

Two Staged Incentive Contract Based on Efficiency and Innovation: A Case Study of Critical Chain Project Management

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Abstract:

Purpose: The purpose of this paper is to define the relative optimal incentive contract to encourage employees to improve work efficiency effectively while implementing innovative behavior actively.

Design/methodology/approach: This paper analyzes a two staged incentive contract coordinated with efficiency and innovation in Critical Chain Project Management using learning real options, based on principle-agent theory. The situational experiment is used to detect the validity check of this basic model.

Finding: The two staged incentive scheme is more suitable for employees to create and implement learning real options, which will throw themselves into innovation process efficiently in the situation of Critical Chain Project Management. We prove that the combination of tolerance for early failure and reward for long-term success is effective in motivating innovation.

Research limitations/implications: We do not include the individual differences among the perceptions of uncertainty, which might affect the consistency of external validity. The basic model and the experiment design need to improve.

Practical Implications: The project managers should pay closer attention to early innovation behaviors and monitor feedbacks of competition time according to the implementation of Critical Chain Project Management.

Originality/value: This study analysis the incentive schemes for innovation in Critical Chain Project Management using the principal-agent theory, and this method will shorten the completion time of a project as well as push the creative ideas among team members.

Keywords: efficiency, innovation, incentive mechanism, critical chain project management

1. Introduction

As project management has developed as a popular management philosophy adapting to rapid technological change and increased competition in 21st century, many project management systems have emerged to maintain or gain competitive advantages. Meanwhile, the execution of innovation is often promoted as a project. Most innovative endeavors in organizations, however, take place in projects (Edmondson & Nembhard, 2009; McDonough, 2000). Unfortunately, the literature of project management largely ignores innovations considerably in recent decades (Keegan & Turner, 2002). Thus, there is a gap between the efficiency and innovative behaviors in project management. Innovation, like many business functions, is a management process that requires specific tools, rules, and disciplines. Hence, a project which has a defined objective, scope, budget and limitations, can be an appropriate setting of innovative behaviors (Davila, 2006).

Critical Chain Project Management (CCPM) is a relatively new project methodology, in order to complete projects faster, make more efficient use of resources and secure the project deliverables (Goldratt, 1997). The primary emphasis of CCPM is for resources working on tasks to work as efficient as possible to achieve the aggressive scheduled task duration. Critical Chain Project Management is viewed as a short-term strategy which can affect time pressure and negatively affect longer-term change and innovation. The methods of CCPM can facilitate exploitation of existing resource, but block the exploration of creative ideas. What levels of controlling and formalization of planning does an innovation project really need? Thus far, there are no generic models to manage innovation projects, and we have not found satisfactory answers to maintain the innovation climate, help to define the levels of controlling mode in planning and to choose the reference point motivating innovation. This paper examines how to choose incentive schemes to affect the employees to choose innovative

choices in CCPM. The central contribution of this paper is to probe into the incentive schemes for innovation in Critical Chain Project Management using the principal-agent theory, and to encourage the execution of CCPM methods as well as imitative free-riding on the creative ideas of other members in the organization, academically and practically.

2. Theoretical background: A Review of literature

2.1. The Predominance and bottleneck of CCPM

Shorter product sales lives, smaller profit margins or complexity survival, removing these threats depends on management's ability to create and lead changes. This approach is different from a plan-based project methodology such as CPM and PERT, using a traditional approach where there is considerable upfront planning. The CCPM methodology is based on the assumption that traditional project techniques do not recognize critical human behaviors, such as activity duration estimation, student syndrome, Parkinson's Law and multitasking. The methodology claims that failures of many projects are due to the direct results of how safety is built into the task delivery times, and then wasted by human behavior issues. To cope with uncertainty and contingencies, estimated durations in traditional project scheduling typically include a safety time for each task. However, these safety times are often wasted for common reasons, such as that starting a task is left to the last minute (Student Syndrome) or work is expanded to fill the time available (Parkinson's Law) (Goldratt, 1997). CCPM confirms these human problematic behaviors hidden in each task and assumes that resource behaviors can be modified. To minimize the mentioned behavioral problems and to avoid wasting of allotted safety times in the duration estimates of project tasks, CCPM recommends that task duration estimates should be shortened and safeties embedded in duration estimate of each task should be eliminated. Besides, conditions should be provided wherein the baseline schedule with shortened task duration estimates.

