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ITJ

ISSN 1812-5638

INFORMATION TECHNOLOGY JOURNAL

ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

Information Technology Journal 12 (17): 4196-4199, 2013
ISSN 1812-5638 / DOI: 10.3923/itj.2013.4196.4199

Application Research on the Critical Chain Technology in Engineering Project Schedule Management

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Abstract: In this study, based on the actual needs of our country's engineering project schedule management, Dr. Goldratt's critical chain management theory is optimized and builds a critical chain schedule management model which can be widely used in the engineering practice.

Key words: Uncertainty, schedule management, theory of critical chain, buffer

INTRODUCTION

In the process of in-depth research of project management methodologies, national scholars found that the uncertainty in carrying out the project, especially that of decision makers' behavior, is one of the most important factors to impact the accomplishment of the project on schedule. In the project implementation process, the traditional project schedule management methods are usually based on the assumption that the decision-makers are completely rational reason or can be rational to deal with the problem. However, the discovery of overconfidence (Oskamp, 1965), psychological anchor (Tversky and Kahneman, 1974)and other non-rational behavior features makes people question this assumption. Dr. Goldratt first proposed critical chain project management methods against uncertainties arising in the process of project planning and implementation. The critical chain project management method fully considers the impact of the uncertainty of behavior on the project, taking into account resource constraints and the uncertainty of managers' behavior, making use of risk aggregation principle, to shorten the duration of the project. Schedule, established in accordance with the critical chain project management methodology, is closer to the actual situation and has great significance on timely completion of the project.

CRITICAL CHAIN PROJECT MANAGEMENT METHODOLOGY

Critical chain theory: The critical chain is identified as a long quest chain in full consideration of the logical relationships between processes and case of resource constraints. Identification of critical chain is kind of optimal allocation of resources under the conditions of the critical path. Therefore, the critical chain is the longest critical path identified ultimately, starting from identifying different kinds of constraints in the project based on the theory of the critical chain management, then reducing the impact of constraints on the process by taking measures and turning the constraints into a non-constraints step by step.

In response to the uncertainties of the project, the critical chain method proposes the way of setting buffer based on risk aggregation theory. Buffer can be compared to a dummy procedure (Wang, 2007) inserted in the ends of the project, which, however, is totally different. Buffer settings can effectively control uncertainties existing in the project so as to ensure the smooth execution of the project according to the plan. Set the project buffer at the end of the critical chain in order to effectively control the uncertainties on the critical chain and then to avoid occurrence of delayed projects. The buffer should be set at the entrance of non-critical chain joining in the critical chain so as to import buffer to control uncertainties in the non-critical chain, thus ensure the critical chain is not affected, while, the resource buffer is just a warning mechanism which does not consume project time.

Basic consumption of the critical chain theory: The core idea of Critical Chain Project Management is the concretization of the theory of constraints. Its specific application is mainly the following assumptions:

- **Human behavioral assumptions:** In formulating the project schedule, the presence of uncertainty makes the decision-makers often tend to take a higher

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guaranteed rate to estimate the process duration. According to the human behavioral assumptions in the project planning phase, the various processes of the project all set safety time. However, in the actual construction process of the project, the project's extension risk has not been improved and the setting of safety time did not play a great role. Through the study of human behavior psychology, Goldratt thinks that Parkinson's Law (Wang, 2008), the student syndrome (Zhu, 2010) as well as managers' psychological factors in the case of multi-task are the main factors resulting in project extension

- **Taking the critical chain as the constraint of the project:** Traditional project schedule management method thinks that the main factor of restricting the progress of the project is critical path. However, critical chain project management theory thinks that the project's duration is determined by the critical chain (Zhang, 2009). Therefore, the critical chain theory takes the critical chain as the constraints of the entire project and proposes that project's focus is to identify and control the critical chain. And only the critical chain operating smoothly can ensure that the project does not generate extension risk
- **Managers tend to conservatively estimate the process duration in making the plan:** Due to the project faces many uncertainties, policy makers always reserve excessive resources and time to address the impact of uncertainty on the project in the estimation of process duration. In order to complete the project on schedule at the maximum probability, most of the decision-makers dub themselves with higher guaranteed rate of completion in the process duration estimates.

Based on the above assumptions, the critical chain management approach takes important consideration of human behavioral factors, resource supply and other issues and by eliminating redundant safety time, setting three kinds of buffers and the buffer warning system and taking a series of measures to reduce the risk of the project extension.

CONSTRUCTION OF PROGRESS MANAGEMENT MODEL BASED ON CRITICAL CHAIN TECHNOLOGY

The key to improve the existing schedule control model and improve its performance is how to accurately reflect the projects' internal logical relationship between the various processes and their uncertainties as well as effectively reflect in the construction of the model.

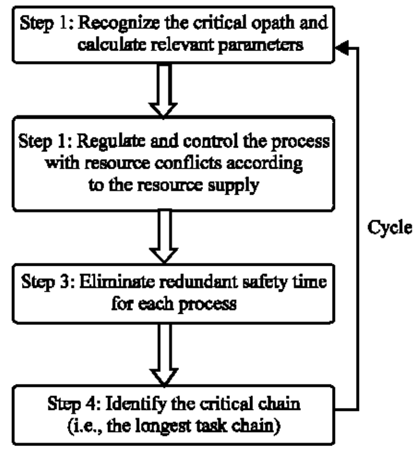

Fig. 1: Specific steps of identifying the critical chain for projects

Identification of the critical chain: The difference between Critical chain method and the traditional schedule management method lies that the critical chain method takes full account of the impact of resource constraints and uncertainty of human behavior on the project in planning the project schedule. Therefore, in identifying the critical chain, we can refer to the critical path. The specific steps of identifying critical chain project are as shown in Fig. 1.

