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Schedule Uncertainty Control: A Literature review

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Abstract

Risk control on project schedule is one of the focus problems in the academic circle and the practical area all the time. Lots of research about risk control on project schedule have been fulfilled and many achievements have appeared in recent several decades. The literature on the techniques of schedule uncertainty control was reviewed. A summary analysis on those chievements is presented such as CPM, PERT, MC, BBN, and so on and in light of that summary analysis a deep discussion in terms of advantages and disadvantages of existing research has been analyzed, so that researchers can continue to refine their research.

Keywords: Construction Project, Schedule, Risk Control, Literature review

1. Introduction

The control of project scheduling is a vital part in the process of project construction, especially for those projects which consider project time and budeget as targets. Deliverying project on-time or not have much to do with earning or losing a profit and/or a return on investment for parties. In that case, many different techniques and tools have been developed to support better project scheduling, and these tools are used widely by a great majority of project planners.

To create schedules, bar charts (Gantt chart)[1] and the critical path method (CPM)[2] have been the best-known techniques for project scheduling through the decades. Bar charts are easily understandable and generally utilized for communication on-site at the worker level, and the critical path method (CPM) is used as the most popular means of monitoring project scheduling [3]. In light of CPM, relations between activities were shown, the critical activities and activity float times can be observed, so that project scheduling can be control.

During project execution, however, project schedules are affected by uncertainties in weather, design, labor efficency, equipment efficiency, site conditions, etc.. Those uncertain factors may directly or indirectly lead to schedule risks. It is well-known that bar charts and CPM are purely deterministic in

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nature without considering uncertainty. In the CPM and bar charts, those duration values can not be changed by various risk factors which lead to an inappropriate critical path identification and a defective completion time estimation. In order to handle uncertainty by taking risk factors into account, program evaluation and review technique (PERT) [4-7], the probabilistic network evaluation techique (PNET) [8], narrow reliability bounds (NRB) [9], critical chain scheluling (CCS) [10] and Monte Carlo simulation (MCS) [7,11] were developed. Actually all those methods mentioned above are improved methods based on CPM.

Schedule risk analysis methods such as PERT, MCS etc. are able to incorporate uncertainty in a restricted way by trying to estimate the variance of completion time based on some kind of probability distribution functions. They are insufficient in identifying the sensitivity of activities or the whole schedule to risk factors. Furthure more, they ignore the correlation impacts between activies and between risk factors [12,13], they assume that the relationship between activities and risk factors are independent. However, there are relationships between risk factors, and when various activities are influenced by the same factor, these activities are connected by the same factor and be correlated, which will increase the variability of path duration, and perhaps will causes highly uncertain to the project completion date [13].

In 1999, a survey by the Project Management Institute[14] showed that nearly 20% of project management softwares support MCS. Now, with the development of computer techniques and scientific theories there is some reason to believe that more than 20% of project management softwares support MCS. For instance, PerMaster [15] utilizes scheduling data from tools like MS-Project and Primavera and incorporates MCS to provide project risk analysis in time and cost. However, MCS assume activity durations and risk factors as independence, therefore PerMaster can not deal with the uncertainty caused by correlationship, then people who use this kind of tool ignore the correlations and even donot understand correlations. In that case, the way to estimate project scheduling lack accuracy and does not in accordance with the practice of real projects.

Bayesian networks (BBNs) [16,17] is an appropriate opproach to handling uncertainty, especially uncertainty derived from correlationship, where the complex causality are involved. A BBN is a directed acyclic graph (DAG)，it provids two kinds of information, one is qualititative information which is defined by a DAG to show the direct independent and dependent relationship between variables, another is quantitative information which is described by conditional probibilites to show the correlation of variables.

2. Literature Review

Researchers have widely discussed scheduling estimation issues for years. As mentioned above, the CPM provides very useful and fundamental information about activities' schedule so as to be studied intensively, especially the resource-constrained issue based on the CPM.