Growing experiences with the CCPM methodology show exceeding benefits across many cases: increased on time delivery of project; reduced project duration (increased speed); increased project team satisfaction, improved teamwork and focus on the urgent task; increased organization throughput with same resources; increased project schedule reliability and predictability (Leach, 2005). Although exceeding benefits become reality, another bottleneck appears. According to Goldratt, take aggressive or optimistic estimate 50% confidence as the activity time is needed (Goldratt, 1997). And many previously results argued different methods to cut down excess activity time. Because of setting of 50% probability of successful completion for each task estimate, 50% of the tasks are expected to be delayed.

Research indicates that if the individual's decision-making time is normally distributed and the average time which is less than one standard deviation values as the time limit, 84% of the

subjects would not have enough time to make decisions (Benson & Svenson, 1993). If the decision-making time is less than 50% of the median or the average decision time, time stress will arise (Weenig & Maarleveld, 2002). As most theorists have predicted, in a strong organizational innovation climate, time pressure impedes creative outcomes (Hsu & Fan, 2010). The dilemma hinders the further application of CCPM methods, and the project management system should confront the trade-off between efficiency and innovation.

2.2. The incentive contract in project management

Contemporary organizations tend to make staff being busy, which means fully occupied and 100% scheduled and this mode leads to organizational inertia, high staff turnover and general inefficiency (DeMarco, 2002). On the one hand, it addresses time pressure for the individual leading to stress and insecurity; on the other hand, the globalization and dynamic competitive circumstances also multiply increased pressures in operation. There is an inverted U-shape curve between the strength level of project management and the degree of innovation, which mean high strength levels of PM become negatively correlated with innovation after a certain threshold (Kavanagh & Naughton, 2009). The CCPM methods face such a embarrassed situation. How to deal with the central dilemmas of CCPM methodology? How to break through this paradox? The optimal incentive schemes should be concerned immediately.

Social psychologists suggest that incentives may not only affect the level of efforts that individuals expend on innovation, but also the quality of those efforts (Sauermann & Cohen, 2012). Other papers have studied principal-agent models, such as multi-task principal-agent model (Hellmann & Thiele, 2011). The incentive contract focused on innovation process, the project innovation performance could improve (Caldwell, Roehrich & Davies, 2009). The key differences across funding streams within the academic life sciences to examine the impact of incentives embodied in research contracts on the rate of scientific exploration, and find that the program which rewards long-term success, encourages intellectual experimentation, and provides rich feedback to its appointees, leads to higher levels of breakthrough innovation (Azoulay, Graff Zivin & Manso, 2011). The optimal innovation-motivating incentive scheme exhibits substantial tolerance (or even reward) for early failure and reward for long-term success through a laboratory experiment (Mans, 2011). Real option attributes are discussed in a decision analytic context and thresholds, which are identified for improved decision-making. Some researchers also present a general discrete time dynamic framework to value pilot project investments that reduce idiosyncratic uncertainty by compound perpetual Bermudan option in different stages (Errais & Sadowsky, 2008; Miller, 2010).

Although researchers considered that the contract design is a proactive approach to managing uncertain projects, little research has been conducted in the area of incentive contract in CCPM until recently (Kwon, Lippman, McCardle & Tang, 2008). Based on the existing achievements,

this paper focuses on the frustrated compensation mechanism, combining with the former buffer management strategies of CCPM, to illustrate the two staged incentive contract coordinated with efficiency and innovation. The main objective of this paper is to define the relative optimal incentive contract to effectively encourage employees to improve work efficiency while actively implementing innovative behavior.

