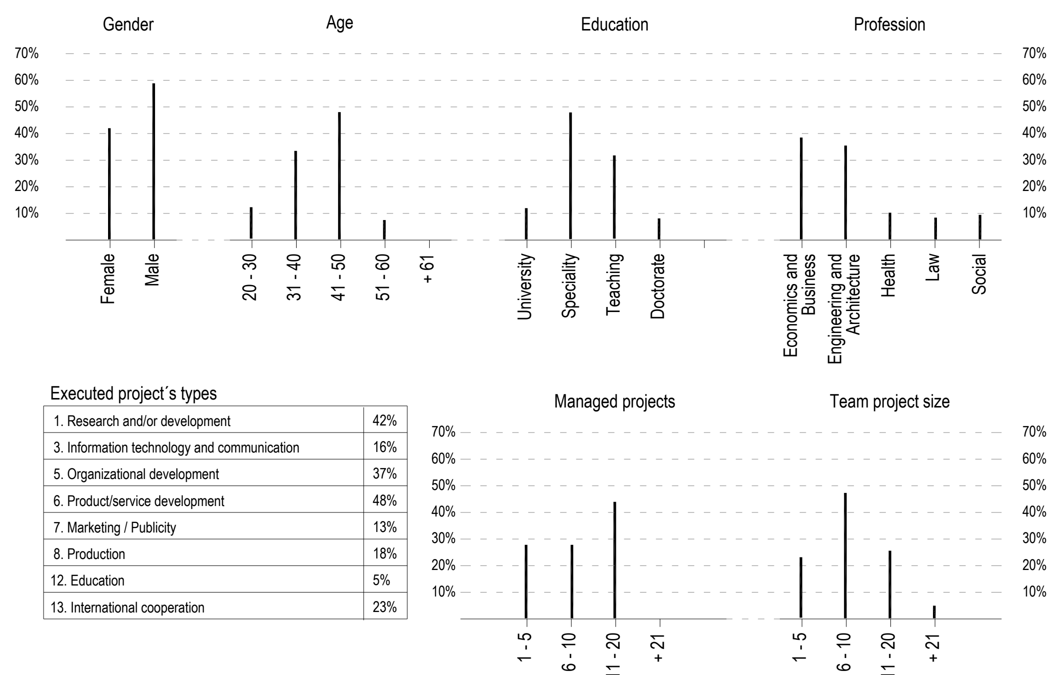
4. ANALYSIS AND DISCUSSION OF RESULTS

Using information collected through the questionnaire, we analyzed various topics of interest in order to answer the question and hypothesis presented in this research. Overall results of the sample were classified by variables (gender, age, education level, profession and occupation) to determine whether any of these had an impact on performance aspects. Other variables such as number of managed projects, project type, and number of people in the team were used to characterize the elements that determined the type of projects in the sample.

We identified the frequency of using the variables for each technique and tool for project monitoring and control, gathered from the analysis of literature and standards. In addition we assessed the relation between each tool or technique and the variables assigned to measure project performance.

The most used tool in the work of project managers was identified. With the last part of the questionnaire we characterized the type, the measurement frequency and the final percentage of completion of each project. The variables that determine the performance were related to the variables identified for techniques and tools, assessing whether there was correlation between them and project performance.

From the overview analysis it can be seen that most managers interviewed were male, 59% male and 41% female. About half of the study population was between 41 to 50 years, and the remaining were mostly those between 31 and 40, which guaranteed, in principle, that the interviewed managers had professional experience. The most prevalent education level was specialization and expertise, which indicates that most had a post-graduate degree and only a minority had only professional studies (11%). Profession and occupation of professionals were mostly in the area of Economics and Business, and Engineering; which confirms that these areas are the most applicable for project management. Figure 2 shows the main results of the sample's overview.



Executed project´s types

1. Research and/or development	42%
3. Information technology and communication	16%
5. Organizational development	37%
6. Product/service development	48%
7. Marketing / Publicity	13%
8. Production	18%
12. Education	5%
13. International cooperation	23%

Figure 2. Sample's overview results.

The types of projects implemented were varied and allowed more general characterization in terms of typology. The number of managed projects and team size indicate that the selected sample had experience in the area. In addition, the managers interviewed had mostly been in charge of medium-sized teams, which also indicates that the projects managed were of considerable size. It can be seen that the types of projects most executed by the managers were research and development, organizational development and product and service development. This means that the projects were carried out mostly in areas of Economics and Engineering, corresponding to the education characteristics of the sample.

With regard to the adoption of methodologies, we can find a large number adopted from the PMBOK; although in general there was a low use of methodologies. It can be seen that the PMBOK had high acceptance and use (approximately 35% of the sample) whereas other standards' were generally low (between 2% and 12%). The other most used methodology was PRINCE2, which coincides with results of studies described in the literature, where PMBOK and PRINCE are said to be the most used methods in some European countries. Approximately 35% of managers did not often use methodologies developed from the mentioned standards, in some cases because they did not use any procedures at all, and in others because they used in-house methodologies or techniques. Figure 3 shows a chart comparing the results of adopting methodologies by the managers who were part of the study.

With respect to the use of monitoring and control techniques of projects, generally one can see a use of more traditional tools like the Gantt chart (21%); and in other cases, the use of newer techniques such as performance indicators (11%) and earned value (10%). It is also interesting to note that a considerable proportion of the sample (11%) do not normally use any technique for project monitoring and control. Figure 3 shows the most general and representative results of the use of techniques. Not included are those techniques that, taken from the reviewed standards, were placed in the questionnaire but whose adoption result was very low (between 0 and 1%).

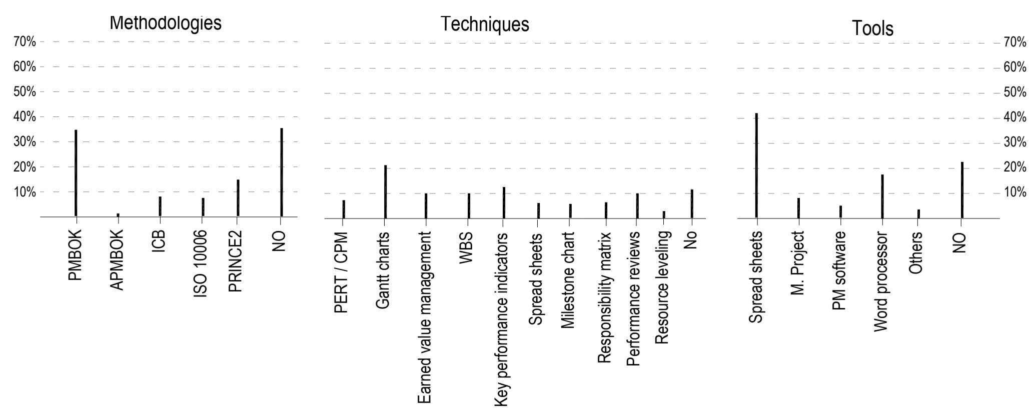


Figure 3. Adoption of methodologies and techniques/tools for monitoring and control.

With respect to the use of tools, it is remarkable the considerable and widespread use of the spread-sheet as a monitoring and control tool. This may be because it is the IT tool for project planning and budgeting. Likewise, it is possible to note the use of word processing, probably due to the application of templates; and a considerable proportion of managers who did not use any monitor and control tools. Other tools like Microsoft Project or other software applications were used in a low proportion (5% and 8% respectively). Figure 3 shows the overall results of adoption of tools. Not included are those with very low results of tool adoption, although they were included in the questionnaire. It can be noted that the lack of knowledge of tools is higher than that of techniques, indicating the existence of different systems other than computers' to manage projects. Among the tools classified as "other" are applications such as spring project, free software and in-house tools.

With the descriptive statistical analysis we studied the correlations between variables pertaining to the use of methodologies, techniques and tools and the projects performance criteria. In the correlation analysis only those variables with the highest percentage of use (methodology, technique, or tool) were taken into account.

Regarding the use of methodologies, a positive correlation with performance was generally found. The strongest positive correlation occurred between the use of methodologies and the project scope, especially the PMBOK standard. That is, the more methodologies are used the better the project scope results are. Another variable with strong positive correlation was between the use of methodologies and project cost and time, that is, generally the use of methodologies improves key variables of project management results.

The correlation results can be seen in the diagram of Figure 4. Although the correlation with other performance variables (quality, activities and stakeholders) was not as representative as for the rest, one can see that the correlation remained positive. This indicates that although there are variables that are affected more than others, managers who used project management methodologies found better results.

Regarding the correlation between the use of techniques and tools and performance, the variables with the strongest positive correlation were cost, activities, time and scope of projects. In this case the activities were affected by the use of techniques and tools, indicating that with these, control on operational execution was improved, so were the results. The other variables (quality and stakeholders) showed positive correlation; and like with the use of tools, although not strong, maintained some degree of influence on the results.

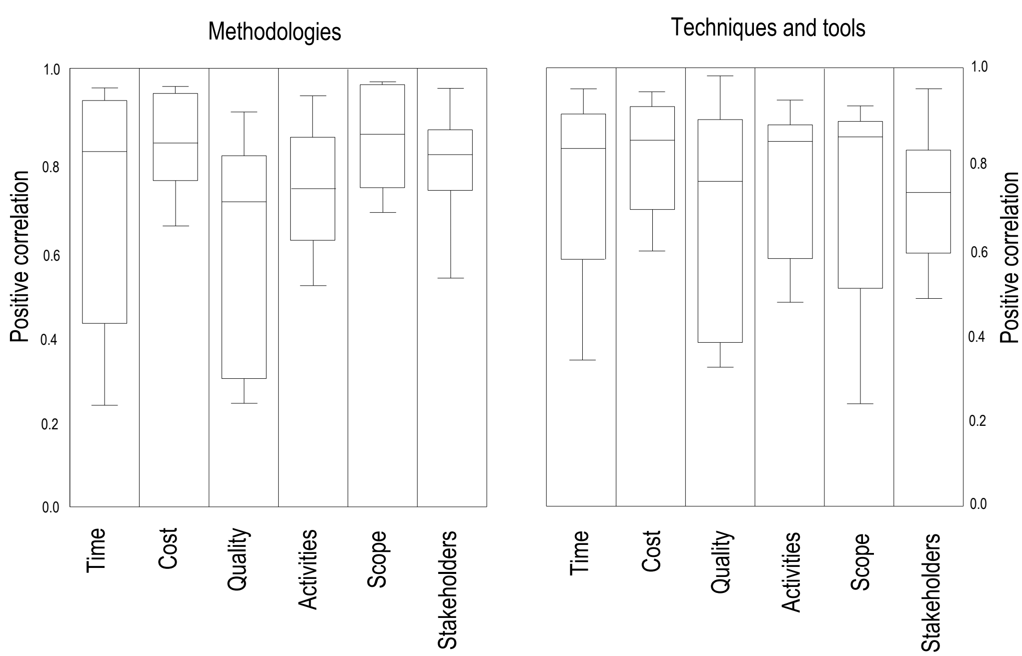


Figure 4. Correlation between variables and project performance.

The diagram in Figure 4 shows the overall results of the correlation between the use of techniques and tools and performance of projects managed by the interviewees. Figure 4 shows the average rate of correlations. The left part illustrates the correlation between the use of methodologies and all performance variables of the study. The results of this correlation are positive, indicating that their adoption affected project performance. Of all parameters assessed, the most influenced were cost and scope.

The right part of Figure 5 illustrates the correlation between the use of techniques and tool and performance variables. The results of this correlation are also positive, indicating that their adoption improved performance. The parameters most correlated with performance were cost, activities and scope.

CONCLUSION

The monitoring and control is considered as the action of checking frequently progress in project implementation. The influence of its proper implementation over on the criteria for project success generates interest in learning and applying instruments, techniques or tools that keep stable all the variables that affect performance. This paper analyzes the adoption of monitoring and control methodologies, techniques and tools; and their influence on project management performance. According to the review and interpretation of literature and Bodies of Knowledge and application of the questionnaire, this research provides empirical evidence to establish whether the adoption of techniques and tools and the use of methodologies developed from representative Bodies of Knowledge influences project results.

The results showed that project management literature and Bodies of Knowledge do treat with monitoring and control techniques and tools adequately. However, in terms of adoption, there was a low rate of use, prevailing traditional ones. Managers' poor training was one of the causes for the outcomes, which resulted in limited applicability. However, Bodies of Knowledge and standards were proved to be known, so probably the issue is about applying their guidelines.

It is considered that standards such as PMBOK and PRINCE2 structure detailed application monitoring and control, in part because they assume that this is a process in the distribution of process groups. PMBOK includes actions to monitor the status of the project, analyzing the impact on the management plan, performance report and relevant decision making. However, documentation systems have to be used as formats and / or templates to transform the totality of the standard and increase its usefulness in the effective implementation of projects.

With regard to techniques and tools that are included in the bodies of knowledge and standards, traditional techniques are suggested but supported by computer tools or software management systems. This validates the usefulness of these techniques still in force and the need to include information technology as support for project managers. Similarly the technique of earned value management is perhaps the most popular today, and suggested by all standards.

The frequency of use of methodologies, techniques and tools shown by the sample managers was low. However, their adoption affected project performance with greater or lesser impact. There was not general consensus about the most used technique or tool, since there were not significant differences in their use. It was found that there was more adoption of traditional management techniques applied in project management. The techniques most correlated with performance were related to the use of key performance indicators, such as earned value, or review systems.

Although satisfaction and adoption of more known and used traditional tools were high, they were not the ones that generated better results on project performance. The adoption of newer techniques and tools could generate a considerable improvement in project performance, thus promoting new strategies for the development of the discipline.

It is considered that the methodology used to prepare the study is useful in project management contexts and provides a procedure that allows an adequate analysis, data processing and results presentation, both interpretively and graphically. It is suggested that the methodology could be used in similar studies to relate the success factors in a project to it's performance and outcome.

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Monitoring systems and their effectiveness for project cost control in construction

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Abstract

This paper reports on a research to investigate the effectiveness of some commonly used monitoring systems, in detecting deviations from the planned cost and performance. The monitoring systems used in this work are:

1. Leading parameter technique
2. Variances method
3. Activity based ratios technique

The paper describes these monitoring systems; their characteristics, the measures they use and their effectiveness for assessing performance. The systems are first evaluated on a theoretical basis and then on the basis of results from investigations carried using simulation approach. A project model has been developed which realistically simulates the progress of the project and which generates information relevant to these monitoring systems. Factors affecting the project cost and performance are represented by changes in the project plan and inflation rates. It has been found that some of the earlier monitoring systems have more response to changes than the others. The research has also shown that the Activity based ratio's technique gives a clearer and simpler indication of the overall progress of the project than the other two techniques.

