MODELING THE PROJECT PLANNING DETAILS TO MINIMIZE COST

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Abstract

From a management perspective, the key to a successful project lies in its perfect planning and complete execution. An excellent project plan minimizes the risks and, consequently, results in a smooth project execution. In addition, proper cost and time control as well as zero project changes during the execution stage enable a project to be implemented according to schedule.

In planning a project, it is crucial that the plan be detailed enough, as the details of the plan will impact subsequent phases; however, in executing a project, the key lies in the completeness of project execution. A detailed plan makes it easier for the team to identify potential risks of the project, enhance its feasibility, and minimize any project changes that may be required during the execution stage. If a project is not well planned and fails to identify all potential risks, it will require constant adjustments during the project execution that will directly increase the project cost and completion time. The drawback of having such a detailed plan is that it takes longer time to formulate, which also affects the overall project cost and the time required for completion. Thus, professionals are constantly trying to strike a balance between perfect planning and cost-effective execution.

In this study, a mathematical model is proposed that can achieve the abovementioned objective. Taking into consideration planning time, cost, and level of changes, the model proposed can determine enough project planning details that minimizes overall cost.

Keywords: Project planning details, planning time, level of changes, project cost

1 Introduction

Researchers on project management practices constantly look for the best way to manage projects and increase their chances of achieving successful execution. Freeman tried to extract the factors of success from successful projects (Freeman, 1992). Cooke studied over 70 projects conducted by national organizations and defined 12 crucial factors of success (Cooke, 2002). Lin indicated that for a professional manager, the key is to use the limited time and resources to produce a well-planned project that minimizes total project execution time, meets the strategic objectives, and obtains competitive advantages for the enterprise (Lin, 2009). Atkinson believed that in project management, time, cost and quality are the three benchmarks most frequently applied (Atkinson, 1999). Other factors contributing to success include project performance (Ahsan & Gunawan, 2009) and project life cycle analysis (Wang, 2009). However, few studies have explored how project planning details are related to project planning time, cost, and level of changes.

After a project is initiated, it enters immediately the subsequent management phases, including planning, execution and controlling until close-out. In practice, project managers are required to lead their teams to complete the planning before the project sponsors can ratify its execution. A perfectly detailed project plan requires a longer time to formulate; hence, more costs are generated. However, if a project is not well planned, changes due to unexpected events arising during project execution will be required. Whatever the level of changes, they involve costs, which directly increase the pressure on project cost management.

Taking into consideration project planning time, project cost and project changes this study establishes a model for deciding project planning details that minimizes cost. First, the relation between project planning details and the time required to formulate the plan is examined. Then, the future level of change to the project is explored. Lastly, a mathematical model that considers both the planning cost and change cost is established.

2 Literature review

According to Meredith, a project is defined as an impermanent work that is done to create a unique product or service. It needs to be completed within a certain period of time and is complex in its technicality; a project requires constant coordination to control its progress, process, costs and performance (Meredith, 1992). Loo pointed out that project management processes can be defined as the execution of professional technique, complex procedures and professional knowledge. Project management can be categorized into five processes: initiating, planning, executing, controlling, and closing (Loo, 1996).

The goal of project management is to establish a mechanism that allows an organization to efficiently integrate personnel and resources within a limited period of time in order to complete the project. This mechanism is a complex decision-making process that constantly consumes project time and involves relentless costs (Payne, 1995; Ghomi and Ashjari, 2002). Konchar suggested that project performance can be reviewed from various aspects such as project delivery, completeness of organization objectives and profits (Konchar, 1998). Project performance outcomes are assessed in terms of project delivery results, budget execution, project progress and quality. Morris used time, cost and quality as three variables to explore the keys to a successful project, and investigated how the project scope, cost and time relate to its success (Morris, 1988; Morris, 2000).

