Research Journal of Applied Sciences, Engineering and Technology 5(4): 1407-1412, 2013
DOI:10.19026/rjaset.5.4880
ISSN: 2040-7459; e-ISSN: 2040-7467

Submitted: July 09, 2012 Accepted: August 08, 2012 Published: February 01, 2013

Research Article

Risk Element Transmission Model of Construction Project Chain Based on System Dynamic

Cunbin Li, Gongshu Lu and Peng Li
Department of Economic and Management, North China Electric Power University, Beijing 102206, China

Abstract: This study aims to study the dynamic risk transmission process through project chain among multi projects, which means the risk of one project would influence other projects through project chain. Based on system dynamic, a model of risk element transmission in cost-period chain between 2 construction projects is established and then accordingly studies how the risk element influences the other project. At last an example is simulated by using system dynamic software and the final effect on other project result from risk element transmission is calculated, under which the risk managers would take reasonable risk response measures for risk management. Besides, the simulated result of model provides strong support for using system dynamic to do research on risk element transmission.

Keywords: Construction project chain, risk element transmission, risk management, system dynamic

INTRODUCTION

With the continuous development of science technology and social economy, the scale of modern enterprises is enlarging rapidly. Once upon a time, most of enterprises just managed one project at a fixed time, but now several projects are implemented by an enterprise at the same time. As a result, project management is no longer confined to the objects of single project and then in order to maximize the overall efficiency of enterprises, the integrated management which includes procurement management, human resource management and cost management etc is needed. At the same time, the project risk management should also take risk element transmission among multi projects into account, viz., the problem that risk of one project would affect other projects should be concerned particularly.

In the field of project risk management, lots of different models, tools and techniques were studied and used in project risk management. Kash Barker proposed a framework of quantitative risk for analysis, in which a model was used to measure the sensitivity of the uncertainty of the basic parameters probability distribution affected by the consequences of extreme events (Kash and Yacov, 2009). This approach avoided the human influence factor in expert assessment method and had a good effect on the risk decision making. Alejandro Balbás transformed the risk function into an infinite-dimensional Banach space of linear programming and the general simplex algorithm was given (Alejandro *et al*., 2009). Besides, there are also many researchers use method of artificial neural networks (De Beule *et al*., 2007), genetic algorithms (Cahit *et al*., 2007), Monte Carlo simulation (Siu *et al*., 2007) to solve the project risks problems, respectively.

Foreign scholars have done a lot of risk management research and the related theory is mature, but the research on risk element transmission among projects is not enough. While some domestic scholars do some research on risk element transmission. Li cunbin defined the basic risk variables as risk element and proposed that the project objectives (such as period, cost, etc.) often fluctuate when the risk elements fluctuate randomly. This kind of transmission is called risk transmission (Li *et al*., 2004). He also introduced the 3-dimensional model of generalized project risk element transmission theory, in which a risk element transmission analytical model was proposed in order to study the transmission impact of project period risk element (Li and Wang, 2007).

Based on analysis above, it is easy to find out that the single project risk management theory is mature now and the study of project risk element transmission is limited in single project. While the research of project risk management should not only study the impact of risk element to the current project, but also to study the impact of risk element to other projects. Some people argues that some chain structures exist among multi projects, for example, there is project period (life cycle) chain, cost control chain, resource allocation chain and so on and sometime the synthetically chain

Corresponding Author: Cunbin Li, Department of Economic and Management, North China Electric Power University, Beijing 102206, China

may exist, while the project risk may transmit in those chains, then the concept of “project chain” was proposed (Cunbin and Liang, 2009). So, the project risk transmission impact on other projects can be seen as risk element transmission impact in different projects chains.

In this study, a model-based system dynamic approach is proposed for project chain risk element transmission problem. Having defined risk element transmission influence as the model purpose and the construction cost and period as system boundary, this study describes the feedback loop of 2 interrelated construction projects and then establishes a model developed using system dynamics. Finally, by simulating the model and contrasting results of different situations whether the risk element exists, it examines the effect of risk element of project 1 on object of project 2.