Keywords: Cost control; Monitoring systems; Construction; Progress; Simulation

1. Introduction

In a project, plans are usually drawn to ensure that work is carried out to the desired quality; in the allowed time; and according to budget. Divergences from the plan however occur and within construction such occurrences are common. Such divergences are nevertheless expected because of the nature of construction work and the uncertainties associated with it. In the case where the differences between the plan and the actual work performance are large, control action is normally required to try to bring the actual performance on course with the desired state of the plan.

Progress on the project is required to be monitored and compared as the work proceeds in order to be able to identify and measure these differences. The measurements made are usually limited in number because of cost related to data collection. There are a number of systems that are traditionally used in construction to monitor and report on the progress of the work. Some of them rely on information related to activities while others are based on work types. Although all of these systems are used to produce measures of project performance, financially or otherwise, the basis of measurement used and its interpretation of work performance is different in each of them. For this reason hence it is expected that, for particular real situation, some of these systems will produce measures that may call for control action while perhaps others may fail to do so.

This paper contains a review of a number of commonly used monitoring systems and their characteristics. A project model has been developed which realistically simulates the progress of the project and which generates information relevant to these monitoring systems. Factors affecting the project cost and performance

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are represented by changes in the project plan and inflation rates. The paper concludes with the results of the experimentations as to which monitoring systems are more effective in drawing management's attention to problem areas than others.

2. Monitoring and control

A project is highly unlikely to proceed in all respects entirely according to plan, particularly when the plan has been expressed in some detail. At one level a plan represents a model of the work method and divergences from the plan may be thought of as showing defects in the model. At another level a plan may represent a document of contract, an agreement between two parties concerning how a project will be carried out. Divergences from the plan in the latter case represent breaks in the agreement, which may or may not be of concern to the parties. Small deviations between plan and actual performance may be seen both as being within the limits of uncertainty of the model building process and as not sufficiently great to cast doubt on the achievement of the major objectives of the project. Larger differences however may require a revision of the model of future work to ensure that it is realistic. In the case where the plan represents an agreement, such revision may indicate that the major objectives of the project are no longer attainable and alterations in both the method and the objectives may be necessary.

The classical control cycle involves three stages:

1. Measuring the state of the system.
2. Comparing these measurements with the desired state of the system.
3. Taking corrective action to return the system to its desired state or to minimise some loss function [1].

Ideally such system should be stable, respond quickly to changes and be relatively insensitive to small amounts of noise and measurements inaccuracies. Time lags in such systems have been shown to degrade performance [1].

In a construction project context, the steps in the control cycle could be considered as:

1. Make a plan.
2. Implement the plan.
3. Monitor actual output and record it.
4. Report actual and planned parameters and their variations.
5. Take action.

The first four stages constitute the monitoring part of the process. Monitoring provides quantitative information on which control action may be based. It will always fall short of perfect accuracy and the possible size of errors should be borne in mind when control action is taken. Great accuracy can usually only be bought at the cost of delaying the information to an unacceptable degree. Control action will be demanded from management and, in the absence of formal information from monitoring, the management will take control action based on their use of informal information systems; hunches; beliefs and advice. Some managers are highly successful in their use of informal information systems but such success is by no means universal. There is no reason to believe that informal systems should be abandoned in favour of formal systems. Control action will be a product of the total information available to the manager.

3. Methods of monitoring projects

As indicated earlier, monitoring project performance involves making measurements as the project proceeds and comparing those measurements with the desired or expected values. The measurements made are limited in number because of the cost of data collection and also by company policy and precedent. Performance in a project is complex and a limited number of measurements will provide a less than complete picture of the performance. This partial picture may be adequate for the purposes of controlling the work or it may not.

Much of the available work on project performance measurement is embedded in the work on project control. Typically, the parameters used for assessing performance are financial. They are, at least in theory, easily calculated and easy to interpret. They are also very important to the people doing the collection and analysis—usually the contractors and clients. Three of the most commonly used monitoring techniques are involved here and are discussed later.

3.1. Leading parameter

Just like 'unit costing' Gobourne [2] and Pilcher [3], the leading parameter is a technique based on the idea of choosing one or more of the major types of work as measures of the performance of the whole project. For example, in a project where concreting forms a large portion of the work, the amount of concrete poured at any one time of the project can be used as a measure of the performance of the work. The actual cost per leading parameter as well as the total cost of the project is usually compared with the planned during the same period of time. This technique can also be used for a project which consists of many sections with different kinds of work in each of them. In this situation it is possible to use a different parameter as a measure of performance for each section.

A major problem with this technique as an effective tool for cost control is that projects often involve many important types of work and that the ' goodness' of the single parameter selected for assessing the project performance may well vary with time. In an attempt to overcome this, sometimes different parameters are used at different stages throughout the project. Whilst going some way to solving the problem, this introduces difficulties in the changeover period between one parameter and the next. Also although it is possible for this technique to show the deviations of the project performance from the plan, it does not show the reasons for these deviations.

3.2. Activity based ratios[4,5]

This is a financial control technique that employs the ratios between the earnings and expenditures of the project activities as measures of performance. The system can also be used to measure the performance of the whole project as well as that of the activities. The three ratios the system relies on for the calculation of performances are:

$$\text{Planned Performance} = \frac{\text{Planned Earning}}{\text{Planned Expenditure}}$$

$$\text{Actual Performance} = \frac{\text{Actual Earning}}{\text{Actual Expenditure}}$$

$$\text{Efficiency} = \frac{\text{Actual Performance}}{\text{Planned Performance}}$$

These ratios can be calculated at any time and over any duration for which a plan is available. Both planned and actual work must be evaluated using the same rates for earning and the same rates for expenditure. If the earning rates come from the original estimate, the performance measures calculated above give an evaluation of the performance against the estimate and the efficiency gives a measure of the project performance against the plan. All values should, in theory, be unity although since it is sensible to plan slightly optimistically, it is perhaps advisable to aim for 1.05 for planned performance and efficiency.

The measures used by this technique are both simple to calculate and simple to interpret. They require relatively little data and can be applied at a range of levels on a project. They can for example be prepared for a whole project or a section of it and can therefore be useful in measuring contributions of individual subcontractors to a project.

Based on the above, it can be concluded that the measures used in this method are excellent communication tools and particularly useful for short-term applications. The forecasts made are based solely on the plan and are not statistically reliable.

3.3. Variances and Earned Value Analysis (see Staffurth [6], Lockyer and Gordon [7]and Harrison [8]

In this context, variances are differences between two values. In project measurement and control they are usually differences between two expenditures—the planned and actual, although the incomes or any other values could be used.

The use of Variances to measure project performance is perhaps one of the oldest and most commonly used techniques. By considering the current and final state of the actual and the plan, it is possible to build a quite detailed picture of the project. Indeed, because it is possible to produce these figures for the whole project or for any section of the project, they are commonly used to assess the whole of a project, sections of it or, for example, the performance of single subcontractors. Basically by plotting various expenditure curves such as those for the first project budget; the last estimated total cost; latest estimated expenditure; and budget value of work done, two main types of variances can then be determined. These are the 'Budget Revision Variance' and the 'Total Cost Review Variance'. They are the main project variances, which may indicate an increase in the cost of the project compared with its budgeted expenditure. They do not however identify the causes of this increase.

It is possible to break these two main variances down into more detailed sub-divisions in order to assist in recognising the reasons for the changes in cost. For example the 'Total Cost Review Variance' can be broken down into the 'Current Budget' and 'Future Budget' variances. A current budget variance, for example, means that the incurred cost of work done to date is greater than the planned expenditure. It does not show, however, whether the project is behind schedule or if overspending has occurred. Further sub-dividing this variance into two more components as follows can see this:

$$\text{Performance variance} = \text{Budget value of work done} - \text{budget expenditure to date}$$

$$\text{Efficiency varaiance} = \text{Incurred cost} - \text{budget value of work done}$$

The 'Performance Variance' indicates that the progress of the project is ahead of schedule if it is positive, or behind schedule if it is negative. The 'Efficiency

Variance' on the other hand indicates over-spending if the variance is positive, and under-spending if it is negative.

An extension of the idea of the method of variances is the Earned Value Analysis technique. In this system the original tender prices are used, together with the schedule, to establish what should have been spent (or earned) at any time. As work progresses, the normal variances can be calculated but, in addition, the actual work performed is evaluated using the original tender figures and the budgeted value of work performed is calculated. Using the planned and actual values of work performed enables comparison of the current and future states against an independent measure. The tender is commonly used for this purpose.

This technique is relatively popular. However, it requires rather more data and effort to calculate than the other systems described so far. It also produces a large number of parameters to describe the state of the project. This makes it more difficult to use and rather more difficult to communicate to all levels of staff. The 'forecasts' just as with the previous systems are based solely on the plan and not statistically reliable.

4. Measures of effectiveness of control

In practice, a control system consists of making measures of performance; judging these against standards, and taking any necessary control action. The effectiveness of control is an amalgam of the effectiveness of each of these features.

In this work control action is assumed standard and the efficiency of the control system is directly related to the content and clarity of the information provided by the monitoring system. There are many different means by which a cost control system can indicate efficiency or inefficiency. To be effective, a cost control system must draw the project management's attention to problem areas. The detail and reliability in which any particular system can do this may be considered as a measure of its effectiveness. For example, a system which can only indicate project profit or loss may be considered less effective than one which can highlight the fact that carpenters are working below standard on column formwork. The effectiveness, if so defined, is not necessarily the only reason for choosing a particular system.

The control system should also take into consideration the amount of detail required in reports, which will vary according to the level of management for which the reports are introduced. Usually higher management level will be interested in the overall picture of the performance of the project while project management level will require more detailed reports, but still not as the detail required by the site agent or the site engineer.

Another area of indication of the efficiency of any cost control system is that of providing information to estimators. This should include cost of jobs with full descriptions of the conditions and work involved. Work conditions in the construction industry tend to vary considerably between one contract and another and hence there is a need for using this information wisely. It is perhaps most useful when the information is concerned with the outputs of machines on the site.

The cost control system should also provide data for the evaluation of variations which may occur during the contract, in order to help the contractor to build up his new rates of the work according to this information.

Finally control action will be based on the information provided by the control system and therefore the information should be clear and good at showing to the different levels of management any divergence from the planned performance.

5. Model structure

To test the effectiveness of the various monitoring systems described above, a project model has been developed to realistically simulate the progress of a construction project and which generates information relevant to these monitoring systems. The model can be used to simulate any project but the project used in this work represents the construction of a bridge that is represented by a 40 activities precedence network.

The model is designed so that it can provide data about the progress of the project in order to be used by the different monitoring systems. An outline flow chart of the model is shown in Fig. 1.

5.1. The scheduler

The model is designed to be a day-by-day scheduler that has variable resource levels and which gives variable duration for the activities. It is a serial sort scheduler in which the network calculations are performed only once at the beginning of scheduling [7,9,10]. It is based on the assumption that a certain predetermined number of each type of resource required by the activities being available for the use of the project. The scheduler uses the latest start time as a major sort. This implies that, at any one time, if two or more activities compete for the same resources when there is insufficient number of these resources to operate all of them concurrently then priority will be given to the activity with the earliest latest start time. If required, this decision rule can be changed without any alteration to the structure of the model.

The scheduling of the activities in the model is considered daily. If an activity needs either of resources or of materials cannot be satisfied then that activity has to

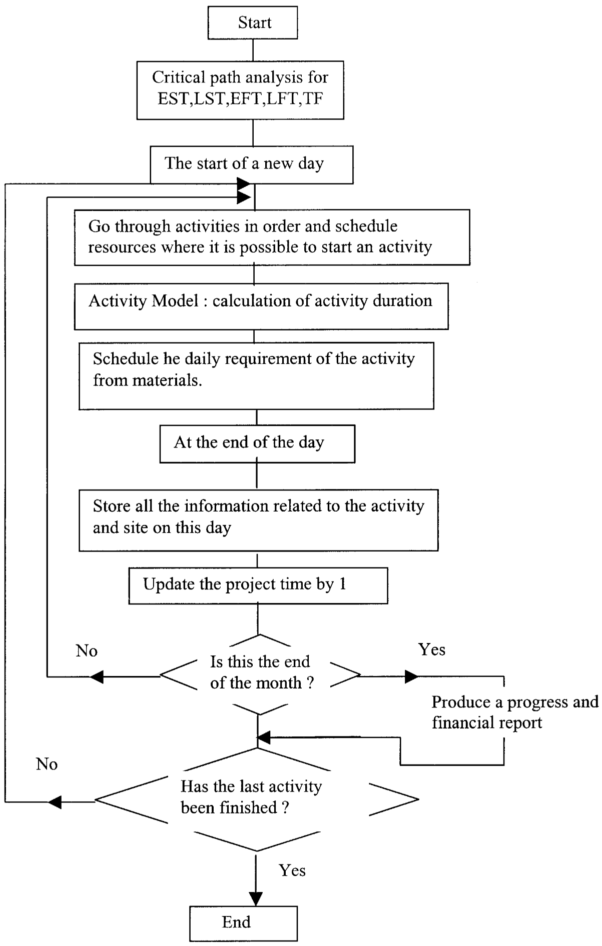

Fig. 1. The model flowchart.

be abandoned for that day. As a natural consequence of this, an activity can be stopped due to the shortage of either resources or materials and then restarted when there are enough of both of them to schedule the activity. This means that an activity can be split over two or more periods of time and then proceed at different rates of progress depending on the level of resources available.

The model allows changing the duration of an activity by altering the amount of resources between specified limits. Several authors in the past have suggested this type of model since variable duration activity, in general, is closer to real life than fixed duration model [9,12]. An upper limit of each resource is assumed above which an increase of that resource will not affect the speed of the activity. This limit differs from one resource to another. This assumption is made because, in real life, the number of resources working on an activity is usually affected by the type of work involved and the space available for these resources to work on that activity. There is a physical limit, for example, to the number of excavators and labourers that can work in or near a hole to be excavated on a construction site. If the number of resources on the activity exceeds a certain limit, it will result in extremely inefficient working conditions and might result in no work being carried out at all. Also too many resources in a limited space will undermine safety on site.

As well as the upper limit of resources that can be used by any activity, a minimum limit of resources below which work will not proceed is assumed, such as 1 labourer or 1/10 of a machine. The allocation of part of a machine to an activity means either a full machine is working part of the duration or a full machine is shared with other activities. For convenience of simulation, the division of machines has been made into 10 parts.