Recent project management studies have been increasingly precise in considering the particularity of various industries. Researchers have proposed new perspectives and actively developed new tools for project management. For example, Sterman pointed out that construction projects are mostly complex and dynamic, as they involve multiple information feedback and non-linear correlations. Hence, a construction project needs unique planning and controlling methods. The industry usually applies tools such as critical path method (CPM) and program evaluation and review technique (PERT) to plan and control projects. However, as Ballard argued these planning tools are not suitable for highly dynamic projects; thus, new planning methods are needed. (Ballard, 2003). This is corroborated by Sterman, who maintained that the application of CPM and PERT results directly in imperfect project planning as well as difficulties in project control (Sterman 2002). Salari et al. (Salari et al. 2014) proposed a Z-number method to measure the progress of a project under uncertain conditions. Laryea (2013) developed a multi-criteria decision model to help managers know the profit outcome of their projects for efficient resource allocation.

2.1 Project planning and project cost

Taylor once indicated that the phase of project planning is to take the concepts developed in the initiating phase further to a phase where concepts are clarified with greater details. Following that, the project will be well developed according to the clarified concepts. Once the sequence of the project work is ready, project time and cost will also be planned out, and that will conclude project planning (Taylor, 1937). Hartman believed that bad project planning is the main contributing factor to the failure of a project (Hartman, 2004), and he tried to develop a new smart project planning framework to modify existing methods and systemize project planning method with the aim of producing a project planning process of better quality.

However, a detailed project planning process may increase the time to complete the project as well as the costs; therefore, a trade-off between time and cost will be required. A longer planning time allows the production of a detailed project plan, which increases directly the project planning quality and its chances of success. Nevertheless, this does not guarantee a reduction in overall costs, since more resources invested in planning a project imply a higher project planning cost.

Some researchers used linear and non-linear programming to explore the relations between project time and cost. For instance, Fulkerson and Kelly both used linear programming to identify these relations (Fulkerson, 1961; Kelly, 1961); while Moder used a non-linear model to explore the relations between the time and cost of each project (Moder, 1983).

Feng et al. believed that analytic calculation cannot provide answers to a large scope of CPM network. As a result, the TCGA program was developed to solve TCTP. TCGA used a genetic algorithm and Pareto set to calculate the objective function (Feng et al., 1997).

2.2 Management of changes

Changes are inevitable during the course of project execution, and changes happen because future events are always uncertain. However, they need to be supervised and managed, and they should not unnecessarily stray from the original project objectives. After a project is initiated, the management of changes should adhere to the management process, which predicts their emergence in the project, as well as their effects on quality, cost and schedule. The processes should include requests for changes, definition of new opportunities, coordination of changes, execution of decision, decision-making policies regarding the approval of changes, and execution policies regarding the management of changes. In managing changes, professional management teams need to first evaluate the aforementioned items, which impact project delivery, risks, schedule, costs, quality, and so forth. In addition, a comparison between the change and the project performance baseline needs to be conducted. Once the change is accepted, the entire plan should be adjusted accordingly.

Ling (Ling, 2009) studied the performance of a Singaporean business project implemented in China and demonstrated that project performance is influenced remarkably by how a project is pragmatically managed, and particularly by the level of management, which includes acceptable changes made under quality supervision and control, the changes made on the continuity of contracts, and so on.

Studies on construction projects attempted to standardize change processes by analyzing successful change models in order to generate the best way to initiate changes. The Construction Industry Institute (CII, 1994) ascertained a concept of project change management where change is considered as a modification to an agreement between project participants. The project elements are subject to change and will affect the change process as project scope, project organization, work execution methods, control methods, contracts and risk allocation. Furthermore, recommended practices for managing change efficiently were organized for each project phase of the project life cycle (CII, 1996). Ibbs established a progressive management systems of project change (Ibbs, 2001).

Motawa developed an example of an integrated system produced for change management in the construction industry (Motawa, 2007), in which, fuzzy logic is employed to predict changes, which allows the system to be capable of controlling and making dynamic plans as well as evaluating negative impacts of changes on the performance of construction projects. Studies on engineering also explored various issues regarding engineering change management. For example, configuration management allows a project to use changes to improve the performance and to modify its design within its own life cycle (Rouibah, 2003).