SYSTEM DYNAMICS

As a new subject, System Dynamics (SD) was introduced by Forrester as a method for modeling and analyzing the behavior of complex social systems in the late 1950s (Forrester, 1961). Now, it has been used to analyze industrial, economic, social and environmental systems of all kinds. The SD is an applied science based on feedback control theory that combines qualitative and quantitative studies on the dynamic behavior of the development and changes of the system mainly in virtue of computer simulation technology and it is a branch of system science (Tao and Gong, 2008). The main idea of SD is as follows: First is the systems analysis, which determines the boundary of the system and makes clear of the system factors and purpose. Second, find out the cause-effect relationship of various factors of the system and then construct the feedback loops of factors. Finally, establish the system model and simulate it by related SD stoneware.

With its feedback and endogenous perspective, SD approach is effective in dealing with interacted, dynamic project risks, to which most of the traditional modeling techniques are inappropriate (Wang *et al*., 2005). As we know, risk element transmission process represents the dynamic nature of project risk, so we can apply the SD to study project chain risk element transmission problem and simulate how the risk element affects other project through project chain.

SYSTEM ANALYSIS

System purpose: As to risk element transmission in project chain among multi projects, Li cunbin once proposed a four dimensional structure model in Fig. 1 (Cunbin and Liang, 2009). Based on this model, this study selects construction enterprise in the enterprise application facet; In the risk transmission and controlling method facet, SD approach would be applied for the research method and theoretical support; While in the project chain type facet, supposing there is no project quality problem, so this study focuses on the objectives of construction cost and period, viz. “cost-period chain” would be the project chain; Accordingly, chained risk transmission structure is selected in the risk transmission route facet.

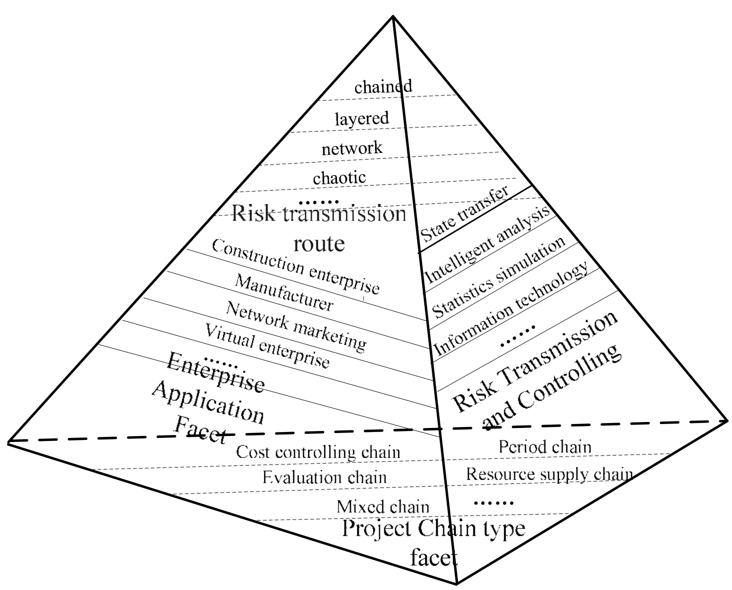

Fig. 1: Model of project chain risk element transmission

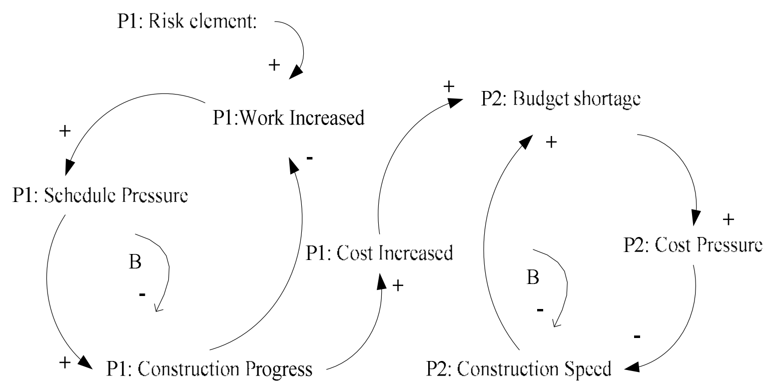

Fig. 2: Feedback loop of two interrelated projects

For clarity in analysis, there are just 2 interrelated projects-project 1 and project 2 in this thesis and according to actual situation, just because the total budget of all projects is limited, the shortage of cost of project 1 should be adjusted by the fund of project 2. From the construction enterprise perspective, project suffers delays and overruns mainly result from changing work quantities, so those factors which would lead to work quantities change will be considered as risk element. When risk element of one project arises and leads to work quantities change, how does it transmit to other projects and impact their cost and period, which is considered the main purpose of the system.