The duration of an activity for a resource can be calculated as shown:

$$D_{i=}\frac{w_i}{n_i}+M \tag{1}$$

where D_i = the duration required by resource i to complete the activity; w_i = work quantity for resource i; n_i = number of resource type i used; and M = minimum duration of the activity.

In addition to the limits of resources on activities, the model also simulates the effect of supervision on the progress of the work and the productivity of labour. It uses exponential mathematical relationship between the productivity of labour and the ratio of the number of foremen to the number of operatives. It assumes labour productivity to be 50% of the optimum if no supervision is involved in the work. Using such assumption, a ‘productivity factor’ is calculated using the following formula:

$$\mathrm{PF}=1-\frac{0.5}{e^R} \tag{2}$$

where PF = Productivity factor
and

$$R=\frac{\text{Number of foremen}}{\text{Number of operatives}}$$

The final duration of an activity can then calculated as being the maximum duration based on resources divided by the productivity factor as indicated in formula 3.

$$D=\frac{D_i\,(\max)}{\mathrm{PF}} \tag{3}$$

5.2. Model representation of resources

Physical resources in the model have been divided into three categories:

1. Operatives, skilled and unskilled.
2. Machines.
3. Subcontractors.

Each of these categories was given a different code number in order to be able to distinguish between them during scheduling.

The utilisation factor of the resources in the model is calculated as being the ratio between the total resources employed and the total resources provided.

To be realistic, the model also addresses the problem of non-attendance of resources by using a uniformly distributed random number between 0 and 0.2 for the allowance of absenteeism within labour. This means that there is a possibility of non-attendance of 20% of the total number of labour every day as a maximum.

The hiring and firing of resources in the model take place at the end of every week if required. The decision of hiring and firing is made in accordance with the planned schedule times of these resources. The procedure is performed in such a way that the type and number of resources are associated with the section number for or from which these resources are hired or fired.

5.3. Model representation of materials

In order for scheduling to take place in the model, requirements of activities from materials should be also gratified. Materials in the model have been classified as consumable, special and re-usable. Consumable materials are used throughout the project by all the activities such as sand, cement, etc. Materials of this kind usually become part of the work they have been used to construct and therefore can be used only once.

Special materials are those that are not in common use among many activities. They are used for special kinds of activities and not for the others. An example of such materials would be bridge bearings.

Re-usable materials differ from the others in that materials of this kind can be used more than once (e.g. shuttering and scaffolding).

A different wastage factor for each material is assumed from experience and wastage is considered to occur on delivery, although in reality it is generally a function of duration and condition of storage as well as usage. This has been done to simplify the model.

The problem of orders and deliveries of materials in real life has been simulated in the model by keeping a predetermined list of order and delivery times for all the materials on site. The delivery of each kind of material then takes place automatically at the specified time.

5.4. Model representation of finance

5.4.1. Bill of quantities

The estimate prepared for any project forms an important means for financial control of that project. In order to make the simulation model behaves like a real system, the financial aspect of the project involved in this work is based on the original bill of quantities for the bridge project mentioned above. This in turn is based on CESMM (Civil Engineering Standard Method of Measurement), see Barnes [11], with some modification to the code numbers of the items. For example all the (E) items representing the different types of the excavation of foundations have been combined into one bill item (1), which represents the total amount of excavation in foundations.

A ' bill split' has also been produced; see Scott et al. [13]. This is the distribution of the bill of quantities items to the activities. For example, the activity which represents the construction of pier 1 contains 5% of bill item 4 (designed mix for ordinary concrete structures...), 50% of bill item 8 (Reinforced concrete column and piers, cross-sectional area 0.25–1.0 m^2), and 4% of bill item 14 (Reinforcement mild steel bars diameter 15mm). The bill split has many uses, including giving the facility to calculate the value of the work done. This can be done quickly at any time according to the percentages of work done on the activities.

5.4.2. Cost heads

Cost heads are assumed to be of six different kinds namely labour, plant, materials, supervision, sub-contractor and overheads.

Bill items have been split under the earlier headings according to the estimated amount of each of these cost heads involved in any bill item.

All the other information required for the calculation of the value of work and the cost is included in the model. This includes the cost of resources, materials and the hire and fire cost of each resource.

6. Experimentation and findings

Many experiments have been carried out to test the effectiveness of the monitoring systems used, in showing the effects of some factors, on the cost and progress of the project. Several factors are used, each represent a change. Among the changes introduced and imposed on the original project are, for example; increase in the costs of resources and materials with time due to different inflation rates; sudden changes to specific resources and material costs and the use of a more optimistic plan.

The method employed was to change one factor at a time and fix the others. In this way it was hoped to determine which of the monitoring systems indicates the effect of that factor. Samples of the results produced from some the experiments are discussed later.

6.1. The project prior to changes

The following sections are concerned with the discussion of the graphs, which represent the state of the project prior to any change.

Fig. 2 represents the results obtained using the leading parameter technique. It represents a typical section in the project, which uses concrete as a leading parameter. The graph shows that the concrete work in the project commences during month three in both the plan and actual and finishes at month eight and nine respectively. The graph indicates that actual cost per leading parameter was less than the planned except at month three and five. The earning values per unit of the leading parameter were almost according to plan.

Fig. 3 shows the variances of the project plotted cumulatively over the duration of the project. It can be seen that except for month four, 10 and 11, the total cost of the work done was less than the planned expenditure as indicated by the negative current variance. The graph also shows that the project has a negative performance variance between month five and nine. This means from the definition of this variance that the project is behind schedule during this time. The efficiency variance is also negative at the same time, which means that money has

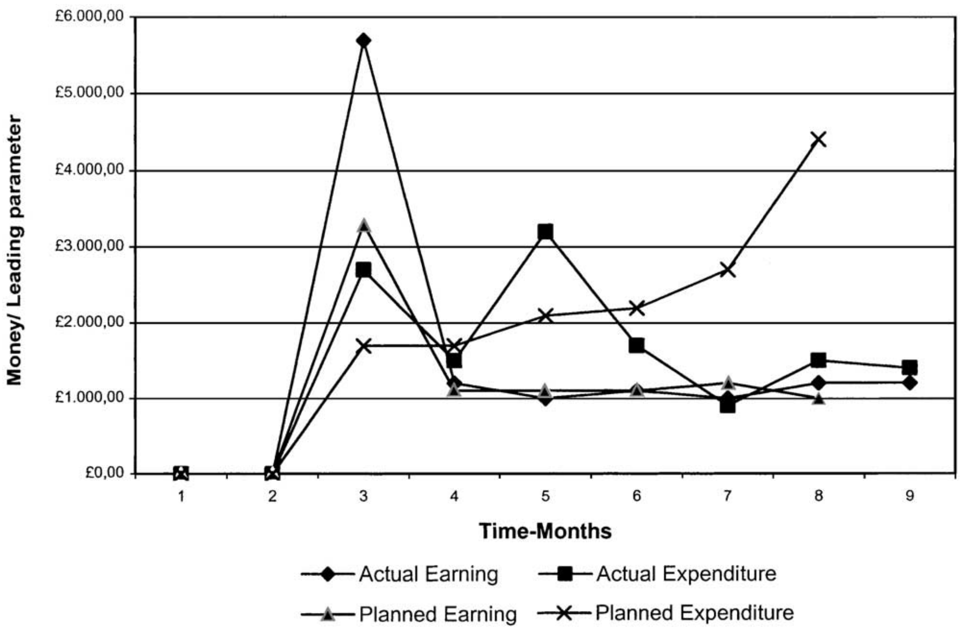

Fig. 2. Period expenditure and earning results of concrete as a leading parameter prior to any changes.

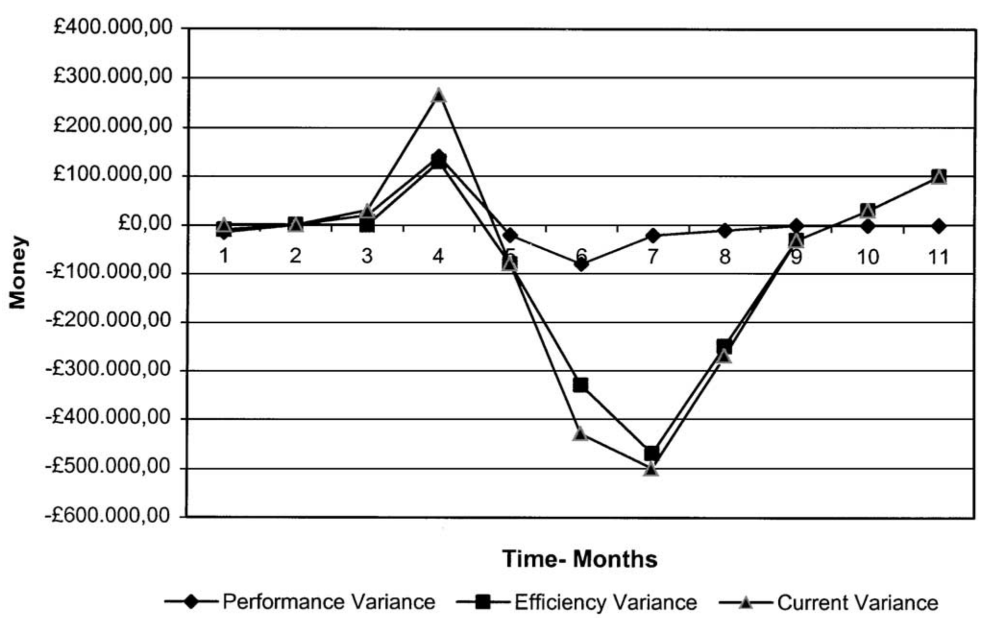

Fig. 3. Cumulative Variances of the project prior to any changes.

been saved compared to the plan. Overspending however has occurred in the other periods. The overall picture given by this graph is that the cost of the project, on average, was almost according to the planned expenditure.

The activity based ratio technique has also been used in the experimentation as shown in Fig. 4. This figure represents the cumulative efficiency of the activities and the whole project. It can be seen that the activity efficiency was better than that of the whole project. This could be caused by a number of things such as material wastage or excess overheads. It also indicates that the total project was running at an average efficiency of 95% of the plan. This is almost the same picture given by the other monitoring systems graphs.

6.2. The project after changes

Figs. 5, 6 and 7 were produced from one experiment and show for example how the various systems reflected the effect of a 54% inflation rate per year on the progress

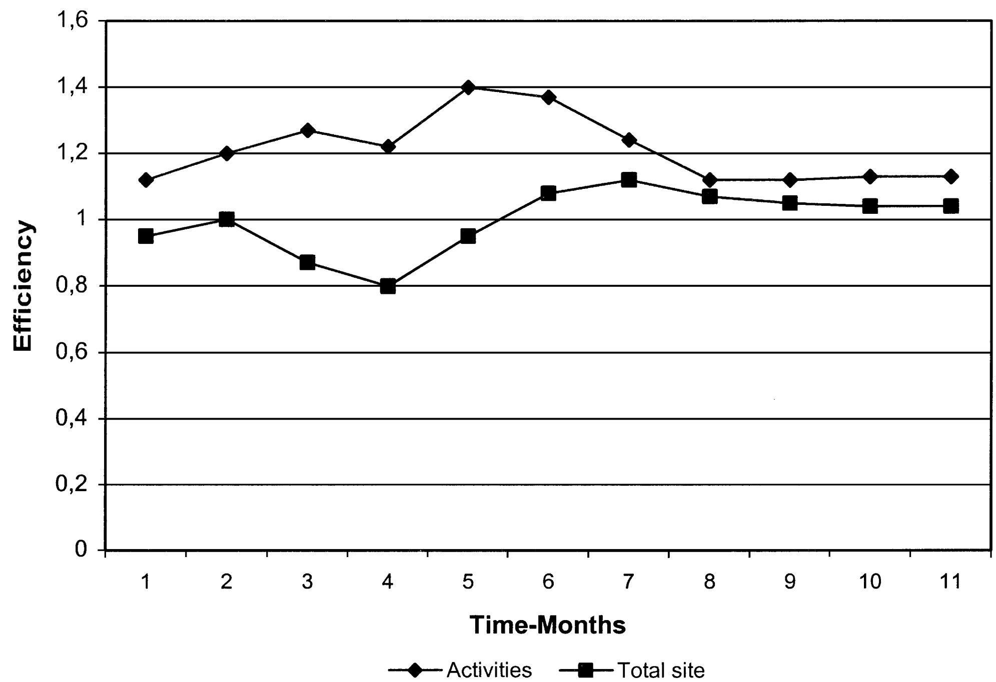

Fig. 4. Cumulative project efficiency results prior to any changes using activity based ratios.

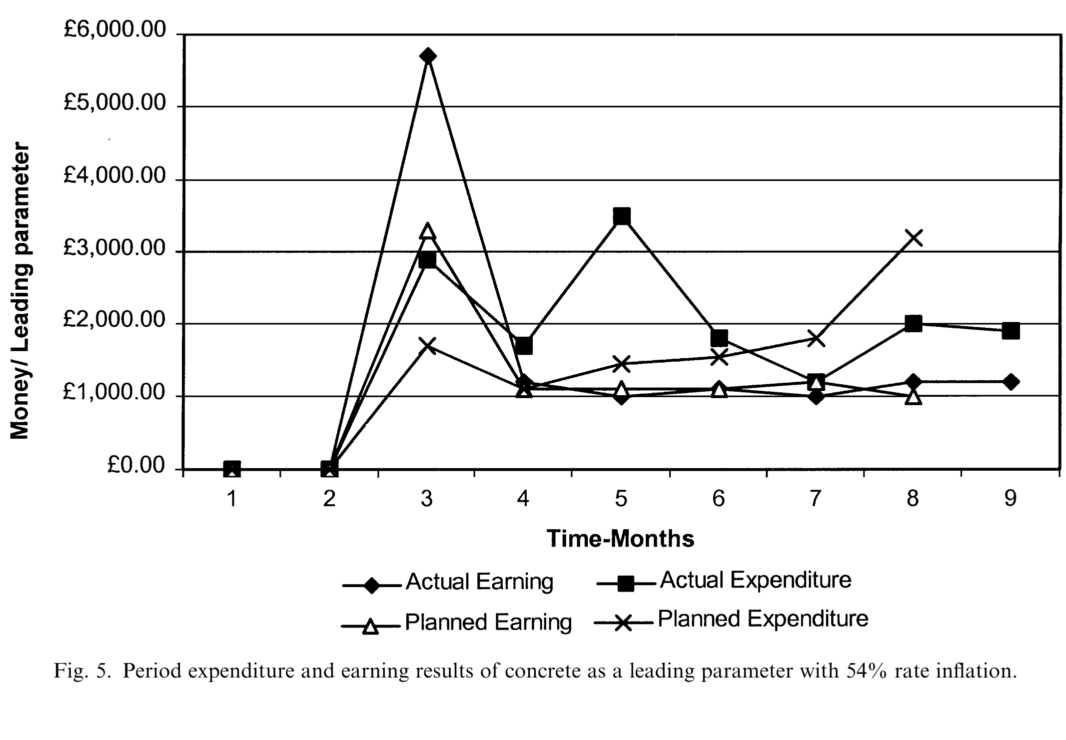

Fig. 5. Period expenditure and earning results of concrete as a leading parameter with 54% rate inflation.

and cost of the project. These results are to be compared with those of the project performance without the influence of this change as shown already in Figs. 2, 3 and 4, respectively.