Studies also showed that the process of engineering change management is regarded as the most complex and problematic issues in an organization (Taylor, 2008).

3 Model formulation

For a project to meet the scheduled objectives, professional teams might be required to make a detailed project plan during the planning phase, because detailed planning is generally able to predict future uncertainties with more accuracy. However, the more detailed the project planning is, the more time and cost it needs. Hence, this study aims to formulate an appropriate project plan that minimizes cost. To meet this objective, a mathematical model is proposed. This model first examines the relation between the project details and the time it takes to achieve them. It then considers the level of future changes that can be predicted within this detailed project plan, as well as the time and cost it takes to make the plan. Lastly, a cost-minimizing mathematical model that considers planning details, time and the level of changes is generated. The computation is demonstrated in the following steps.

Step 1: Specify the relation between project planning details d_k, and the time T it takes to achieve them. Project planning details are divided into five levels, as shown in Table 1.

Table 1 Five Levels of Project Planning Details

Planning details	Not detailed at all	Fairly detailed	Moderate	Detailed	Very detailed
d_k	d_1	d_2	d_3	d_4	d_5

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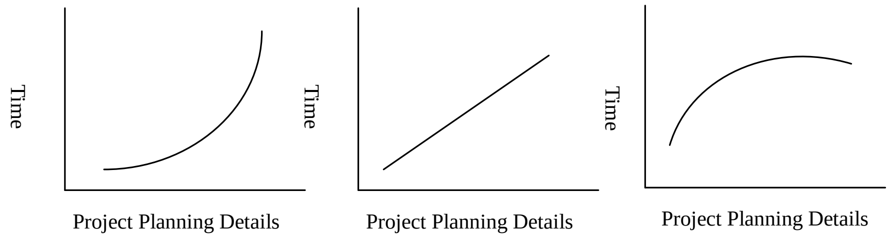
Suppose each level takes a certain amount of time *T*, and project planning time is assumed to be the function of the project planning details. In other words, $T = f(d)$. This study applies a quadratic polynomial to relate planning time and details as shown in Equation (1), which expresses the relations between project planning details and time required for completion.

$$T = f(d) = ad^2 + bd + c \qquad (1)$$

where *a*, *b* and *c* are coefficients of the equation. The variations of these coefficients will affect the time needed in planning project details. The effects can be seen in the three graphs shown in Figure 1.



(a) T_1 (b) T_2 (c) T_3

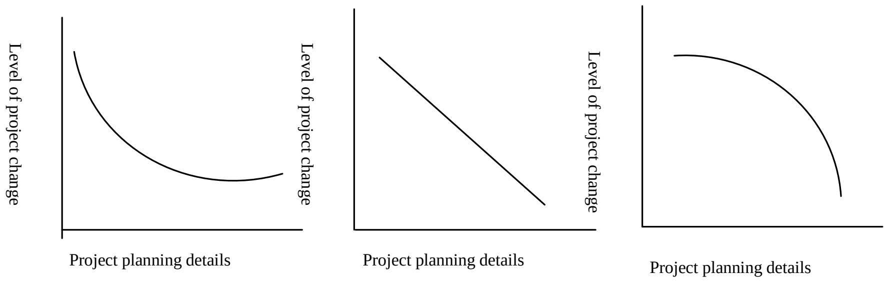
Figure 1 Relations Between Planning Details and Time Required

Step 2: Specify the relations between project planning details *g* and the level of project changes in the future

A project in greater detail will induce fewer project changes in the future. In other words, project planning details (d_k) will impact the level of project changes (g). The level of project changes can therefore be assumed as a function of project planning details. This can be described as $g = f(d)$. This study utilizes a quadratic polynomial to express the relations between project planning details and the level of future changes as illustrated in Equation (2):

$$g = f(d) = md^2 + nd + p \quad (2)$$

where *m*, *n* and *p* are coefficients of the equation. The variations of these coefficients affect the relations between project planning details and the level of change. The effects can be seen in the three graphs shown in Figure 2.