3. Basic model

Our paper inquires into a simplified mode. The project is modeled as a single task with no information asymmetry in a single-agent decision problem. We focus on examining which forms of project contracts can coordinate the CCPM method optimally. A deadline benefits the firm by eliminating the agent's dynamic incentives to shirk and lowering the firm's payroll costs (Zhang, 2014). The whole duration of a task is divided into two stages based on the buffer design strategy in CCPM; the early stage contains the setting of 50% probability of successful completion for each task, the later stage equals to the project buffer focused on the single task. This design is aimed to excavate possible learning real options, and take full use of the existing CCPM strategies as well.

The employee works for two periods during task execution. In each period, the employee takes an action $i \in I$, leading to two kinds of output, success (with probability p_i) or failure (with probability $1 - p_i$). In this paper, letter S means success and letter F means failure. As a result of the heightened uncertainty of project innovation, the employee cannot afford to predict the probability p of success, but he can revise it with learning incessantly. $E[p_i]$ is the unconditional expectation of p_i , $E[p_i|S, j]$ is the conditional expectation of p_i given a success on action j , $E[p_i|F, j]$ is the conditional expectation of p_i given a failure on action j . When the employee takes action $i \in I$, $E[p_i] = E[p_i|S, j] = E[p_i|F, j]$, $j \neq i$.

The employee can obtain cost and related information between exploration of new actions and exploitation of well known actions through continuously explored. In each period, the employee has two choices: Firstly, he may get the conventional work method i with a known probability p_i of success, such that $p_1 = E[p_1] = E[p_1|S, 1] = E[p_1|F, 1]$; Secondly, he can insist the new work method with an unknown probability p_i of success, such that $E[p_2|F, 2] < E[p_2] < E[p_2|S, 2]$.

When the employee fulfills the task with a creative method, he updates his adjustment about the probability of success, p_2 , with the innovative one, then

$$E[p_2] < p_1 < E[p_2|S, 2] \quad (1)$$

Let assume that the agent is risk-neutral, and he chose the scheme $\langle i_k^j \rangle$ to maximize his own expected benefit. The payoff is specified as follows:

$$R(\langle i_k^j \rangle) = \{E[p_i] \cdot S + (1 - E[p_i]) \cdot F\} + E[p_i] \{E[p_j | S, i] \cdot S + (1 - E[p_j | S, i]) \cdot F\} + (1 - E[p_i]) \{E[p_k | F, i] \cdot S + (1 - E[p_k | F, i]) \cdot F\} \quad (2)$$

$i \in I$ is the first-period action, $j \in I$ is the second-period action in case of success in the first period, and $k \in I$ is the second-period action in case of failure in the first period. Action plan $\langle 1_1^1 \rangle$ means sticking to conventional method. Action plan $\langle 2_1^2 \rangle$ provide an expedient to choose the creative method in case of success in the first period, and revert to the common method in case of failure in the first period. If the total payoff of $R(\langle 2_1^2 \rangle)$ from exploration is higher than the total payoff of $R(\langle 1_1^1 \rangle)$, then the threshold is defined as follows:

$$E[p_2] \geq p_1 - \frac{p_1(E[p_2 | S, 2] - p_1)}{1 + (E[p_2 | S, 2] - p_1)} \quad (3)$$

The employee should try to obtain new information to internalize and decrease the uncertainties of innovation, meanwhile, to obtain the learning real options as well. Only in this way, the employee can make objective judgments on the valuation of new technology and method. Such adventure in first period is conducive to the whole team's innovative motive and behavior. In each period, the employee expends different private cost due to conventional or creative work methods, c_1 for taking conventional action, $c_1 \geq 0$; c_2 for taking creative action, $c_2 \geq 0$. If $c_2 > c_1$, the employee take more efforts to explore and perform new ideas; if $c_1 > c_2$, which means the employee disgust the unalterable operating modes, and prefer to get new patterns to make substantial values.