Fig. 5 represents the results related to concrete as a leading parameter. The graph shows again that the actual cost per unit of concrete works was more than the planned at the time between months three and six, however, it does not show a clear indication of the effect of inflation when compared with Fig. 2.

In the case of the Variance method as shown in Fig. 6, it is indicated that the cumulative current variance in this case was very high and hence indicates clearly that the actual incurred cost of the work done to date was greater than planned. The small positive performance variance also means that the project was slightly a head of schedule. In contrast to the previous fig. this graph simply shows, at an early stage of the project, that work was not according to plan and that control action should be taken.

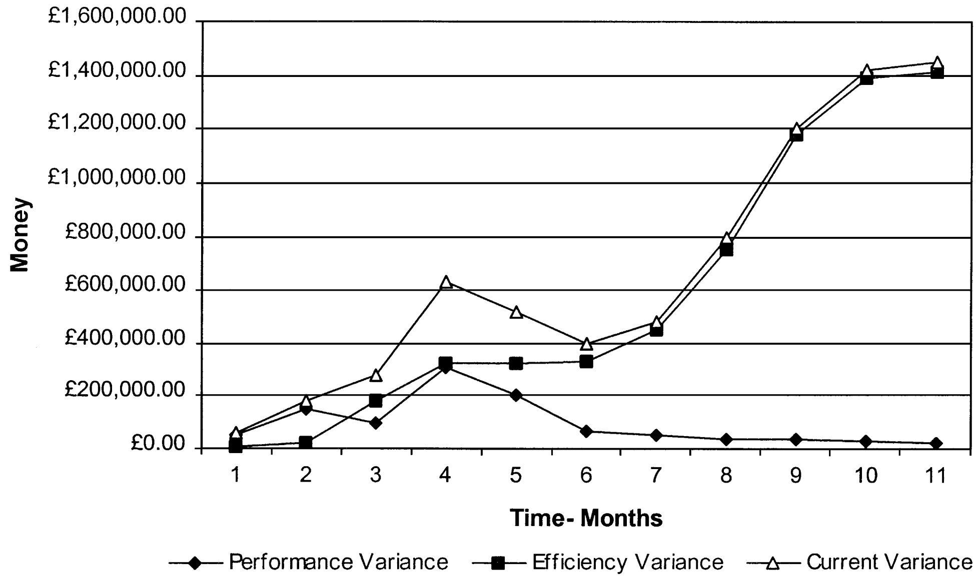

Fig. 6. Cumulative Variances of the project with 54% rate inflation.

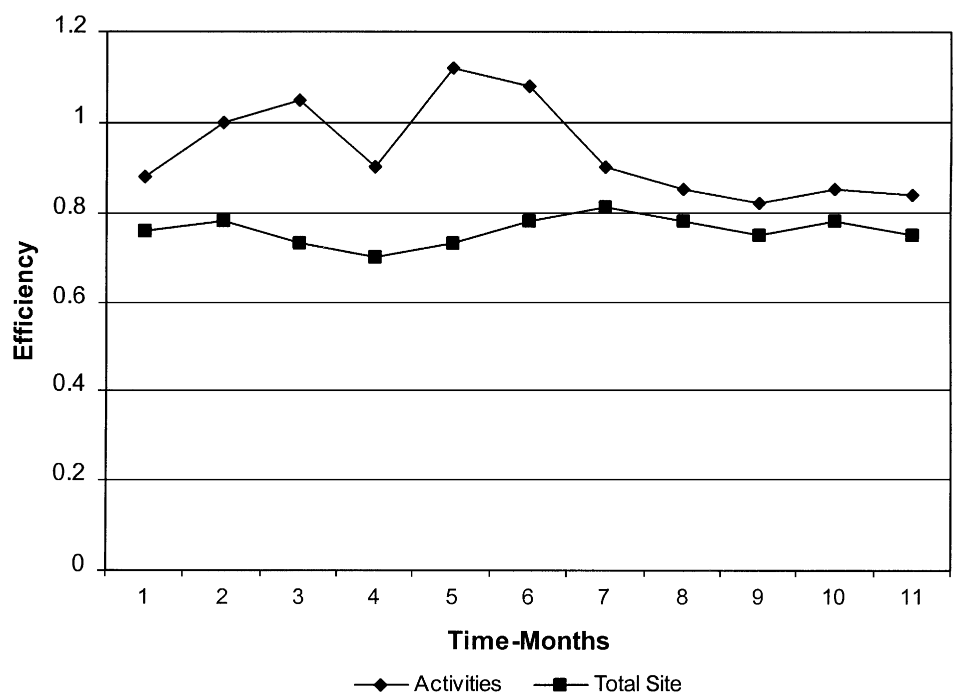

Fig. 7. Cumulative project efficiency results with 54% rate inflation using activity based ratios.

In the case of the ‘ Activity based ratios’ technique, Fig. 7 indicates that although the efficiency of the activities was almost as planned in the beginning, it was then started to diverge at month seven until the end of the project. It also clearly shows that the efficiency of the total site, on average, was only 75% of the plan compared to an average of 105% before inflation as shown in Fig. 4.

The results of the experiments indicated that the effectiveness of the monitoring systems in showing deviations of the project performance from the plan varies considerably from one system to another and that both the ‘Activity based ratios’ and the Variance systems have shown the effects of the introduced changes better than the ‘Leading parameter’ technique.

It is noticeable from all the earlier results that the ‘ Activity based ratios’ technique gives a simpler and a clearer indication of the overall progress of the work than the other two systems. In the case of Fig. 4 for example, it is indicated in a very clear way that the efficiency of the total project was not according to plan, but on average only 75% of it, and that control action should be taken.

7. Conclusions

This paper has introduced several monitoring techniques and their use for project cost control. Comparisons of these systems on a theoretical basis have indicated that different systems are suitable for different situations. ‘Activity based ratios’ technique for example is more suitable for short-term applications than ‘The Variance method’. The results of comparisons have also shown that some techniques are simpler and clearer to interpret than others. Depending on the system to be used, the amount of information required by the system and consequently its use as a communication tool have to be considered.

It can be also concluded, on the basis of the experiments carried out, that the effectiveness of the monitoring systems in showing deviations of project performance varies considerably from one system to another. Some systems are more effective in indicating the need for control action than others. The paper has indicated that the ‘Activity based ratios’ and the ‘Variances’ techniques have both shown the effect of cost factors on the system better than the ‘ Leading Parameter’ technique. It has also been found that the ‘Activity based ratio’ technique gives a simpler and a clearer indication of the overall progress of the work than the other two systems. It remains however very difficult to generalise these results on the basis of the limited results presented.

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Construction Project Risk Management in Singapore: Resources, Effectiveness, Impact, and Understanding

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Abstract

While previous studies have focused on the need for Project Risk Management (PRM), highlighting its potential benefits, resources invested in PRM have been rarely identified. This study aims to investigate the resource allocation, effectiveness, impact and understanding of construction PRM in Singapore. To achieve the objectives, a questionnaire survey was conducted with professionals and 43 complete questionnaires were returned. The results revealed that higher proportion of costs was invested in PRM than time and labor resources, and that more resources invested would not necessarily lead to a higher level of PRM effectiveness and greater assurance with the achievement of project objectives. Also, the results showed the low-level understanding of PRM in the survey firms and suggested that the overall impact of PRM on project outcomes differed according to levels of understanding. Despite the low-level understanding, all the nine PRM principles and guidelines were significantly agreed. Hence, this study provides a clear picture of PRM in the Singapore construction industry. The findings of this study can help practitioners to better implement PRM and assure the achievement of project outcomes.

Keywords: *resource, effectiveness, impact, project risk management, construction industry, singapore*

1. Introduction

Project Risk Management (PRM) is a critical component of project management as risks that are not well-managed may lead to project failures (Royer, 2000). This, in particular, is a concern to construction projects. A typical construction project may involve all forms of risks such as contractual, financial, operational, political and technical risks. The evanescent nature of the venture, the multitude of players with conflicting personalities and their different understanding of risks, make PRM a daunting task right at the onset. This is compounded by variations in the project such as harsh weather and productivity problems that make PRM a challenging process throughout its lifecycle. It is thus considered "truth" that no single project may be able to eliminate risks completely.

Mills (2001) pointed out that the construction industry had a poor reputation for managing risks, with many projects failing to meet deadlines and cost targets. The potential losses of poor PRM hence range from thousands of dollars (e.g., liquidated damages for small scale projects) to millions or billions of dollars (e.g., project failure). Typical reasons for poor PRM include but are not limited to contractors' lack of information and knowledge, insufficient resources such as money and time, and lack of expertise in risk techniques (Hlaing *et al.*, 2008). On the contrary, well-planned PRM from the initial stages of a project would allow a more credible estimate of the final project costs. Furthermore, Mills (2001) highlighted that PRM can be a form of opportunity management, arguing the earlier it is done, the more potential commercial benefits can be reaped later, which agreed with the double-edged nature of risks (Zou *et al.*, 2007), namely risks can encompass both threats and opportunities (Ward and Chapman, 2003).

While there have been extensive studies on the process of PRM and its consequences, little investigation has been conducted to assess the extent to which PRM is employed in projects, and its impact on project performance. Hence, the objectives of this study are:

(1) To explore the amount of resources invested in PRM and specific types of risk;
(2) To evaluate the effectiveness and impact of PRM on project outcomes and its association with the resource invested;
(3) To investigate the understanding of PRM and the relationship between such an understanding and the overall effectiveness and impact of PRM; and
(4) To examine the agreement to the principles and guidelines for PRM.

The results would highlight the effectiveness of PRM in

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relation to the resources allocated. Also, the recognition of the impact of PRM would assist the industry players to review their current strategy for PRM, principally in the context of Singapore.

2. Background

2.1 Benefits of Project Risk Management

Construction firms should implement PRM because construction businesses are usually plagued with complex and diverse risks (Deng and Low, 2013; Low *et al.*, 2009; Ock and Han, 2010; Zhao *et al.*, 2013) and they mainly depend on construction projects to earn revenue and profits. Previous studies indicated that PRM can bring about a number of benefits. Simister (1994) revealed that the benefits of project risk analysis and management included the formulation of more realistic plans, an increased understanding of the risks in a project, the assessment of contingencies that actually reflected the risks, the increased benefits from more rational risk taking, as well as the identification of the party best able to handle a risk. Also, Mok *et al.* (1997) pointed out that PRM allowed decision makers to confront risks in a more realistic manner and thus improved decision-making. Ali (2000) indicated that in addition to helping projects completed on time and within budget, PRM could develop different scenarios with different impacts, clarify the importance of project risks, and make management aware of possible project outcomes. Pennock and Haimes (2002) found that proper PRM can reap great benefits in terms of reducing technical and programmatic risks. In addition, Mills (2001) believed systematic risk management could produce a series of benefits, including a cost-benefit assessment of risk control actions, removal of unnecessary contingency, clear recognition and acceptance of risk at an early stage to avert risks at the minimum cost, and achievement of realistic cost estimating by itemizing and quantifying risks. Moreover, Hilson (1998) argued that PRM should become fully integrated into both the management of projects and into the organizational culture, and then projects teams can gain full benefits from PRM. Furthermore, Klemetti (2006) proposed a co-operative risk management model and indicated that construction projects can benefit from this model in the form of shorter decision-making, less transaction costs or better allocation of risks to the parties that can best handle them.

To implement PRM properly, reduce losses and obtain the potential benefits, various resources should be invested. In the long run, the benefits can far outweigh the resources invested in PRM. Thus, the resources invested can be justified by the benefits and PRM becomes convincing. However, few studies have investigated the amount of resources invested in construction PRM. Hence, this study attempts to investigate the resources distributed to PRM and the association between these resources and PRM effectiveness and impact on project outcomes.

2.2 Project Risk Management in the Singapore Construction Industry

A few studies have been conducted to investigate PRM in the Singapore construction industry. Chan and Mak (2000) found that the contractors in Singapore were reluctant to perform PRM due to the lack of a systematic method and the perception that PRM was a laborious process without substantial tangible benefits. Thus, Chan and Mak (2000) proposed a systematic PRM method for these contractors to better manage their risks and believed that the advancement in information technology would improve the efficiency in PRM and help demonstrate more benefits. Also, Ali (2000) investigated the application of PRM in preparing construction project cost estimation and capital budgeting and found that the "Estimating using Risk Analysis" method was superior over other traditional methods. Woo and Tee (2001) identified the risks relating to construction project delays in Singapore and found that delayed decisions and decisions based purely on costs made by owners were detrimental to project schedule performance. Moreover, Khan and Narasimhan (2006) focused on the risk analysis techniques and concluded that the application of the Monte-Carlo simulation in modeling project cost and schedule data can produce fairly accurate and realistic results in the Singapore construction industry. However, few studies have focused on PRM effectiveness and impact on project outcomes in the Singapore construction industry. Thus, this study attempts to evaluate the PRM effectiveness and impact, and to examine their relation to the understanding of PRM in Singapore contractors.

3. Methodology and Data Presentation

3.1 Research Design

In order to assess the resource, effectiveness and impact of PRM with regards to the construction projects in Singapore, an understanding of the current scenario and implementation status of the above is vital. A questionnaire survey was performed to study the extent to which PRM was implemented in the Singapore construction industry. In addition, professionals were interviewed to capture a comprehensive picture of the opinions and information from construction companies towards PRM. This would help ascertain solutions to effectively manage the risks identified, thereby encouraging an active risk management culture.

The professionals who participated in the survey and interviews had experience and knowledge relating to PRM. The sampling frame consisted of construction companies identified through the Contractors Registry System (CRS) at the Building and Construction Authority (BCA) website. The pilot study was conducted with four professionals to solicit comments on the readability, comprehensiveness, and accuracy of the questionnaire. Based on their comments, revisions were made to improve the readability and accuracy of the statement and footnotes were added to explain the terminologies used in the questionnaire.