（a）g_1　　　（b）g_2　　　（c）g_3

Figure 2 Relations Between Planning Details and Level of Change

Step 3: Specify the function of project planning cost

Project planning takes time, which can be transferred into cost. The longer a project takes in planning, the higher the project planning costs are. Hence, the time a project takes in planning and its cost can be expressed as $C_T = f(T)$. Thus, Equation (3) can be derived from Equation (1) as below.

$$
\begin{aligned}
C_T &= f(T) = f\left(f(d)\right) \\
&= \alpha_4 d^4 + \alpha_3 d^3 + \alpha_2 d^2 + \alpha_1 d + \alpha_0
\end{aligned}
\tag{3}
$$

Step 4: Specify the function of project change cost

A project planning process that does not take sufficient details into consideration might need constant changes during the project execution phase. Each change made will lead to an increase in project cost. The larger the level of project changes, the higher the overall cost of the project is. Therefore, the level of project changes and its cost can be described by Equation (4), which is developed from Equation (2).

$$
\begin{aligned}
C_g &= f(g) = f\left(f(d)\right) \\
&= \beta_4 d^4 + \beta_3 d^3 + \beta_2 d^2 + \beta_1 d + \beta_0
\end{aligned}
\tag{4}
$$

When factors *a*, *b* and *c* in Equation (1) and *m*, *n* and *p* in Equation (2) change, so do the relations between the project planning details, the time project planning takes and the level of the future changes. Tables 2 and 3 demonstrate the variations of α_4、α_3、α_2、α_1、α_0 in Equation (3), as well as the changes implied by factors β_4、β_3、β_2、β_1、β_0 in Equation (4).

Table 2 Project Planning Cost

T = Required time $T = f(d) = ad^2 + bd + c$		C_T = Planning cost $C_T = f(T) = a(T)^2 + b(T) + c$ $= \alpha_4 d^4 + \alpha_3 d^3 + \alpha_2 d^2 + \alpha_1 d + \alpha_0$	
T_1	$a > 0, b > 0, c > 0$	C_{T1}	$\alpha_4 > 0, \alpha_3 > 0, \alpha_2 > 0, \alpha_1 > 0, \alpha_0 > 0$
T_2	$a = 0, b > 0, c > 0$	C_{T2}	$\alpha_4 = 0, \alpha_3 = 0, \alpha_2 = 0, \alpha_1 > 0, \alpha_0 > 0$
T_3	$a < 0, b > 0, c > 0$	C_{T3}	$\alpha_4 < 0, \alpha_3 > 0, \alpha_2 < 0, \alpha_1 \geq 0, \alpha_0 > 0$

Table 3 Project Change Cost

g= Level of change $g = f(d) = md^2 + nd + p$		C_g= Change cost $C_g = f(g) = m(g)^2 + n(g) + p$ $= \beta_4 d^4 + \beta_3 d^3 + \beta_2 d^2 + \beta_1 d + \beta_0$	
g_1	$m > 0, n < 0, p > 0$	C_{g1}	$\beta_4 > 0, \beta_3 < 0, \beta_2 > 0, \beta_1 < 0, \beta_0 > 0$
g_2	$m = 0, n < 0, p > 0$	C_{g2}	$\beta_4 = 0, \beta_3 = 0, \beta_2 = 0, \beta_1 > 0, \beta_0 \geq 0$
g_3	$m < 0, n > 0, p > 0$	C_{g3}	$\beta_4 < 0, \beta_3 > 0, \beta_2 > 0, \beta_1 < 0, \beta_0 < 0$