Casual feedback loop analysis: Based on the system analysis, casual feedback loop analysis should be taken to analyze the inter-relationship of the 2 projects. Casual feedback loop diagram is a kind of directed graph, which is often used to analyze complex relationship, existing in dynamic system. It is composed by casual chains, which composed of factors and arrows and the arrows represent influences between the different factors, which are divided into 2 kinds of casual chains, reinforce chain and balance chain. Reinforce chain is represent by an arrow headed line with a symbol "+" and balance chain is with a symbol "-", the loop composed by casual chains is called casual feedback loop. Then the feedback loop is divided into 2 kinds according to the number of the balance chains in the feedback loop. If the number is an even figure or equals to zero, then the feedback loop is called balance loop and represent by symbol "B-". On the contrary, it is called reinforce loop and represent by symbol "R+". Reinforce loop can enhance the variables' fluctuations existing in loop and balance loop can limit the variables' fluctuations existing in loop (Tao and Gong, 2008).

In the process of project construction, the risk element of project 1 may lead to work increased someday, which result to schedule pressure, then to relieve the schedule pressure, construction progress should be accelerated, which will reduce increased work but also induce cost increased. For providing fund to project 1 with cost overruns, the manager should cut the budget of project 2 and then there will be cost pressure of project 2, which slows down the construction progress of itself. Of course the decelerated construction progress of project 2 can alleviate budget shortage of itself. All these cause-effect relationships of 2 interrelated projects can be illustrated in Fig. 2, in which P1 and P2 is the abbreviation of project 1 and project 2, respectively.

SYSTEM DYNAMIC MODEL

Establish the model: According to the feedback loop of 2 interrelated projects, we can establish a dynamic construction model developed using SD to quantitatively analyze the effect on project 2 by the risk element of project 1. The main SD software can be used to build model as follows: iThink, Power Sims and Vensim. In this study, we use software of iThink to build a model as in Fig. 3. As the same, P1 and P2 is the abbreviation of project 1 and 2, respectively.

As to risk will occur in some day in the process of project construction, *P*1: *Added Rate* is calculated by the ratio of *P*1: *Work Available* when the project 1 progresses to a certain period (after day of X and before day of Y), in which the ratio is reflected by *Risk Element*. It is obvious that the more serious of risk, the larger the value of *Risk Element* and *P*1: *Added Rate*. Then *P*1: *Added Rate* will be:

$$P1: \textit{Add Rate} = \text{if } (P1: \textit{Remaining Period} > \text{X}) \text{ and } (\text{Y} > P1: \textit{Remaining Period}) \text{ then } P1: \textit{Work Available} * \textit{Risk Element} \text{ else } 0 \quad (1)$$

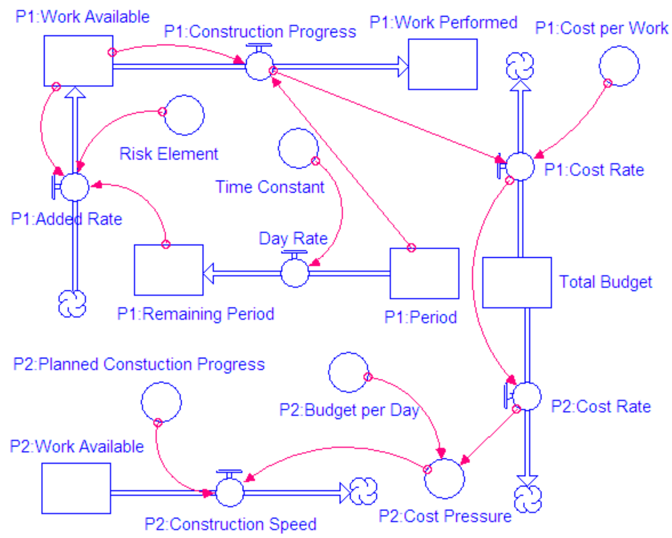

Fig. 3: System dynamic model

Table 1: Parameter values

Parameters	Projects Project 1 (P1)	 Project 2 (P2)	Units
Work available	50000	100000	Unit less
Period	250	250	days
Cost per work	20	20	Yuan
Total budget	1000000	2000000	Yuan
Budget per day	4000	8000	Yuan
Planed CP	200	400	/day

Another factor should be noted is *P2: Cost Pressure*, whose value should be between 0 and 1, and the larger the value of result of *P2: Budget* per Day minus P2: Cost Rate, the greater of P2: Cost Pressure. So P2: Cost Pressure according to the following formula:

$$P2 : Cost\ Pressure = \frac{(P2 : Budget\ per\ Day - P2 : Cost\ Rate)}{P2 : Budget\ per\ Day} \quad (2)$$

Model test and analysis: The model will be simulated with the following setting: The scale of project 2 is 2 times than project 1, but they have the same period, more parameters value of 2 projects as indicated in Table 1, where CP is the abbreviation of construction progress.