Liu and Shih [18] proposed a framework of schedule constraints named critical resource chain where three scenarios of schedules were successfully analysed, such as a CPM-based schedule, an (resource-constrained project scheduling problem) RCPSP-based schedule with the goal of minimized overall schedule duration, and an RCPSP-based schedule considering a time–cost trade-off. Lu and Lam [19] introduced the problem of how to incorporate the effects of multiple resource calendars on CPM scheduling, and presented a new method for accurately assessing the effect of an activity in extending the total project duration, with the results compared against those produced from P3, then identified the accurate TF for those activities whose TF were overstated by P3 in the two case studies. Kim and de la Garza [20] proposed the resource-constrained critical path method (RCPM), and evaluatesd the RCPM's performance by comparing it with five related previous studies, which (and this comparison) showed that RCPM performed well in identifying resource links and alternative schedules, compared to other other studies provided in Wiest [21], Woodworth and Shanahan[22], Bowers [23,24] and Lu and Li [25]. Christodoulou [26] applied Ant Colony Optimization artificial agents to a esource-constrained network and utilized that method in examining the effects of resource availability constraints to critical path calculations and project completion time.

For considering schedule uncertainty, Kuklan et al. [27] presented a procedure which was proposed to assign a priority ranking to every activity, compute the highest completion delay absorbable at each activity, and determine, for all activities, the probability of completion within their latest allowable time. Zhong and Zhang [28] calculated the noncritical path float in PERT to copy with the uncertainties within the network implementation and the results of a example showed the consistent path float under required completion probability and required duration. zaron and Tavakkoli-Moghaddam [29] developed a multi-objective model for the resource allocation problem in a dynamic PERT network, where the activity durations were exponentially distributed random variables and the new projects were generated according to a Poisson process. Lee and Arditi [30] describes a stochastic simulation-based scheduling system (S3) that integrated the deterministic CPM, PERT, and the stochastic discrete event simulation(DES) approaches into a single system and leted the scheduler make an informed decision as to which method is better suited to the company’s risk-taking culture and allowed researchers to compare the outcome of CPM, PERT, and DES under different conditions such as different variability or skewness in the activity duration data, the configuration of the network, or the distribution of the activity durations. Based on improved-PERT, Zhang and Sun [31] used the Monroe method to estimate probability distribution of important activities and the equivalent-weight probability method to amend project duration. Then the probability of project schedule risk was computed based on probability theory, and so successfully gains the project risk-level .PERT is able to deal with schedule uncertainty with probability without taking correlationship between risk factors and between activities into account. Castro et al. [32] defined a new rule for the resolution of the slack allocation problem in a PERT network, a new rule for the allocation of slack in a PERT network based on the duration of the activities, which allowed a schedule to be made at any point during the execution of a project, then a schedule can be planed at the beginning of the project or be adjusted once a delayed or a time-saving process appeared.

With the improvement of simulation techniques, Cheng et al.[33] discussed a way to apply Monte Carlo simulation to PERT to deal with the stochastic time of activity. Li et al. [34] analyzed a real project’s network program with Monte Carlo simulation technique, and the results showed that the stochastic network program provided more substantial schedule information than ordinary network program. Xu [35] applied MC in resource constrained project scheduling problem. Huang and Wang [36] applied PERT and MCS in analyzing project duration and the result showed that the MCS method is convenient, effective and efficient under considering of the changeability and randomness of duration for each activity.Wang and Demsetz [12,13] presented the simulation-based model networks under correlated uncertainty(NETCOR), which incorporated the effect of correlation in network schedules and provided factorssensitivity information to support schedule risk management. Diamantas et al.[37] compared the results of the standard MCS with those of PERT and addressed the incorporation of project risk management into the two approaches and revealed that the modelling of risk is more robust when the MCS was used, leading to the conclusion that simulation was a more efficient tool than the other stochastic methods. In Kirytopoulos[38] and Leopoulos’s [39] works, PERT and MCS were used and the results produced under four different scenarios were compared. The findings validate that MCS was superior to PERT and moreover exposed the difference in the results when the suitable distributions were selected based on accurate historical information compared to when historical information was not available. Chu et al. [40] focused on of how to determine the most K Critical Paths (KCP) for stochastic network and proposed a Path Comparison Tracing Algorithms (PCTA) to solve this problem.In their paper numerical results were compared with results of the PERT and the MCS of 20,000 samples, then concluded that the proposed approach was efficient for solving the KCP problem of stochastic networks. Ökmen and Öztaş [41] presented a new MCS-based model—the correlated schedule risk analysis model (CSRAM)—to evaluate construction activity networks under uncertainty when activity durations and risk factors are correlated, this application showed that CSRAM operated well and produced realistic results in capturing correlation indirectly between activity durations and risk factors regarding the extent of uncertainty inherent in the schedule.