3.2 Data Collection

The finalized questionnaire consisted of three sections. The first section included questions meant to profile the respondents.

Table 1. Profile of Respondents

Occupation	Years of Experience								Total	
	<5		5 to 10		11 to 15		>15			
Project Manager	-		5		5		3		13	30%
Quantity Surveyor	6		1		1		3		11	26%
Architect	-		1		5		1		7	16%
Contract Manager	1		4		1		-		6	14%
Risk Manager	1		2		3		-		6	14%
Total	8	19%	13	30%	15	35%	7	16%	43	100%

More specifically, the information about the occupation and years of working experience of the respondents was included.

The second section included several project-specific questions, which were aimed to solicit the data related to a selected project that they were involved. In this section, the data relating to the value, type and duration of projects that the respondents were engaged in were collected. Additionally, the respondents were asked to indicate the amount of cost, time and labor resources allocated for the formulation of the PRM plan and management of the risks identified. Specifically, in this study, the cost resource for PRM is the money allocated to the activities related to PRM in the project budget; the time resource for PRM is the time (hours) spent on PRM during project construction; and the labor resource for PRM is the individuals directly involved in PRM. The respondents can provide either the exact figures of project resources for PRM or the percentages represented by the resources for PRM among the total project resources. Common risks identified from the literature review and pilot study were listed and the respondents were asked to select no more than three risks that were of priority to their projects. Then, the respondents were requested to indicate the amount of resources that they allocated to manage their three prioritized risks, respectively. Also, the respondents were asked to assess the effectiveness of their PRM according to a five-point Likert scale (1 = very ineffective; 2 = ineffective; 3 = neutral; 4 = effective; and 5 = very effective). Moreover, the impacts of PRM on the project outcomes (i.e. project schedule, cost and quality) were rated according to another five-point scale (1 = very insignificant; 2 = insignificant; 3 = neutral; 4 = significant; and 5 = very significant).

The third section consisted of the questions to investigate the understanding level of PRM within the firms of the respondents in accordance with a five-point scale (1 = very low; 2 = low; 3 = middle; 4 = high; and 5 = very high). Also, nine principles and guidelines of PRM were presented in this section and the respondents were requested to rate their agreement to each one according to another five-point Likert scale (1 = strongly disagree; 2 = disagree; 3 = neutral; 4 = agree; and 5 = strongly agree).

A total of 43 completed questionnaires were returned after which the data in the responses were codified and analyzed using the Statistical Package for Social Sciences (SPSS) 17 software.

3.3 Data Presentation

The two largest groups of respondents who answered the survey were Project Managers and Quantity Surveyors, followed by Architects, Contract Managers and Risk Managers, as summarized in Table 1. 81% of the respondents had at least five years of experience in the construction industry. The wide experience range of the professional experience and expertise made the data reliable.

Table 2. Profile of Projects

Project Characteristics		N	%
Project Type	Residential Buildings	7	16%
	Institutional Buildings	11	26%
	Commercial Buildings	10	23%
	Specialized Industries	5	12%
	Infrastructure & Heavy Construction	10	23%
Project Value (Million)	<$1	3	7%
	$1 - $5	26	60%
	$5 - $10	5	12%
	$10 - $15	6	14%
	$15 - $30	0	0%
	>$30	3	7%
Project Duration (Year)	<1	3	7%
	1-3	10	23%
	3-5	30	70%

Table 2 summarizes the characteristics of projects undertaken by the respondents, with Institutional buildings at the top of the list (26%), followed by Commercial and Infrastructure/Heavy construction (23% for both). In addition, as most projects (86%) were in the range of US$1 to US$15 million, indicating that the size of the projects ranged from small to medium scale, with the exception of a few. It can also be seen that all the projects were completed within a period of five years, with the majority between three and five years (70%).

4. Data Analysis and Discussions

4.1 Project Resources Invested in Project Risk Management

Although the respondents could enter either exact figures or percentages of the project resources invested in PRM, the

Table 3. Project Resources Invested in PRM

Resource	% of Resources Invested in PRM	Response		Mean	SD
		N	%		
Cost	5%	8	19%	9.5%	3.0%
	6%	1	2%		
	7%	2	5%		
	10%	26	60%		
	15%	6	14%		
Time	3%	2	5%	7.0%	2.6%
	5%	23	53%		
	10%	18	42%		
Labor	5%	25	58%	6.6%	2.2%
	6%	4	9%		
	7%	2	5%		
	10%	12	28%		

Table 4. Types of Risks

Type	N	%
Contractual Risk	36	80%
Financial Risk	15	33%
Design Risk	20	44%
Procurement Risk	30	67%
Tender Risk	25	56%
Safety and Health Risk	30	67%
Security Risk	5	11%
Human Resource Risk	1	2%

majority of them provided percentages due to the confidential nature of the projects. Hence, the exact figures were converted to percentages to facilitate data analysis.

As shown in Table 3, the surveyed projects invested 5-15% of their costs in PRM, with the majority of projects (N = 26; 60%) having 10% of their project budget dedicated to PRM. On the average, these projects used 9.5% of their budget in PRM. In reality, as some interviewees indicated, there may be no hard-and-fast rule with regards to the amount of budget for PRM and the contextual setting would be more important in the budgeting for PRM.

In terms of time, the mean percentage dedicated to PRM was 7.0%, with 95% of the projects allocating 5% (N = 23; 53%) or 10% (N =18; 42%) of their time to PRM. Some interviewed risk managers highlighted the fact that PRM was an on-going process, and hence it was difficult to put an exact figure with regards to time. Several other professionals concurred, claiming that the time spent varied among the different construction phases. The opinions of the respondents seemed to be in tandem with the view of Flanagan and Norman (1993) that the perhaps assurance for the completion of projects was more important in construction than the amount of time spent in developing PRM strategies during various project phases.

Similar to the time invested, all the projects set aside 5-10% of their labor for PRM while the data distribution indicated that 72% of the projects utilized less than 8% of the project labor for PRM. On the average, the surveyed projects invested 6.6% of their labor in PRM.

Hence, it was found that the mean proportion of the costs invested in PRM was slightly higher than that of the time and labor invested, respectively. Although the amount of resources identified above is worth attention, a couple of interviewees stated that there might be no hard-and-fast rules for investing resources in PRM as the contextual settings of projects were more important to the resource allocation, similar to the conclusion drawn by Wang *et al.* (2004). Also, as Klemetti (2006) indicated, the "soft" method of risk management would benefit construction projects. Tang *et al.* (2006) argued that partnering could play an important role in improving PRM, and would facilitate optimum decision-making to reduce lost opportunities and dealing with project risks. Thus, it can be inferred that just investing resources in PRM would lead to only limited effectiveness of PRM.

4.2 Project Resources Invested in Specific Risks

The major risks expounded by scholars and the respondents in their projects were surveyed. As the list was not meant to be exhaustive the respondents were also encouraged to indicate otherwise. Table 4 summarizes the results.

Contractual risk exhibited the highest frequency (N = 36; 80%). Interviewees revealed that while the contractual framework posed considerable risks, it was still a good mechanism for risk allocation. This was in agreement with Hlaing *et al.* (2008) who pinpointed that flaws in contract documents weighed heavily in the perceptions of PRM of Singapore contractors. Contractual risk was closely followed by procurement risk (N = 30; 67%) and safety and health risk (N = 30; 67%). Procurement risk attracted attention because of the significant changes in construction project delivery methods, which enables clients to allocate more risks to contractors (Hlaing *et al.*, 2008). In addition, safety and health risk was another major concern for the contractors because of the statutory obligations imposed on the stakeholders to mitigate potential occupational hazards and risks. In Singapore, the Workplace Safety and Health Act 2006 has been issued to deal with the relevant safety and health issues.

Moreover, tender, terrorism, design, financial and human resource risk were also considered by the respondents. However, a project manager interviewed indicated that tender risk can overlap with contractual risk, and hence it would be sufficient that resources for the former were set aside for managing the latter. Also, financial and terrorism risks could be more or less mitigated by insuring projects while design risk may be largely left to professionals such as architects or professional engineers to deal with. Interestingly, human resource risk was given the least attention despite the argument that human resource plays a crucial role in determining the success of PRM (Edwards and Bowen, 1998). The Construction 21 (C21) study initiated by the

Table 5. Project Resources Invested in the Management of Specific Risks

Type	% of Cost Invested	Response		Mean	SD	% of Time Invested	Response		Mean	SD	% of Labor Invested	Response		Mean	SD
		N	%				N	%				N	%		
Contractual Risk (N=36)	1%	3	9%	3.8%	1.1%	2%	3	8%	3.1%	1.3%	2%	2	6%	4.2%	1.1%
	2%	12	33%			3%	18	50%			3%	9	25%		
	3%	8	22%			4%	1	3%			4%	9	25%		
	4%	4	11%			5%	13	36%			5%	13	36%		
	5%	9	25%			6%	1	3%			6%	3	8%		
Procurement Risk (N=30)	1%	9	30%	2.2%	1.0%	1%	2	7%	3.4%	1.3%	1%	4	13%	3.0%	1.3%
	2%	9	30%			2%	6	20%			2%	7	23%		
	3%	9	30%			3%	9	30%			3%	8	27%		
	4%	3	10%			4%	5	17%			4%	7	23%		
	-	-	-	-	-	5%	8	26%			5%	3	10%		
	-	-	-	-	-	-	-	-	-	-	6%	1	4%		
Safety and Health Risk (N=30)	1%	9	30%	2.1%	0.8%	1%	11	37%	1.8%	0.7%	1%	4	13%	2.7%	1.2%
	2%	9	30%			2%	15	50%			2%	11	37%		
	3%	12	40%			3%	4	13%			3%	10	33%		
	-	-	-	-	-	-	-	-	-	-	4%	2	7%		
	-	-	-	-	-	-	-	-	-	-	5%	2	7%		
	-	-	-	-	-	-	-	-	-	-	6%	1	3%		

Ministry of Manpower of Singapore had taken note of this aspect. As a result, professional development programs, improvement of curriculum, stricter codes of conduct and licensing to improve standards were introduced. In view of labor skills, similar efforts were initiated. This enrichment of human resource ensuring their self-sufficiency and quality could be a probable cause for the negligence of human resource as risk in Singapore.

Based on the top three risks indicated by the respondents, analysis on the amount of resources invested towards their management was carried out. As summarized in Table 5, on the average, projects devoted approximately 3.8%, 3.1% and 4.2% of resources in terms of cost, time, and labor, respectively, to the management of contractual risk. More specifically, 33% of the respondents spent 2% of costs on contractual risk management, 50% devoted 3% of time to managing this risk, and 36% assigned 5% of labor to dealing with this risk.

In case of procurement risk, on the average, projects set aside 2.2%, 3.4% and 3% of cost, time, and labor resources, respectively. The slightly lower figures than those for contractual risk can perhaps be explained by its close relationship with contractual risk. Contractual framework is a preferred method and an important tool for allocation of procurement risk (CIDB, 2004; Edwards and Bowen, 1998). This may cause more resource allocation to the contractual risk which in broad included some portion of procurement risk.

Safety and health risk should be emphasized because contractors had to comply with the act related to occupational hazards and risks. Hence, PRM cannot afford to overlook such an important area. However, as shown in Table 5, the proportion of the resource allocation for safety and health risk is, on average, 2.1% for cost, 1.8% for time and 2.7% for labor, which is much less an investment than the rest of the two areas. In addition, 40%, 50% and 37% of the respondents invested 3% of costs, 2% of time and 2% of labor in the management of this risk, respectively. Considering that legislations strictly require projects to mitigate potential safety and health risks, the analysis result was of interest and the possible reason may be that potential losses caused by poor management of the aforesaid risks might be greater than those of safety and health risk. However, this could seriously undermine the effectiveness of PRM in the event of accidents. Thus, the work would be forced to stop, leading to project delays, and more troubles might follow in the form of cost escalation and liquidated damages.

Another aspect of significance is the distribution of resources with the type of risk. It can be noted that higher proportion of cost and labor resources were invested in contractual risk management while higher percentage of time was spent on procurement risk management. It can therefore be inferred that resource allocation was highly dependent on the nature of risk. The greater importance attributed to contractual risk supported the higher proportion of cost and labor resources invested, thus partly confirming the result that higher percentage of costs was invested in PRM than time and labor (see Table 3).

4.3 Effectiveness and Impact of Project Risk Management

The respondents were asked to comment on the effectiveness of PRM using a five-point Likert scale (1 = very ineffective and 5 = very effective). The one-sample t-test was performed to test whether the PRM effectiveness and the impact were significant. As summarized in Table 6, the mean score of the overall effectiveness of PRM was 2.98 without significance (p-value = 0.844), suggesting that the overall effectiveness was perceived neutral. Also, the respondents rated the effectiveness in identifying and assessing risks. Although the mean score of 3.19

Table 6. Effectiveness and Impact of PRM

Code	Indicators	Response	1	2	3	4	5	Mean	SD	p-value*
OE	Overall Effectiveness	N	-	13	18	12	-	2.98	0.77	0.844
		%	-	30%	42%	28%	-			
EIAR	Effectiveness in Identifying & Assessing Risks	N	-	8	19	16	-	3.19	0.73	0.103
		%	-	19%	44%	37%	-			
OI	Overall Impact on Project Outcomes	N	1	11	20	8	3	3.02	0.91	0.868
		%	2%	26%	46%	19%	7%			
IPS	Impact on Project Schedule	N	-	11	24	8	-	2.93	0.67	0.498
		%	-	25%	56%	19%	-			
IPC	Impact on Project Cost	N	-	12	23	8	-	2.91	0.68	0.377
		%	-	28%	53%	19%	-			
IPQ	Impact on Project Quality	N	-	11	23	9	-	2.95	0.69	0.660
		%	-	26%	53%	21%	-			

*The results of the one-sample t-test (test value = 3.00, two-tailed).

Table 7. Correlation among the Indicators

Indicators	OE	EIAR	OI	IPS	IPC	IPQ	Cost	Time	Labor
OE	1.000								
EIAR	0.430*	1.000							
OI	0.441*	0.421*	1.000						
IPS	0.458*	0.562*	0.549*	1.000					
IPC	0.357*	0.131	0.194	0.402*	1.000				
IPQ	-0.002	0.112	0.191	0.096	0.294	1.000			
Cost	-0.025	-0.112	-0.057	0.174	0.060	0.105	1.000		
Time	-0.024	0.062	0.210	0.191	0.347*	0.093	0.000	1.000	
Labor	-0.384*	-0.172	-0.326*	-0.311*	-0.247	0.128	0.075	0.008	1.000

*Correlation was significant at the 0.05 level (two-tailed).

was larger than 3.00, this lacked statistical significance (p-value = 0.103). Thus, the result indicated that the respondents were neutral towards the effectiveness. However, the mean score over 3.00 could indicate that PRM was slightly effective in risk identification and assessment. This result echoed KPMG (2010), which claimed that PRM was effective at least in the areas of risk identification and assessment.