In the basic model, the manager and the employee are assumed to be risk-neutral, and the manager offers the basic incentive contract \vec{w} in advance. $\vec{w} = \{w_F, w_S, w_{SF}, w_{SS}, w_{FF}, w_{FS}\}$, $\vec{w} > 0$. When the manager offers the employee contract \vec{w} , the employee takes action plan $\langle i_k^j \rangle$, and the total expected payments is:

$$W(\vec{w}, \langle i_k^j \rangle) = \{E[p_i] \cdot w_S + (1 - E[p_i]) \cdot w_F\} + E[p_i] \{E[p_j | S, i] \cdot w_{SS} + (1 - E[p_j | S, i]) \cdot w_{SF}\} + (1 - E[p_i]) \{E[p_k | F, i] \cdot w_{FS} + (1 - E[p_k | F, i]) \cdot w_{FF}\} \quad (4)$$

The corresponding total expected costs is:

$$C(\langle i_k^j \rangle) = c_i + E[p_i] \cdot c_j + (1 - E[p_i]) \cdot c_k \quad (5)$$

The incentive contract model is:

$$\max \Pi(\langle i_k^j \rangle) = \max[R(\langle i_k^j \rangle) - W(\bar{w}(\langle i_k^j \rangle), \langle i_k^j \rangle)] \quad (6)$$

s.t.

$$R(\langle i_k^j \rangle) = \{E[p_i] \cdot S + (1 - E[p_i]) \cdot F\} + E[p_i] \{E[p_j | S, i] \cdot S + (1 - E[p_j | S, i]) \cdot F\} \\ + (1 - E[p_i]) \{E[p_k | F, i] \cdot S + (1 - E[p_k | F, i]) \cdot F\} \geq \theta > 0 \quad (7)$$

$$W(\bar{w}, \langle i_k^j \rangle) - C(\langle i_k^j \rangle) \geq W(\bar{w}, \langle i_n^m \rangle) - C(\langle i_n^m \rangle) \quad (8)$$

$i, j, k, m, n \in I$, $R(\langle i_k^j \rangle)$ is the total expected payments for the employee's action plan $\langle i_k^j \rangle$;

$W(\bar{w}(\langle i_k^j \rangle), \langle i_k^j \rangle)$ is the optimal incentive contracts for corresponding action plan $\langle i_k^j \rangle$, (6) is the objective function, means the maximum of expected earning of a specific project; (7) is the rationality constraint of employee, means the feasible condition of expected payments is equal or greater than θ ; (8) is the incentive compatibility constraint to ensure maximization of the expectant benefit. The optimal contract that motivates innovation can be implemented via a combination of real options with long vesting periods.

In order to simplify analysis, let $\langle i_k^j \rangle = \langle 2_1^2 \rangle$, the above model can translate to

$$(E[p_2] \cdot E[p_2 | S, 2] - p_1^2) \cdot w_{SS} + (p_1 - E[p_2]) \cdot w_F + (p_1 - E[p_2]) \cdot p_1 w_{FS} \geq (1 + E[p_2])(C_2 - C_1) \quad (9)$$

This is the optimal incentive contracts to promote the employee for adopting innovative methods in first period.

4. Analysis of the model

In the optimal incentive contracts, $w_F \neq 0$, this is the positive compensation signal for innovation protection, even if the first try is not optimistic. In order to not abandon oneself to exploration throughout this two periods, $w_{SS} \neq 0$ and $w_{FS} \neq 0$, the later success is worth affirmation. On the other hand, the project manager should control the expected payments strictly, the trade-off between w_F and w_S is full of wisdom, and the main principle of decision is the degree of innovation. The exploratory innovation needs a higher w_F to highlight the importance of taking creative risk in first stage, a lower w_F is more suited for the exploitation innovation to emphasize the incentive effect of w_{SS} .