Step 5: Formulate model for deciding project planning details to minimize cost

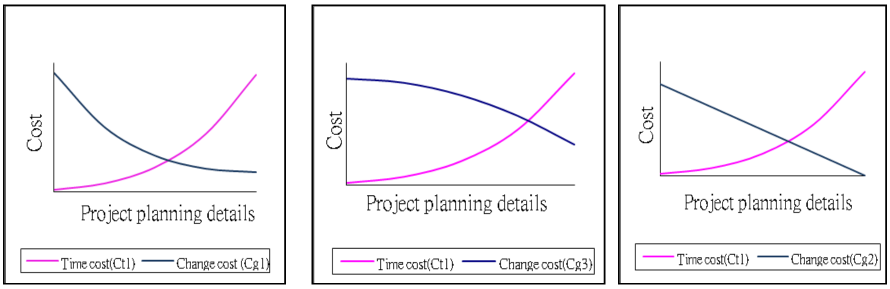
Summing project planning cost and change cost will yield the total cost of project *C*, as shown in Equation (5). Finding the first-order differentiation of *C* will yield the level of planning details that can minimize project cost, as shown in Equation (6).

$$C = C_T + C_g \tag{5}$$

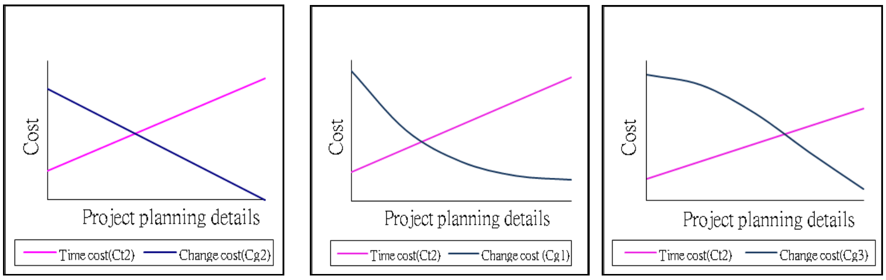
$$= \sigma_4 d^4 + \sigma_3 d^3 + \sigma_2 d^2 + \sigma_1 d + \sigma_0$$

$$\frac{\partial C}{\partial d} = \omega_0 + \omega_1 d + \omega_2 d^2 + \omega_3 d^3 = 0 \tag{6}$$

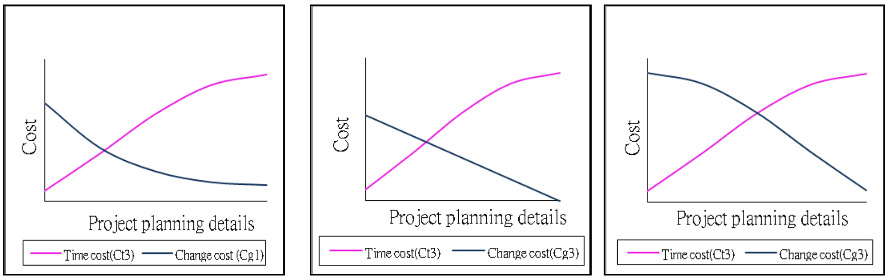
Combining the planning cost equation and change cost equation will generate nine situations, as shown in Figure 3.