Furthermore, the impacts of PRM on project outcomes were gauged according to another five-point scale (1 = very insignificant and 5 = very significant). In terms of the overall impact, the mean score was 3.02 with the p-value of 0.868, indicating that the respondents were neutral towards the question and that PRM was not almighty to affect the construction project outcome significantly. This was also supported by the results from the subsequent survey questions, which investigated the impact of PRM on project schedule, cost and quality. Project schedule, cost and quality are recognized as the most common project objectives, which can be associated with project performance indicators (Ling *et al.*, 2009). The mean scores were 2.93, 2.91 and 2.95, respectively. The one-sample t-test result indicated they were not significantly different from 3.00 (neutral). Thus, the impact of PRM on project schedule, cost, and quality was also neutral.

The Pearson correlation was performed to investigate the association among the six indicators relating to the effectiveness and impact of PRM (see Table 7). The results showed that overall effectiveness of PRM was positively associated with the overall impact on project outcomes (r = 0.441). This was probably because the impact of risk managemet on project outcomes could be considered as an element of PRM effectiveness. Similiarly, the overall effectiveness was positively associated with the effectiveness in identifying and assessing risks (r = 0.430) because risk identification and assessment are elements of PRM. These two correlations can explain the positive association bewteen the overall impact and the effectiveness in risk identification and assessment (r = 0.421). In addition, the impact of PRM on project schedule was positively correlated with the overall effectiveness (r = 0.458), the overall impact (r = 0.549) and the effectiveness in identifying and assessing risks (r = 0.562), respectively. However, the impact on project costs was only positively associated with the overall effectiveness (r = 0.357) while the impact on project quality was not correlated with the effectivess and overall impact of PRM. Furthermore, the impact on project costs was positively correlated with that on project schedule (r = 0.402), while the impact on project quality was not associated with that on project schedule and costs.

Also, the Pearson correlation was used to examine the association beween the resources invested in PRM and the six indicators relating to the effectiveness and impact of PRM (see Table 7). It was found that the time invested was only positively associated with the impact on project costs (r = 0.347). This implied that the more time spent on PRM was likely to lead to the better assurance of the project cost objective. In addition, the labor invested for PRM was negatively assciated with the overall effectiveness (r = -0.384), overall impact (r = -0.326) and impact on project schedule (r = -0.311), respectively. The results suggested that the higher labor invested would result in the lower effectiveness and impact of PRM. Moreover, the costs invested were not significantly associated with any indicator relating to the effectiveness and impact of PRM, indicating that high costs allocated to PRM would not necessarily bring about effectiveness and impact of PRM. This was consistent with the findings of some previous studies. Rahman and Kumaraswamy (2002) believed that the optimal PRM should minimize the total cost of risk to a project and allow all the project parties to jointly manage risks. Kutsch and Hall (2010) indicated that social and cognitive factors, such as the deliberate ignorance of risk-related information, could constrain the effectiveness of project risk manageemnt. Klemetti (2006) also suggeted that the relationships among the project players would influence the effectiveness of PRM. Furthermore, the three types of resources (i.e. costs, time and labor) invested in PRM were not associated with each other as the three correlation coefficients were very close to 0.000, which confirmed the opinions of some interviewees that the contextual settings of projects can significantly affect the resource allocation for PRM.

4.4 Understanding of Project Risk Management

The understanding level of PRM within the firms of the respondents was evaluated according to with a five-point scale (1 = very low and 5 = very high). The mean score of the understanding of PRM within the company of the respondents was 2.44 (see Table 8). The one-sample t-test result suggested that the understanding of PRM was significantly low (p-value = 0.000). As the interviewees reported, the poor understanding of PRM was mainly due to the insufficient knowledge, apathetic attitude and inadequate time for PRM implementation. This seemed to coincide with Hlaing *et al.* (2008), who found that the lack of time was ranked as the first barrier to PRM implementation in the Singapore construction industry. In addition, Ahmed and Azhar (2004) observed a similar lack of time trend in the Florida construction industry. Furthermore, Uher and Toakley (1999) found that the lack of knowledge and inadequate skill were the two most important obstacles to applying PRM to work processes. This signified the reason for neutrality in the assessment of effectiveness of PRM. A positive impact might not be experienced unless the PRM process is applied in a comprehensive manner to the project as a whole.

As the firms with higher understanding level of PRM are likely to have the PRM programs with higher overall effectiveness and impact on project outcomes, two hypotheses can be drawn: H_1: The effectiveness of PRM differs according to the different levels of understanding of PRM; and H_2: The overall impact of PRM on project outcomes differs according to the levels of understanding of PRM.

The one-way Analysis of Variance (ANOVA) was conducted to test the hypotheses at the 0.10 significance level (see Table 9). The F value of 1.666 with the p-value of 0.178 indicated that there were not significant differences in the overall effectiveness of PRM among the firms with different levels of understanding of PRM. Thus, H_1 had to be rejected. In addition, the F value of 3.094 with the p-value of 0.027 implied significant differences in the overall impact of PRM on project outcomes among the firms with different levels of understanding of PRM. Thus, H_2 could be accepted. The Tukey test was used as the past hoc test to identify the understanding levels between which the PRM impact on project outcomes significantly differed. Through the multiple comparison shown in Table 9, the Tukey test results suggested that there were significant differences in the overall impact of PRM on project outcomes between the companies with level 1 and level 5 (p-value = 0.011), level 2 and level 5 (0.072), and level 3 and level 5 (p-value = 0.047), respectively. Hence, the firms with very high levels of understanding of PRM could implement PRM with significantly more impact on project outcomes than those with middle, low and very low levels of understanding. In other words, the firms that can better understand PRM would benefit more from PRM.

Table 8. Understanding of PRM

Score	N	%	Mean	SD	p-value
1	12	28	2.44	1.27	0.007*
2	12	28			
3	12	28			
4	2	5			
5	5	11			

*The one-sample t-test result was significant at the 0.05 significance level (two-tailed).

Table 9. Effectiveness and Impact of PRM by Understanding

Indicators	One-way ANOVA		Post hoc test (Tukey)	
	F	p-value	Comparison	p-value
Overall effectiveness	1.666	0.178	No significant differences	
Overall Impact on Project Outcomes	3.094	0.027*	Level 1 and 2	0.863
			Level 1 and 3	0.947
			Level 1 and 4	0.984
			Level 1 and 5	0.011**
			Level 2 and 3	0.999
			Level 2 and 4	1.000
			Level 2 and 5	0.072**
			Level 3 and 4	1.000
			Level 3 and 5	0.047**
			Level 4 and 5	0.434

*The ANOVA result was significant at the 0.10 significance level (two-tailed).
**The post hoc test results were significant at the 0.10 significance level (two-tailed).

Table 10. Level of Agreement on PRM Principles and Guidelines

Statement	Mean	Rank	p-value
Training and education is important for construction professionals to deal with risks effectively.	3.70	7	0.000*
There is no one-size-fit-all risk management program for construction projects.	4.23	1	0.000*
Construction professionals and companies should continuously maintain a health record of risk management data.	3.86	3	0.000*
Technology, especially Information Technology, is important for companies to adopt effective risk management in international projects.	3.51	9	0.000*
Involvement of employees (not only limited to risk management teams) is essential for effective risk management in projects.	3.77	5	0.000*
Forming collaborative partnerships with groups such as subcontractors is important for risk management.	3.58	8	0.000*
Risks and opportunities are two-sides of the same coin.	3.79	4	0.000*
Assessment of risks should be done systematically based on facts and figures, with as little human subjectivity as possible.	3.72	6	0.000*
Risk management should be able to interoperate with other management theories and systems such as Total Quality Management.	4.07	2	0.000*

*The one-sample t-test (test value = 3.00) result was significant at the 0.05 significance level (two-tailed).

4.5 Risk Management Consultancy Firms vs. In-House Experts

Respondents were enquired if they were aware of the existence of risk consultancy firms that could provide training for construction-related risks. The result indicated that 86% of them were unaware while the remaining 14% were unsurprisingly, risk managers themselves. This could be attributed to the following two scenarios: (1) there were too few risk training firms; or (2) PRM was not considered very important. If it was the latter, it would explain the reason for qualitative or expert judgment-types of non-quantitative analysis techniques that have been predominantly used (Thevendran and Mawdesley, 2004; Wiguna and Scott, 2006). These techniques do not require complicated software but rely primarily on human experience, which is a more commercially 'viable' option since it requires less resources (Akintoye and MacLeod, 1997). Since PRM is considered unimportant in the opinions of the respondents, it also explained the rationale behind the tendency towards neutrality as to whether PRM is crucial for the achieving of the corporate objectives.

Closely related to the awareness of risk training firms, 77% of the professionals replied that their company did not have in-house construction risk experts. Supposing that indeed there was a low awareness with regards to risk training firms, then the high response rating for 'no in-house risk experts' should not be surprising since there might not be any relevant training for professionals. The low awareness and lack of PRM expertise were a concern of Edwards and Bowen (1998), who argued that PRM techniques would only offer advantages if the project partakers were knowledgeable and proficient in using them. Thus, it would appear that the quality rather than quantity of human resource for PRM would be able to explain the effectiveness level of PRM. However, this human oriented aspect associated with PRM has rarely been focused on.

4.6 Principles and Guidelines for Project Risk Management Practices

The last question of the survey required respondents to indicate their level of agreement with certain principles and guidelines of PRM (1 = strongly disagree and 5 = strongly agree). The one-sample t-test results suggested that all the nine principles and guidelines were significantly agreed by the respondents (p-value = 0.000). As summarized in Table 10, the statement "there is no one-size-fit-all risk management program for construction projects (mean = 4.23)" got the highest level of agreement. This result ecohed the findings of Wang *et al.* (2004). Construction projects are one-off endeavors with unique features such as long period, complicated processes, abominable environment, financial intensity and dynamic organization structures (Zou *et al.*, 2007). Thus, each project tends to involve a unique environment and the PRM appropriate for one project may be inappropriate for another.

The statement with the second highest level of agreement was "risk management should be able to interoperate with other management theories and systems such as Total Quality Management" (mean = 4.07), suggesting that the respondents agreed that PRM should be incorporated into other management processes. This was consistent with the fundamental concept of Enterprise Risk Management (ERM) that risk management should be fully integrated into the business and management processes of an enterprise (Chitakornkijsil, 2010; Sharman, 2002). In addition, such a high level of agreement indicated that ERM would be implemented in the construction industry, which confirmed the forecast of Adibi (2007) that ERM would grow in construction firms.

Another mostly agreed principle was "construction professionals and companies should continuously maintain a healthy record of risk management data" (mean = 3.86), indicating that the respondents agreed that PRM data should be recorded. This was consistent with the ISO31000:2009 (ISO, 2009), which recommended that the risk management process should be recorded to enable risk management activities to be traceable, thereby providing the foundation for continuous improvement in the overall process.

Althought the statement realitng to the infromation technology was ranked the bottom, it still got a significant level of agreement. Information technology should play a key role in enabling information flow across a project and an enterprise (Dafikpaku, 2011). In most cases, inforamtion technology is not considered as a single source for guaranting successful PRM implementation. Instead, it would function as a tool to increase synergy among the rest of the principles and guidelines.

5. Conclusions

This study explores the amount of resources invested in PRM and specific types of risk, evaluates the effectiveness and impact of PRM on project outcomes and its association with the resource invested, investigates the understanding of PRM and the relationship between such an understanding and the overall effectiveness and impact of PRM, and examines the agreement to the principles and guidelines for PRM. To achieve the objectives, a questionnaire survey was conducted and 43 complete questionnaires were returned. The analysis results implied that most projects set aside a significant portion of project resources for PRM and that higher proportion of costs was invested in PRM than that of time and labor resources, respectively. Also, the results indicated that higher proportion of cost and labor resources were invested in contractual risk management while higher percentage of time was spent on procurement risk management. Thus, the allocation of resources towards depends on the nature of risk. In addition, despite the resources invested, both the overall effectiveness of PRM and the effectiveness of risk identification and assessment were perceived at the neutral level. Similarly, the overall impact of PRM and the impact on three project objectives, i.e. schedule, costs and quality were also neutral. Moreover, the results of the Pearson correlation implied the positve association between the time spent and the impact on project costs and the negative associations between the labor invested and the overall effectiveness, overall impact and impact on project schedule, respectively. However, the costs invested were found not associated with the indicators relating to the effectiveness and impact of PRM. Thus, more resources invested would not necessarily lead to a higher level of PRM effectiveness and greater assurance with the achievement of project objectives. Furthermore, the analysis results indicated the low-level understanding of PRM in Singapore contractors and suggested that the overall impact of PRM on project outcomes differed according to the levels of understanding. Finally, all the nine principles and guidelines presented in the questionnaire survey were significantly agreed, indicating they could be used to guide PRM practices in construciton projects in Singapore.

Although the objectives of this study were achieved, there were some limitations to the conclusions drawn from the results. First, the amount of the resources for PRM and the effectiveness and impact of PRM was estimated based on their experience and subjective judgment because there would not be clear boundaries among the time, cost and labor resources invested and PRM could be integrated into other management and business processes in most cases. As most assessment relating to PRM on experience and subjective judgment (Raz and Michael, 2001; Wiguna and Scott, 2006), the imprecision and subjectivity could be seen as common problems. Second, as the statistical tests were performed with a small sample, cautions should be warranted when the results are interpreted and generalized. Lastly, in some cases, the impact of PRM on project outcomes may be intangible as PRM is conducted to guarantee the achievement of project objectives. This could disturb the perceptions of the respondents on the impact of PRM on project outcomes.

This study provides the industry practitioners with the benchmarks of resource allocation for PRM, predominantly for small-to-medium sized projects. Future studies are recommended to investigate the resource invested in PRM in large-scale projects. Also, as the contextual settings of projects were more influential for resource allocation, it would be interesting to explore how some specific projects invest resources in PRM using in-depth case studies.