To fully realize long-term compensation effect of the optimal incentive contracts, the employee must be protected against failure, the $w_F + w_{FS} > w_S + w_{SS}$. The employee who recovers from early failure has a higher compensation than an employee who obtains short-lived success. In

CCPM philosophy, operation time of a task is divided into two stage: the compressed time and project buffer for overall monitoring. The optimal incentive scheme must inspire potential motivation to pursuit earlier exploratory method; the clarity of uncertain creative information may lead to learning real options and affect the overall result. Project manager have to design appropriate parameters in \vec{w} , to incentive innovative behavior discriminatorily. Although the probability of early success is lower, a proper design of w_s is to be highlighted.

Several parameters are simplified in basic model, such as duration time, expected cost, and discount factor normalized to one. Some improvements might adopt to make the model more widespread. To capture the time value of money and the notion that the effective reward decreases in the project completion time, we set the continuous time discount rate equal to α , $\alpha > 0$. Suppose that the project completion time T is an exponential random variable with parameter λ , satisfies $E\{e^{-\alpha T}\} = \lambda/(\alpha + \lambda)$. Assume that the employee pays a cost of λ^2 at each instant until the project is completed, the discounted cost until completion C satisfies $C = \lambda^2 \int_0^T e^{-\alpha t} dt$, where $E(C) = \lambda^2(1 - E\{e^{-\alpha T}\})/\alpha = \lambda^2/(\alpha + \lambda)$. To establish a benchmark for the employee's optimal work rate and optimal profit, the numerical restriction is introduced to the basic model, namely, $c_i + \max(c_j, c_k) \leq \lambda^2/(\alpha + \lambda)$ (10), λ is the optimal work rate that maximizes the expected discounted profit for creative work. The expanded time-based model is efficient because it does not require the project manager to monitor the employee's actual work rate or to verify the employee's actual operating cost. The project manager may be able to use this information to negotiate better payment terms with the employees, and makes better application of optimal incentive contract \vec{w} to implement innovation project effectively.

5. Situational experiment

In a controlled laboratory setting, we provide evidence that two staged incentive contract is effective in motivating innovation than the traditional mechanism.

5.1. Experiment design

We make an empirical study by questionnaire and situational experiment through a common course in college, known as electronic ERP training course. A total of one hundred and sixty-eight juniors in Zhejiang province take part in this experiment. According to CCPM method, the whole duration of each critical task is divided into two periods; the first period is 50% probability of successful completion time, namely two classes. The second one equals to the project buffer shared by single critical task, namely one class. As a rule of thumb, the probability of finishing critical task on time is 75%. The most creative task is designed to

execute the optimal incentive contract to avoid behavior deviation for accumulation learning effects. All the participations have engaged in entrepreneurship education. There are three kinds of incentive contracts, and the rewards are reflected in the comprehensive score of this course directly. Before we start the experiment, the five different scenarios are announced to the participants, and the participants required to put forward acceptable bonus scores in each scenario. The average value is determined to be the real data in incentive scheme. Every person is assigned to adopt only one predetermined contract randomly. At the end of experiment, the participants will be required to finish questionnaires immediately.

Contract 1: If you have finished the critical task in two classes, you will get 10 points as bonus points besides aggregate score; if the duration exceeds two classes, but you have finished it in period two, you will get 5 points as bonus points.