Currently, there are many ways to identify the critical chain, but there is not a generally accepted best one. Based on the goal of minimizing the duration, formula of model is as follows:

$$\text{Min}T_m \quad m = 1, 2, 3, \ldots, n \tag{1}$$

$$s.t. ST_j - ST_i \geq d_i, \quad i, j \in A_t \tag{2}$$

$$J = 1, 2, 3\ldots, N; \; l = 1, 2, 3, \ldots, M \tag{3}$$

In Eq. 1, $\text{Min}T_m$ indicates the shortest critical key with the shortest project cycle in the certain ones. Equation 2 shows a constraint relationship between processes. The duration time of process i is formulated with d_i, while the planned time of process i with ST_i and all the processes included in link t is with A_t. Equation 3 gives the project's resource constraints. R_{jl} indicates process j's demand for resource l in period time t. R_{tl} indicates the total supply of resources. Here, we suppose that the process' demand for resources will never surpass the total supply. However, in the actual operation process of the project, the situation where the project is restricted by a single resource is rare and most of the projects are also subject to a variety of resource constraints.

Setting of buffer: Buffering mechanism is the core and key chain of critical chain technology. The aim of setting the buffer is to deal with in the impact of the uncertainties on the progress of the project, especially human behavior uncertainties. Setting of the buffer is to put all the safety time together and apply it reasonably to the buffer according to the needs, which is the application of the principle of risk aggregation. Thus, it does not increase the overall project completion risk and can effectively shorten the duration time of the process at the same time, so that the total project duration could be shortened.

Setting of coefficient: The commonly used methods are cut and paste method as well as and root variance method. But all of these methods don't take into consider such problems as risk preferences of decision makers and nature of in-process uncertainties. Therefore, although the calculation is simple, it cannot effectively achieve its original purpose. Taking full account of policy-makers risk preferences, characteristics of the process and differences of uncertainties, the article comes up with a new buffer calculation method, on the basis of the traditional three-point (a, m, b) valuation method.

Cumbersome coefficient a of process operation: Cumbersome coefficient of processes operation is the value earned by dividing the total number of immediate predecessor activity by the amount of process in the link. And it is represented by letter A. Its calculation method is as Eq. 4, that is, immediate predecessor activity included in process i is formulated with N_j and the amount of the process in the link of process i is with N_i. Immediate predecessor activity owned by a process has a tight effect of the uncertainty. The two are in proportional relationship:

$$B = \frac{m-a}{b-a} \tag{4}$$

Importance coefficient ρ of process: In the step of calculating the buffer's size, we may introduce the importance coefficient ρ of process. It represents the incidence of each step to the buffer. In order to facilitate the calculation, ρ's data will be set to a range from 0-1. Importance coefficient is given by the experienced experts and technicians according to the actual situation.

Risk degree B of process extension: Risk degree of process extension is a method to identify the risk degree of the process, which is on the basis of three-point estimation method made up of the most optimistic value a, the most probable value c and the most pessimistic value b. In the process of calculating the buffer's size, we could control the potential effects of each process on the project within an acceptable range by introducing risk degree of process extension. As shown in Eq. 5, the size of value B indicates the risk degree of process extension. The higher of value B, the greater probability of the process extension. So, it should be highlighted controlled:

$$A_i = \frac{N_j}{\sum_{i=1}^{n} N_i} \tag{5}$$

Adjustment coefficient δ of manager's risk preference: Manager's risk preference has an important impact on project schedule. According to different construction projects, policy-makers face different degree of risk. The risk degree of policy-makers determines their attitude towards the project. The greater risk policy-makers face, the stricter they are with the projects. If the process is enough, then the project duration is normally distributed. And under the 95% guaranteed rate of completion, the safety time is 2 times of that of process standard deviation. Assuming the level of risk preference of decision makers is ϵ, then the standard deviation under the assurance rate of 1-ϵ is f_{rg} (the value can be obtained by checking the normal distribution coefficient table).And the adjustment coefficient δ is calculated as follows:

$$\delta = \frac{f_{rg}}{2} \tag{6}$$

Setting procedure of the buffer:

- Eliminate safety time of the process and determine the critical path, namely, bottlenecks of the project
- Determine the value of ρ, A and δ
- The calculation is as follows:

$$PB = \sum_{m \in C} \rho_m (t_m - T_m)(A_m + B_m)(\delta \pm 1) \tag{7}$$

$$FB = \sum_{m \notin C} \rho_n (t_n - T_n)(A_n + B_n)(\delta \pm 1) \tag{8}$$

- Insert the size-determined buffer in the proper position of the process chain. Check whether the original critical chain is the longest one of the project after the insertion. If the original key chain is no longer the longest path, we need to re-identify a new one. However, if it is still the longest, then you can implement the schedule

CONCLUSION

Critical chain technology is a major innovation of project management and a major breakthrough of project schedule management as well. On the basis of scholars at home and abroad, the text considers the situation where the process' scheduling problem is affected by multi-resource constraints and have an in-depth discussion about issues such as identification of the critical chain and setting of buffer with the However, as a new approach to project management, the critical chain method is still immature and it also can't solve all the problems of the project management. So, it is still necessary to make a further in-depth study and discussion.

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