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Chinese Traditional Management Philosophy and Project Risk Management

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Viewpoint

CHINESE TAKE PROJECT RISK MANAGEMENT AS THE KEY OF A PROJECT SUCCESS. THE MAIN REASON IS THE INFLUENCE OF THE TRADITION PHILOSOPHY AND CULTURAL OF CHINESE. There are many historical Chinese books deal with the law of changes for risk management. The most important book is named "*Book of Changes*" that influenced Chinese management philosophy and methodology more than 6000 years. There are two main cultural schools of Chinese originated from this book. All these make Chinese believe that project change and risk management are the most important thing in project management because all certain things have fixed results but all uncertain things have different results depended on people management.

Keywords

Chinese philosophy,
Change management,
Project risk management

INTRODUCTION

Project risk management is one knowledge area in all European and American project management styles. There is the project risk management knowledge area in A Guide of Project Management Body of Knowledge (PMBOK)[1] by Project Management Institute(PMI). And there exists the same thing in IPMA Competence Baseline (ICB)[2] of International Project Management Association (IPMA).

But Chinese style of project risk management are different in attitude, principle and methods to project risk management because of the influences and effects of traditional Chinese cultural and management philosophy. The most influence comes from a book named *Book of Changes*[3] originated more than 6000 years ago. And there are two main schools of Chinese cultural, the Taoism and Confucian who also influence the Chinese style of project risk management. Both of them started more than 2700 years ago and all originated from different editions of the *Book of Change*.

The influence of the observation by ancient Chinese

The *Book of Changes* is originated from the observations of ancient Chinese about all changes in the world. First of all, they found the sky changes since the sun is on during the day time and the moon is on during the night time. Then they found the earth changes because mountains raised in somewhere and rivers cut down in somewhere. They also found human being changes as some of them become men and others become women. And they found even animals and plants changes as some of them become males and others become females.

At last, they made the conclusion that all these changes and all changes are cause by two original powers or elements, Yin (with the abstract like ▬ ▬) and Yang (with the abstract like ▬▬▬). They are the unity of two opposites that makes the world change and develop. Therefore, they got the attitude that change is the only things people need to manage because people can decrease loses and increase benefits through the changes control. As a matter of fact, this is a kind of attitude about risk management as well as project risk management.

One ancestor or god of Chinese named *Fu Xi* (BC3272-3157)[4] founded or invented the Eight Diagrams (eight combinations Yin and Yang) as the eight drivers that cause all changes. From then, Chinese use the eight diagrams to identify and control all changes of all things. They apply that in the agricultural industry and they have Spring Planting, Summer Growing, Autumn Harvest and Winter Storage. And they apply these in Chinese medicine to dell the illness like Yang is too strong and Yin is too wake or in contrast. All these are illustrated in the figure 1 as follows.

The influence of the *Book of Change*

Then anther ancestor king of Chinese named Yan Di (BC3103-2986)[5] founded or invented the first edition of the Book of Changes that including 64 doubled diagrams that combined two single Fu Xi's Eight Diagrams. That Book of Changes is named as Lian Shan Yi because the first combination in it is about the changes of mountains. That shows Yan Di and his people thinks mountain is the center of the world and everything in the world changes caused by the change of the mountain. From then, Chinese use that Book of Changes for managing changes and risks. For example, they apply these principle and method in Chinese traditional Feng Shui for construction project management, and these started to forecast crisis or emergency by observation of changes. In fact, that Book of Changes is the first book about change and risk management in Chinese history and that tells how everything changes, how to deal with all these changes, and how to make good use of all these changes.

About 300 years later, one more ancestor king of Chinese named Huang Di (BC2697-2494)[6] invented or edited the second edition of the Book of Changes. This Book of Changes is named as Gui Cang Yi. The main different of this edition form Lian Shan Yi is that the first combination is about changes of the earth, but not mountains. That shows Huang Di and his people believes that the earth is the center of the world and everything in the world changes caused by the change of the earth. That is a great progress in the outlook or attitude of Chinese about the world. Huang Di has written another book named Huang Di Nei Jing[7] that is the origination of Chinese medicine. From that time, Chinese start use the change of the 4 seasons of the sky and the 24 solar periods of the earth for agricultural and other things. In fact, Chinese start to make good use of changes management to get wealthy and healthy and to do things in accordance with the law of changes about the earth from that time and that make Chinese own some special nature in change and risk management.

About another 1400 years later, another ancestor king of Chinese named Zhou Wen Wang (BC1152-1056)[8] edited

1 The standard committee of PMI, A Guide of Project Management Body of Knowledge, 5th edition, PMI, 2012.

2 International Project Management Association, IPMA Competence Baseline, 3rd edition, IPMA, 2013.

3 Sun, Honggang, Book of Change and Strategies, New World Press, Beijing, 2010.

4 Du Songqi, Research on Fu Xi Cultural, China Social Science Press, 2013.

5 Lei, Shaosheng, Yan Di: Thousands Years History Earlier than BC, HuBei People Press, 2011.

6 Liu Mingwu, Cultural of Huang Di and Cultural of Emperor, Shenzhen, Sea and Sky Publishing Co. 2010.

7 Yao Chunpeng edited and noted, Huang Di Nei Jing Beijing, Chinese Press, 2010.

8 Yang Li, Zhou Wen Wang, Beijing, China Chinese Federation, 2014.

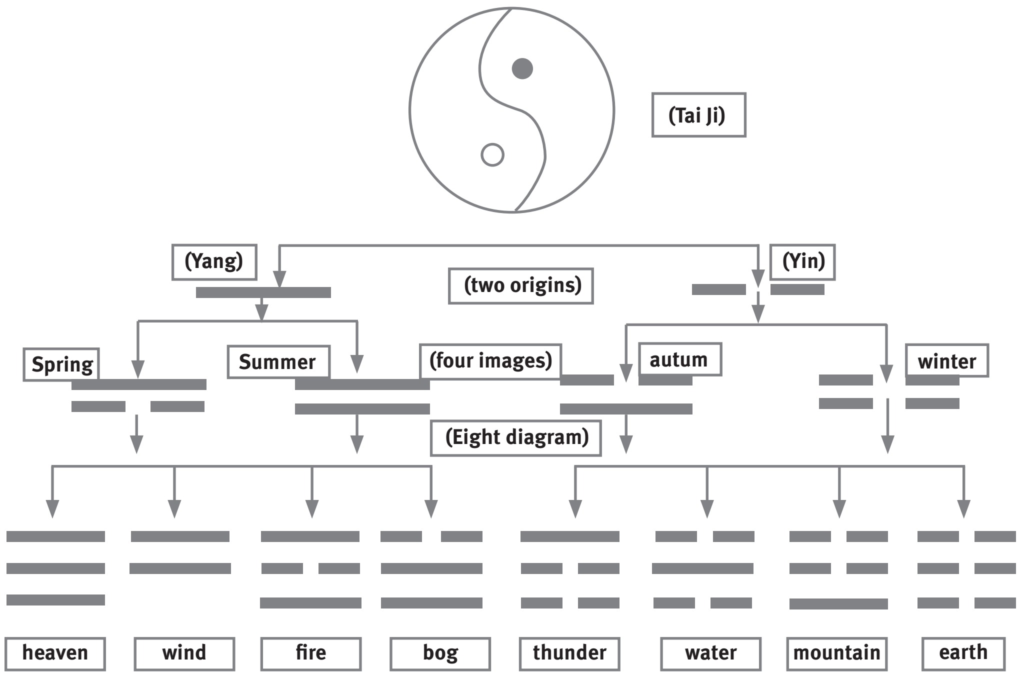

Figure 1.
the Eight Diagrams System of Fu Xi

or invented the third edition of the Book of Changes. This Book of Changes is named as Zhou Yi. The main different of former two editions is that the first combination of this edition is about changes of the heaven. That shows Zhou Wen Wang and his people believes that the heaven is the center of the world and everything changes in accordance with the change of the heaven. It is an of big other great progress in the outlook or attitude of Chinese about the world. Zhou Wen Wang and his successors use these theory in their governance of the country and that made Zhou Dynasty is the only dynasty that lasts for more than 800 years. And that also affects China to maintain as on country for more than 5000 years. Chinese start to make good use of changes and risk management in both the nature world and in the human society and society. In fact, all Chinese cultural and management philosophy, even nowadays, are based on these three editions of *Book of Change*.

The influence of Daoism

About another 500 years later in Dong Zhou Dynasty (BC770 to BC221), China is in the time of hundred schools of thoughts. All these schools applied the theory of the Book of Change into different aspects or areas. And two main schools of them remained till now is the Daoism and Confucian. They form the core ideas, attitudes and contents of Chinese cultural and management philosophy focused on the change and risk management for productivities, societies and countries.

The founder of Daoism school is Lao Zi (BC570-BC470)[9]. His book named Dao De Jing has a great influence on Chinese cultural about changes and risks management. All principles of the Gui Cang Yi has explained in this book and all the methods of how to deal with changes and risk management is discussed in this book. In fact, this book only contains 4800 Chinese characters, but it last about 2700 years, and it is introduced into western world more than 400 years and has an influence worldwide. The main ideas in the thesis statement of that book is as follows.

- When people can tell the law of something (e.g. project), that is not always the law of that thing because that thing can change along with the time.
- People have no information of a new thing (e.g. project) at the beginning and they will have complete information at the end of that thing.
- Therefore, people need to forecast or foretell the change of that thing (e.g. project) without prejudice, and do feasibility study to find out if their goal can come true.
- A thing (e.g. project) changes again and again. People should have right attitude and methods to deal with all changes and to find the right way to do things.
- All these ideas can be illustrated in the figure 2. It shows that there always exist some information gap at the beginning of a project. Especially, there is no any information about the new project. There may be some historical similar project information but not the new project's information. And later on, people get some information of the new project planning and design. The new project's information gap is made up step by step

9 Lao Zi, edited and noted by Qiu Ye, Dao De Jing, Shanghai, Golden Shield Publishing Co., 2013.

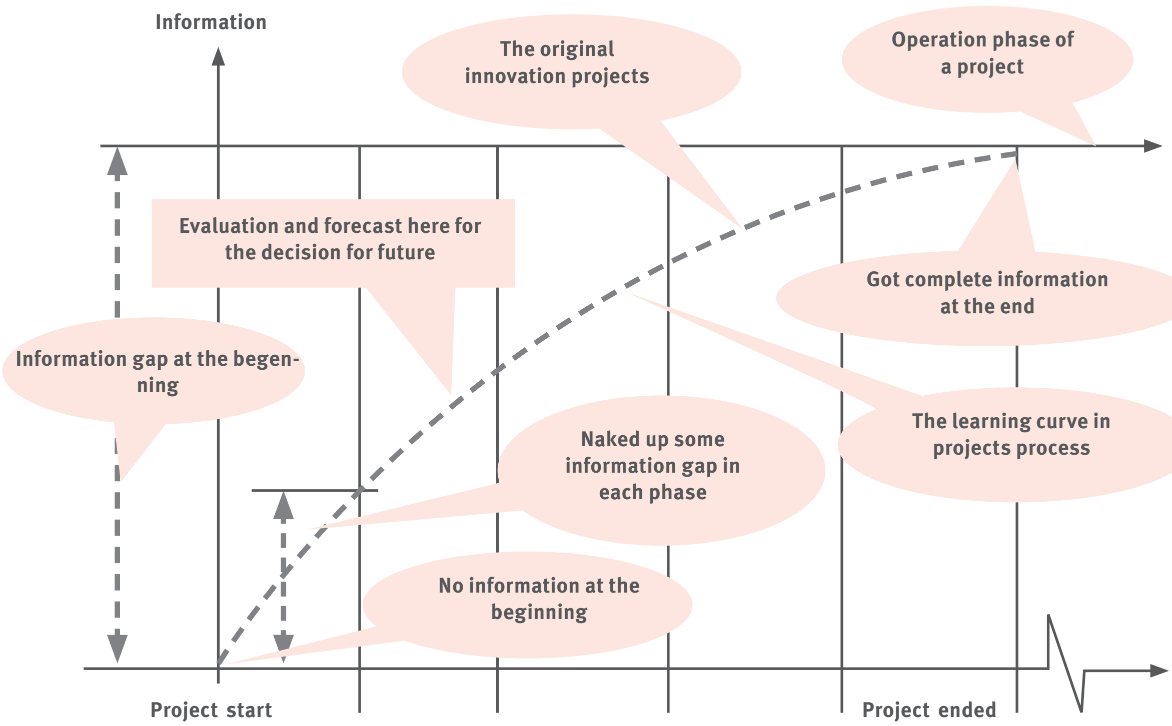

Figure 2. **The illustration of the ideas in the book of Dao De Jing**

when people get more information along with the project execution. At last, people get the complete information of the project and make up the information gap completely. Therefore, the whole project process is a learning process and that forms the learning curve that is shown by the figure 2.

The influence of Confucian

The founder of Confucian school is Confucius (BC551-BC479)[10]. His book of Yi Zhuan has a greater influence on Chinese cultural, governance and management. All principles of the Zhou Yi has explained in this book and the methodology for dealing with changes is discussed in that book from the point of view how to make good use of changes to govern the family, the country and the world. As a matter of fact, this book is not only last about 2700 years but also introduced and influenced all eastern and western countries for many years. The main ideas in this book is as follows.

- Zhou Yi is the book about the law of the whole world and the principles in Zhou Yi is exactly the explanation of the law of nature about changes of the world.
- Zhou Yi comes from people's observation of the sky and the earth. Therefore, it tells the truth of the world for people to deal with the change of the world.
- People will not be against the law of nature if they know the law and people will be success if they do things (e.g. projects) in accordance with the law.
- The unity of opposites of Yin and Yang is the law of nature. All successes come from obey this law of nature. Manager or governor must know this law of nature.
- Change means something is new to the world. Therefore, innovation day by day is the sublime virtue to a manager or governor, and getting their people richer and richer is the most important thing that managers/governors should do.