（a） C_{T1} vs Cg_1 （b） C_{T1} vs Cg_2 （c） C_{T1} vs Cg_3



（d） C_{T2} vs Cg_1 （e） C_{T2} vs Cg_2 （f） C_{T2} vs Cg_3



（g） C_{T3} vs Cg_1 （h） C_{T3} vs Cg_2 （i） C_{T3} vs Cg_2

Figure 3 Relations Between Planning Cost and Change Cost

Table 4 Project Costs

C_T	C_g	$\sum_{C_k} = C_T + C_g$ $= \sigma_4 d^4 + \sigma_3 d^3 + \sigma_2 d^2 + \sigma_1 d + \sigma_0$		$\frac{\partial C}{\partial d} = \omega_3 d^3 + \omega_2 d^2 + \omega_1 d + \omega_0$
C_{T1}	C_{g1}	$\sum_{C_1}$	$\sigma_4 > 0, \sigma_3 < 0, \sigma_2 > 0, \sigma_1 < 0, \sigma_0 > 0$	$\omega_3 > 0, \omega_2 < 0, \omega_1 > 0, \omega_0 < 0$
C_{T1}	C_{g2}	$\sum_{C_2}$	$\sigma_4 > 0, \sigma_3 > 0, \sigma_2 > 0, \sigma_1 > 0, \sigma_0 > 0$	$\omega_3 > 0, \omega_2 > 0, \omega_1 > 0, \omega_0 > 0$
C_{T1}	C_{g3}	$\sum_{C_3}$	$\sigma_4 = 0, \sigma_3 > 0, \sigma_2 > 0, \sigma_1, 0, \sigma_0 < 0$	$\omega_3 = 0, \omega_2 > 0, \omega_1 < 0, \omega_0 < 0$
C_{T2}	C_{g1}	$\sum_{C_4}$	$\sigma_4 > 0, \sigma_3 < 0, \sigma_2 > 0, \sigma_1 < 0, \sigma_0 > 0$	$\omega_3 > 0, \omega_2 < 0, \omega_1 > 0, \omega_0 < 0$
C_{T2}	C_{g2}	$\sum_{C_5}$	$\sigma_4 = 0, \sigma_3 = 0, \sigma_2 = 0, \sigma_1 > 0, \sigma_0 > 0$	$\omega_3 = 0, \omega_2 = 0, \omega_1 = 0, \omega_0 > 0$
C_{T2}	C_{g3}	$\sum_{C_6}$	$\sigma_4 < 0, \sigma_3 > 0, \sigma_2 > 0, \sigma_1 < 0, \sigma_0 < 0$	$\omega_3 < 0, \omega_2 > 0, \omega_1 > 0, \omega_0 < 0$
C_{T3}	C_{g1}	$\sum_{C_7}$	$\sigma_4 > 0, \sigma_3 < 0, \sigma_2 > 0, \sigma_1 < 0, \sigma_0 > 0$	$\omega_3 > 0, \omega_2 < 0, \omega_1 > 0, \omega_0 < 0$
C_{T3}	C_{g2}	$\sum_{C_8}$	$\sigma_4 > 0, \sigma_3 > 0, \sigma_2 > 0, \sigma_1 > 0, \sigma_0 > 0$	$\omega_3 > 0, \omega_2 > 0, \omega_1 > 0, \omega_0 > 0$
C_{T3}	C_{g3}	$\sum_{C_9}$	$\sigma_4 = 0, \sigma_3 > 0, \sigma_2 > 0, \sigma_1 < 0, \sigma_0 < 0$	$\omega_3 = 0, \omega_2 > 0, \omega_1 > 0, \omega_0 < 0$

4 Case implementation

To verify the validity of the model in this study, Figure 4(a) is used as an example case. Factors are randomly given and the model proposed is employed to achieve the project planning details with minimized cost.

Suppose the projects details are categorized into five ranks, namely, not detailed at all, fairly detailed, moderately detailed, detailed, and very detailed. Each rank is rated from 1 to 5 as illustrated in Table 5.

Table 5 Levels of Project Planning Details

Planning details	Not detailed at all	Fairly detailed	Moderate	Detailed	Very detailed
d_k	1	2	3	4	5

Equation (1) displays the relations between the project planning details and the time it takes to formulate the plan, with factors *a*=1, *b*=2 and *c*=1. Hence, the relations between project planning details and the time needed for plan formulation can be translated into Equation (7). Applying Equation (7) to Equation (3) produces cost Equation (8) with project planning details as variables.

$$T = f(d) = d^2 + 2d + 1 \quad (7)$$

$$C_T = f(T) = (d^2 + 2*d + 1)^2 + 2*(d^2 + 2*d + 1) + 1$$
$$= f(T) = d^4 + 4d^3 + 8d^2 + 8d + 6 \quad (8)$$