All above methods, deterministic or probabilistic, are based on following assumptions [42]:

- Number of activities in a project network is defined as a constant,
- The logical relations among activities do not vary by the project executing,
- The activities' duration can be estimated and defined as independent from each other, and
- The total time distribution of a project is approximately normal.

BBNs are graphical tools used to represent a high-dimensional probability distribution and are convenient for making inferences about uncertain states when limited information is available [43] . So far, BBN have been used for making diagnosis in medica and health [44-46] and engineering applications[47,48], fault prediction [49], artificial intelligence [50], and are common in system reliability assessment[51,52], transportation [53], operational risk modelling [54,55], environmental modelling [56,57], traffic accident modelling [58] and national security and terrorist threats [59]. A common target of many of these research is to utilize the abilities of BBNs which are able to cope with quantitative information and qualitative information simultaneously to facilitate reasoning and decision making under uncertainty.

However, Papers concerned specifically with scheduling risk modelling within project management using Bayesian networks are limited, with a relatively short history. These include Nasir et al.[42].and Khodakarami et al. [60].

Nasir et al. presented a new model named Evaluating Risk in Construction–Schedule Mode which used a belief network to evaluate construction schedule. In this paper, firstly, construction schedule risks were identified through a literature review, an expert review, and a group review by a team of experts. Secondly, cause effect relationships among these risks were identified through an expert survey. This leded to the development of the structure of belief network model. Thirdly, probabilities for various combinations of parents for each risk variable were obtained through an expert interview survey and incorporated into the model. The model was tested using 17 case studies with very good results. This paper actually only showed the basic essential factor included in a BBN and introduced the basic working principle of a BBN.

In Khodakarami et al.'s opinions, project scheduling inevitably involves uncertainty. The basic inputs (i.e. time, cost and resources for each activity) were not deterministic and were affected by various sources of uncertainty. Moreover, there were a causal relationship between these uncertainty sources and project parameters; this causality was not modelled in current project planning techniques (such as simulation techniques). They introduced an approach that use bayesian network modelling to produce CPM. Unfortunately, in their paper there was no case to support.

Although there is not much research in risk analysis of project scheduling using BBNs, the characteristics of BBNs enable BBN to be a appropriate tool to deal with correlaionship and simultaneously analyze schedule risks. So far, existing project management softwares like PerMaster can handle uncertainty in limited way without taking into account the effect of correlationship, so that people who use those kind of softwares do not consider relationship between activities, even do not know/understand there are correlation between activities. In fact, the correlation exists between activities and between risk factors, without considering the correlationship will affect the accuracy of evaluation results.

3. Conclusion

Overall, there are a long time for the research of the analysis/control of project schedule, and development of with engineering technology, project management model, computer science, new theories and methods of risk analysis are constantly emerging then in a wide range of applications, which promotes improvement in decision-making. These techniques mentioned above for analysis/control project networks are more and more more realistic which lead us to understand the uncertainty in project network.

It is well known that CPM, PERT, MC are the most popular techniques for project scheduling, but they are not able to or limited in handle uncertainty in estimating project scheduling; BBN is a new techniques especially in the area of project management, which provide a good way to deal with the uncertainty that the can not be handle in troditional ways, such as the uncertainty caused by correlationship between activites and risk factors. In the furture, utilizing BBN in project management and more appropriate techniques considering more uncertainty in the project schedule are necessary for improved outcomes.

Further more in order to meet the evolving needs of project practice, deeper studys required be developed that is the only efficient way to combine theories and practices.

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