In summary, the book of Yi Zhuan is also a book for change and risk management. But it emphasize on the harmonious or unity of opposites of Yin and Yang in changes and change management. Confucian believes that everything is changing and these changes cause different results of things. When people have some information about a thing that is an independent innovation project and when people have no information about a thing that is an original innovation project, all these two kind things or projects need the change or risk management. The figure 3 can illustrate these two kind situations of changes

10 Yan Tao, Confucius and Confucian, Shanghai, The Commercial Press, 2000.

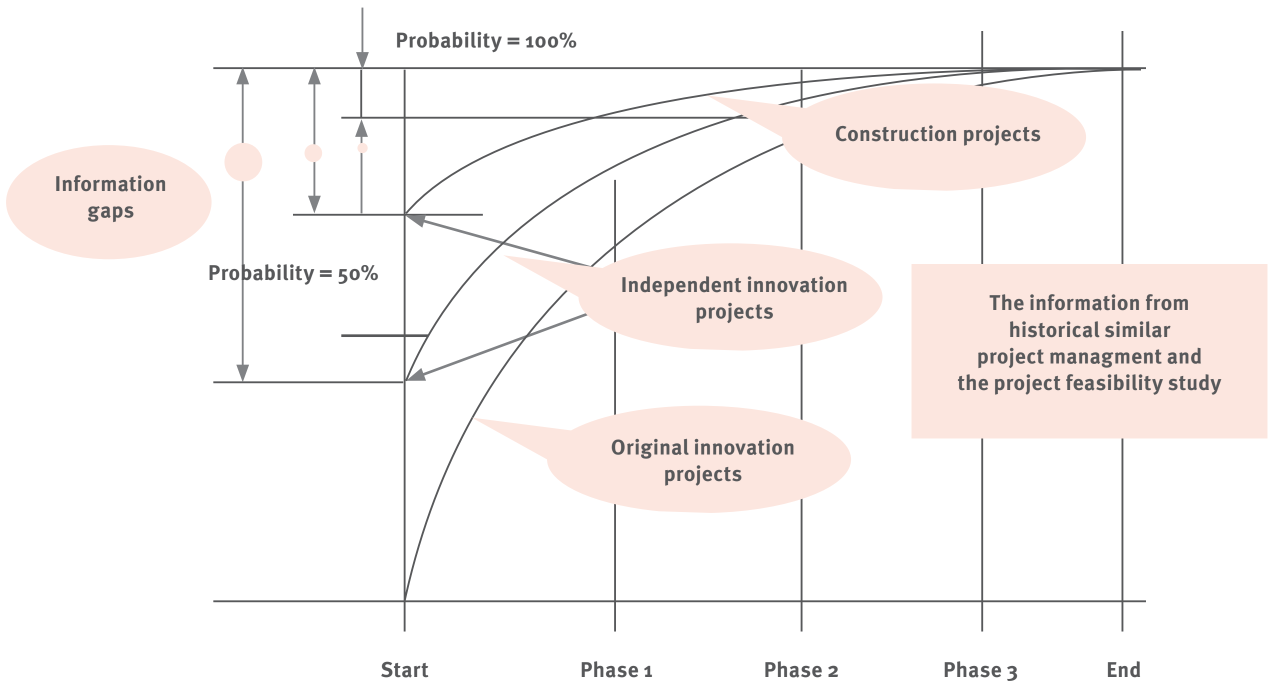

Figure 3: **The illustration of information gaps for different projects**

or risks. The figure 3 shows that there is no information for original innovation projects at the beginning because people have not done this kind of things of projects and there is no any historical similar project information to refer to and that is why this kind of thing or project is called original innovation project. The figure 3 also shows that there is some information for independent innovation projects at the beginning because there are some historical similar projects information people can refer to for the new independent innovation projects. At the end of any kinds of projects (including construction projects), people get the complete information of a project because that project is ended and will never change again.

The Chinese attitudes and ideas of project risks management

In summary, the main difference between Daoism and Confucian school is that Daoism focus on the law of nature about changes or risks and Confucian emphasize make good use of the law of nature about changes or risk management. Chinese use the theories and methods of Daoism to find the law of change or risks in what they are doing and use the theories and methods of Confucian to find the way for risk management for what they will do in the near future. That is why these two Chinese cultural and management schools can last 2700 years together because they are just like Yin and Yang that are unity of opposites. The mixture of these two theories or thoughts consists the Chinese cultural and management philosophy.

According to Chinese cultural and management philosophy, the main work in project management is the management because project is uncertain. Chinese think project risks is the possibility of loss / earning for project stakeholders that is caused by changes of the project conditions and environments or even the change of the project stakeholder's mind.[11] This can be expressed by the formula language as follows:

$$R = P \times (L/E) \qquad (1)$$

In the formula, R means a project risk, P means the probability of a project risk, L means the loss that may be caused by the project risk, E means the earning that may be caused by the project risk. This formula tells the truth that project risks not only can result in losses but also can bring some earnings.

Chinese think project risks management contains three kinds of project management works: to get more information and better cognation about the project, project conditions and environments, to decrease the loss caused by project risks, and to increase the earning raised by project risks[12]. This can be expressed by the formula language as follows:

$$PRM = P\uparrow \times (L\downarrow / E\uparrow) \qquad (2)$$

In this formula, PRM means project risk management, $P\uparrow$ means increasing project, information in order to reduce the uncertainties of the project, $L\downarrow$ means decreasing the losses caused

11 Qi Anbang, Project Risk Management, Tianjin, Nankai University press, 2007.

12 Qi Anbang, Project Management, Beijing, China Science Press, 2013.

by project risks E ↑, means increasing the earnings through project risk management. This formula tells the truth that project risk management not only can decreasing losses but also can increasing earnings.

In fact, there exists some difference in the idea, attitude and methods towards risks and risk management between Chinese and western. For example, in financing and insurance industry defined the risk as the probability of loss (R = P x L). They persuade people to buy their insurance products in order to avoid the loss caused by risks. As a matter of fact, project risk and risk management should be defined as formula 1 and formula 2.

3. SCOPE OF WORKS

1.1 Location of Works

The works to be executed are located**: Guava Road, Point Fortin.**

1.2 General Description

The respondent shall be solely responsible for the works as described herein for the construction of five offices, one conference room, one storage room and one kitchen all on the 2nd Floor.

The scope of works for corrective measures implementation shall include **but not limited to** the following as described in the specific description:

1.3 Specific Description

The respondent shall be responsible for:

1.3.1 Five offices

- Following as per drawings the construction of the rooms using gypsum and glass. Painting of the whole works to prepare and apply one coat primer and two coats emulsion paint to gypsum walls. Installation of two electrical outlets in each office. Installation of glass door in each office. Tinting of glass partitions and glazed doors in aluminum frame. To mud and paint gypsum works.

1.3.2 Conference Room

- Following as per drawings the construction of the room using gypsum and glass. Painting of the whole works to prepare and apply one coat primer and two coats emulsion paint to gypsum walls. Installation of two electrical outlets. Installation of glass door. Tinting of glass partitions and glazed doors in aluminum frame. To mud and paint gypsum works.

1.3.3 Storage Room

- Following as per drawings the construction of the room using gypsum. Painting of the whole works to prepare and apply one coat primer and two coats emulsion paint to gypsum walls. Installation of two electrical outlets. Installation of wooden panel door. Tinting of glass partitions, timber framed solid door and glazed doors in aluminum frame. To mud and paint gypsum works.

1.3.4 Kitchen

- Following as per drawings the construction of the rooms using gypsum and glass. Painting of the whole works to prepare and apply one coat primer and two coats emulsion paint to gypsum walls. Installation of two electrical outlets. To mud and paint gypsum works. Installation of Kitchen cupboards, storage shelving units and skirting. Plumbing work for kitchen sink.

1.3.5 Car Parking Area

- The thermoplastic marking of divider lines.

1.4 Specific Description

- The respondent shall be responsible for all onsite visits at his own expense to ascertain the technical difficulty of job before tendering.
- The respondent shall be responsible for all electrical installation required and all weather wall plugs. **All electrical installation must be certified by a qualified registered electrician.**
- The respondent will be required to clean up all fine dust and materials formed. Removal of all debris and rubbish incurred during the project will be the responsibility of the contractors for disposal.
- The respondent shall remove all equipment from the amenity area so work space has ease of access and is free of equipment and materials.
- The respondent shall ensure there is a smooth transition in and out of rooms to existing court floor and ensure all fire codes and OSH acts are met and adhered to, inclusive of adequate ventilation and hoarding of site.

Above-the-line items	Direct (variable) costs	Direct labour	The wages and salaries of people employed on the project, for time that can be wholly and specifically attributed to the project. These times should be costed at the standard cost rates applicable to each grade of staff.
		Direct materials	Equipment, materials and bought-out services used specifically on the project.
		Direct expenses	Travel, accommodation and other costs chargeable specifically to the project. Can include the hiring of external consultants.
	Indirect (fixed) costs	Overhead costs	A portion of the costs of running the business, such as general management and accommodation. Usually calculated as a proportion of total direct costs. Not applicable if the project is itself charged as an overhead.
Below-the-line items		Contingency sum	An addition, usually calculated as a small percentage of the above-the-line costs, in an attempt to compensate for estimating errors and omissions, unfunded project changes and other unexpected costs.
		Escalation	An addition to allow for costs that increase with time as a result of annual cost inflation. Particularly important for long-duration projects in times when national cost inflation rates are high.
		Mark-up for profit Selling price	These two items apply only to projects sold to external clients. There are various ways in which they can be calculated and their levels are often judged according to the strength of the competition and what the market will stand. These are management decisions, not part of the cost estimating process. Such decisions are always more easy to make when there is confidence in the cost estimating accuracy.
		Provisional sums	The estimated costs of items that are not included in the quoted price which might have to be charged extra if the need for them is revealed as project work proceeds.

Figure 4.1 Summary layout of a project cost estimate

Indirect costs – costs that must be incurred by the organization to provide heat, light, accommodation, insurances, maintenance, accountants, secretaries, welfare, management salaries and other general running costs of the business that cannot be attributed as costs to be charged to a specific project. Because these costs do not vary from day to day they are also *fixed costs*. They are also commonly known as *overhead costs*. However, the administration and accommodation costs of a construction site are a special exception

A GENERAL-PURPOSE COST ESTIMATING FORMAT

An example of a general-purpose estimating tabulation is given in Figure 4.3. This design can be used on many kinds of projects and can be set up as a Microsoft Excel document. It allows for six labour grades to be shown and assumes that all hours will be costed at standard cost rates. Six grades should be adequate, provided that the standard costing system has been designed sensibly and has not been complicated by interference from the 'wouldn't it be nice if…' brigade. The standard grade code and cost rate used should be entered in the space at the head of each column to show the rates used at the time of estimating.

The inclusion of a column headed 'longest lead time' in the materials section might appear unusual in a form intended for cost estimating. However, the people who estimate material costs are usually the same people who can predict delivery times. It is convenient and efficient to collect both these sets of data as early as possible and on the same occasion. This extends the usefulness of this estimating format into a valuable information source for timescale planning.

Additional columns could be provided on the estimating form to allow mark-ups and selling prices to be shown. These were omitted from the example in Figure 4.3, partly through lack of space but particularly because the relationship between cost estimates and project pricing is not usually simple and is often decided by senior management on a project-by-project basis.

COST ESTIMATE

Project number or sales reference:

Estimate number:
Case:
Date:
Page of

Estimate for:

Compiled by:

1	2	3	4		5		6		7		8		9		10	11	12	13	14	15
Code	Item description	Qty	Labour times and costs by standard grade												Total direct labour cost	Overhead cost ____ %	Materials and equipment			Total cost 10+11 +12+13
			Grade 1		Grade 2		Grade 3		Grade 4		Grade 5		Grade 6				Standard or net cost	Materials burden	Longest delivery (weeks)	
			Hrs	£	Hrs	£	Hrs	£	Hrs	£	Hrs	£	Hrs	£						

Figure 4.3 A useful format for general cost estimating

AN ESTIMATING FORMAT FOR MATERIALS PURCHASES ON LARGER PROJECTS

In larger projects, general all-purpose forms are inadequate for listing all the cost estimate considerations for the purchases of materials, components and equipment.

Estimates for many of the materials and components bought for construction projects are often made on very detailed purchase schedules or material 'take-offs' which are specially designed for each of the particular engineering disciplines involved (such as piping take-offs compiled by fluids engineers and steel take-offs worked out by the civil and structural engineers).

Project Cost and Price Summary Format

Project cost and price summary

Project title: | Estimate ref:

Client/customer: | Case number:

Date:

£

Labour costs by standard grade

1 ________ hours at £ _____ = £ __________

2 ________ hours at £ _____ = £ __________

3 ________ hours at £ _____ = £ __________

4 ________ hours at £ _____ = £ __________

5 ________ hours at £ _____ = £ __________

6 ________ hours at £ _____ = £ __________

Total labour cost →

Materials, equipment and bought-out services →

Other expenses (professional fees, licensing, etc.) → __________

Prime cost →

Overhead costs at _____ % of total labour cost →

Materials burden at _____ % (if any) →

Overseas costs and handling charges (if any) → __________

Basic estimated project cost →

Allowances

Escalation at _____ % per annum for _____ years →

Contingency _____ % →

Other allowances (if any) → __________

Total estimated project cost →

Mark-up _____ % →

Indicated selling price → [ ]

Notes, provisional items, etc.

Project Budgeting Exercise

"We kicked off the project on 6 May 2013 with **Requirements Analysis** which should have taken no more than 8 working days. This was followed by **Detailed Design** (5 days) and **Interface studies** (15 days) - they should have started at the same time and run roughly in parallel. As soon as **Detailed Design** is complete we could start **Data Configuration** (30 days).

Prototyping cannot start until **Detailed Design** and **Interface Studies** are both finished and should take 20 days. **Computing Centre Reviews** would start after **Prototyping** and should run for 10 days. **Implementation** follows 8 days after the end of **Prototyping** and should take 15 days.

System Testing (5 days) starts when **Implementation** and **Computing Centre Reviews** have both finished. **Computing Centre Training** (also of 5 days duration) follows when **System Testing** and **Data Configuration** are both complete.

Go-Live is a milestone and follows **Computing Centre Training**. The "go-live" date was identified as 30 August 2013 and all parties were made aware of this.

When asked about who worked on what tasks the following information was scribbled down and handed over (the letters signify initials):

Requirements Analysis (J & T)
Detailed Design (T)
Interface studies (50% of J & 50% of T)
Data Configuration (J & S)
Prototyping (T & B)
Computing Centre Reviews (All 4)
System Testing (All 4)
Implementation (T)
Computing Centre Training (J & B & S)

One of the consultants (Jeremy: £58 per hour) began work on collecting the data, the other (Taz: £55 per hour) began programming a database application to support the work of the Computing Centre team. Both were working initially on a standard 40 hour week.

A suitable office location was rented for the Computing Centre itself and the two IT Consultants were based there along with the Computing Centre Supervisor (Basil - £20 ph) and Project Administrator (Sandy - £12 ph), they worked a 40 hour week.

Assuming that the project had run perfectly to the schedule, generate an overall budget for the project. Include the 4 named contract staff, accommodation costs at £650 per week inclusive, the Project Director's staff costs at £2,250 p.c.m., all new PC hardware (total fixed cost: £54,000) and total miscellaneous fixed costs of £15,000. Show all calculations and totals via suitable report formats.