Contract 2: The premiums are allocated in accordance with the percentage completed on the task and the degree of innovation. *F* represents not finishing task in period one for adopting innovative method; *S* represents finishing task in period one for adopting conventional method; *SS* represents finishing task in period one for adopting conventional method and try innovative solutions in period two; *FF* represents taking creative solutions in two periods, and not finishing task in time; *FS* represents not finishing task in period one for adopting innovative method, but taking conventional method to finish task in time. *SF* does not exist in this case. Combined with the participants' acceptance values, the incentive scheme is

$$\vec{W} = \{W_F, W_S, W_{SF}, W_{SS}, W_{FF}, W_{FS}\} = \{8, 2, 0, 6, 1, 2\}$$

Contract 3: Contract 2 requires a large number of monitoring and control costs, we simplify operation without consideration of *S* and *FF*. The incentive scheme can be rewritten as

$$\vec{W} = \{W_F, W_S, W_{SF}, W_{SS}, W_{FF}, W_{FS}\} = \{8, 0, 0, 8, 0, 2\}$$

5.2. Experiment analysis

After the experiment, all of the participants finish the innovative behavior questionnaire by Scott & Bruce (1994). On a 7-point scale ranging from 1 ("Strongly disagree") to 7 ("Strongly agree"), participants are asked to report how often they promote innovative behavior during the course. 157 copies are valid returned questionnaires. Sample items are: "Develops adequate plans and schedules for the implementation of new ideas"; and "Search out new technologies, processed, techniques, and/or product ideas." Cronbach's alpha of the scale is 0.923, confirmatory factor analysis reveals that the scale has a high reliability, GFI = 0.883, AGFI = 0.857, CFI = 0.916, RMSEA = 0.076.

We use dependent sample Mann-Whitey tests to analyze differences among innovative performance of each incentive schemes, When $\alpha = 0.05$, performance of contract 1 and contract 2 have significant difference (Sig.(2-tailed) = 0.030), the average scores of contract 2 exceed the scores of contract 1 apparently; performance of contract 2 and contract 3 have no significant difference (Sig.(2-tailed) = 0.0325). It reveals the innovative performance of contract 2 and 3 is relative higher than contract 1, and the monitoring cost of contract 3 is much lower than contract 2. Contract 2 is the relative optimal one due to its economical efficiency. The effect of a covariate factors are controlled with an analysis of covariance (ANCOVA) to examine the effect of different incentive mechanism for individual innovation behavior (Table 1).

Variables		Innovation behavior
		F
Control variables	Team size	0.216
	Sex	1.227
	Major	2.561
	Duty	5.362**
Independent variable	Incentive mechanism	9.057***
R^2		0.093
Adjusted R^2		0.075

*P < 0.05, **P < 0.01, ***P < 0.001

Table 1. Results of ANCOVA

This experiment shows that employees may inclined to avoid the risky innovation behavior for risk-aversion and pursuing its own interest based on the conventional linear incentive scheme. The two staged incentive scheme is more suitable for creating and implementing learning real options, which will lead them to carry out innovation. Given the monitoring cost of innovation, the incentive scheme will be simplified in practice. The project managers must pay closer attention to early innovation behavior and monitoring feedback of competition time.

6. Concluding remarks

This paper represents a new problems arising from CCPM philosophy, our goal has indicated a two staged incentive contract coordinated with efficiency and innovation to coordinate the overall benefits. By model solving and situational experiment, we can conclude that the compensation for failure in early period can make full use of learning real options, and promote employees to throw themselves into innovation process efficiently. Although the model is simplified and the experiment is in a controlled laboratory setting, we provide evidence that the combination of tolerance for early failure and reward for long-term success is effective in

motivating innovation. The results of this research are proving to be objectively valid by panel data analysis. Some research have studied the careers of investigators of the Howard Hughes Medical Institute (HHMI), and pointed out that tolerating early failure, rewarding long-term success, and giving its appointees great freedom to experiment are beneficial to increase exploratory performance.

Throughout this paper, we do not include the individual characteristics of uncertain perception, which might affect the consistency of external validity. Anyhow, it's a common issue to construct win-win climate and exploit potentialities from trust, cooperation and communication. Future research might introduce individual variables to extend the applied scope of two staged incentive contract with scrupulous design of experiment conditions. Although there is a dispute in the academic circles, the relationship between motivation and innovation has been one of the hottest topics. The findings of this study should encourage project managers to stimulate their followers by dynamic balance of efficiency and innovation.

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