Equation (2) displays the relations between the level of change of this project and project planning details, with factors *m*=1, *n*=-10 and *p*=0. Hence, the relations between project planning details and the level of change can be translated into Equation (9). Applying Equation (4) to Equation (9) produces Equation (10).

$$g = f(d) = d^2 - 10d + 40 \quad (9)$$

$$C_g = f(g) = (d^2 - 10d + 40)^2 - 10(d^2 - 10d + 40) + 40$$
$$= d^4 - 20d^3 + 170d^2 - 700d + 1240 \quad (10)$$

To achieve the project planning details at a minimized cost, summing time cost of Equation (8) and change cost of Equation (10) leads to Equation (11):

$$\Sigma C = C_T + C_g = d^4 - 8d^3 + 89d^2 - 396d + 623 \quad (11)$$

Finding the first-order differentiation of Equation (11) yields Equation (12) that gives the project planning details with minimized cost, which is represented as *d* = 2.78517:

$$\frac{\partial C}{\partial d} = 2d^3 - 12d^2 + 89d - 198 = 0 \quad (12)$$

Figure 4 shows the total cost curve of this example. When *d*=2.78511, it minimizes the sum of planning cost and change cost. Applying *d* to Equation (7) gives the best value of planning time as *T*=14.32706; applying *d* to Equation (9) gives *g* = 19.90574; and applying *d* to Equation (11) gives minimized cost of *C* = 97.79436.

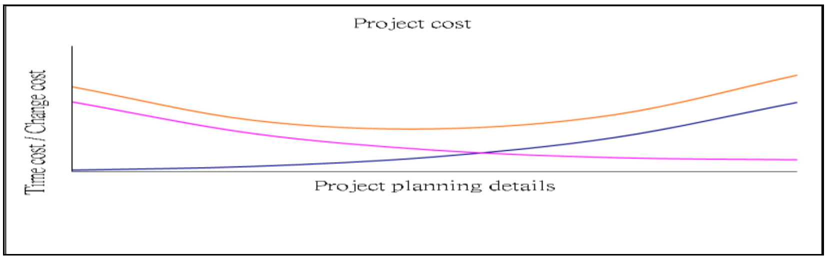


Figure 4 The Total Project Cost Curve

5 Industrial application

Most project managers improve management skills by making mistakes, as a result, many projects can not be completed as planned. Project management skills are composed of project planning, project implementation and project control, and project planning skill plays the most vital role in successfully completing a project. It is not only because project planning stage involves more risks than the other two latter stages, but also a robust method that project managers can utilize remains nonexistent. A poor project plan reduces the possiblity of successful project implementation, and an excellent project control mechanism still can not decrease the possiblity of poor project execution. Therefore, formulating a good project plan is the key to project success. However, projects are often constrained by time and cost for certain reasons; in other words, project manager is always expected by stakeholders to achieve project objective within limited time and budget. Thus, project manager must be able to efficiently and effectively formulate a good enough plan within reasonable time frame and limited budget. The model proposed in this study can help project managers in various industries formulate a project plan that can meet expectation of stakeholders by finding the most proper project planning details which balance the costs incurred by project planning time and future project changes.

6 Conclusion

Project management is the primary method used by enterprises to solve problems and create opportunities. Planning is an important task in enterprises, since the key to a successful project lies in project planning. Traditionally, the planning of a project relies on the experience of the team, and unfortuantely, there exist no best practice to assist planning team in finding the best details of a project plan. This study develops a mathematical model that considers project planning time, the level of change, as well as the planning cost to minimize the overall project cost and change cost. The model first considers the relations between project planning details and the time it takes to plan these details. Secondly, it explores the potential level of project changes that will be required in the future as well as the costs derived. Finally, it integrates all parameters to produce a non-linear mathematical model.

According to the results of the example case, the model proposed can be an effective way to determine the optimal project planning details needed, thus avoiding frequent future changes. In other words, it can prevent a team from spending too much time making over-detailed project plans, while being able to maintain the efficiency of its project execution. This paper is believed to be the first study exploring the level of planning details in project management.

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