At the beginning, the value of Risk Element is set as 0, which means there is no risk in the process of 2 projects, the simulated result shown in Fig. 4. The value of curve 2 (P1: Construction Progress) is keeping 200/day in the entire construction process; On day 250, the values of curve 1 (P1: Work Available), curve 4 (Total Budget) and the curve 5 (P2: Work Available) are 0 and the value of curve 3 (P1: Cost) is 1000000 Yuan, all of which demonstrate the cost and period of projects are the same with the budget and planed period.

Then, suppose the risk occurs during the days of 100 and 120, when the work of project 1 increased at the certain ratio of P1: Work Available, then the certain ratio is reflected by Risk Element is set as 3% and the value of X and Y in Eq. (1) are set as 99 and 121, respectively. Then simulate the model again, the changed result is indicated in Fig. 5.

As to project 1 and project 2, before day 100, the results of Fig. 4 and 5 are the same because the risk doesn't occur then.

As to project 1, after day 100, compared to Fig. 4, 5 shows the values of curve 1 (P1: Work Available) and curve 2 (P1: Construction Progress) increased until day 200, then P1: Work Available decreased but the P1: Construction Progress still keep high level until day 250. Besides, the increase speed of curve 3 (P1: Cost) increased on day 100, which means project 1 suffers cost overruns result from the increased P1: Construction Progress.

As to project 2, after day 100, Fig. 5 shows the decrease speed of curve 5 (P2: Work Available) slow down during the days of 100 and 250, which implies the actual construction progress of project 2 is much more slower than planned construction progress. So, on day 250, when project 1 has been completed on schedule, project 2 hasn't been completed and the value of curve 5 (P2: Work Available) is litter more than 25000, which means project 2 would suffer delays.

Besides, the decrease speed of curve 4 (Total Budget) is always the same, which means the 2 project don't suffer cost overrun although the P1: Construction Progress increased.

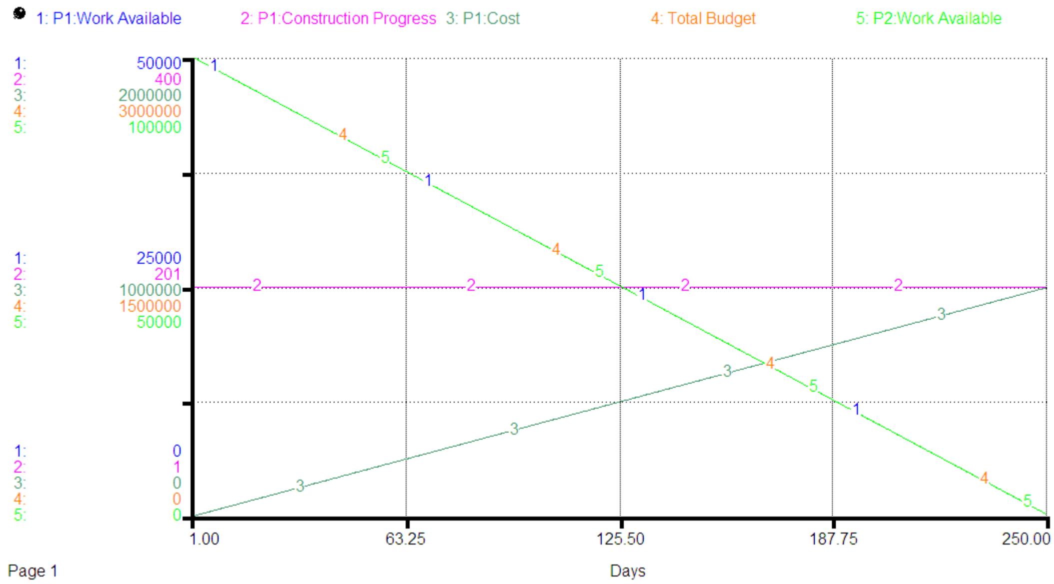

Fig. 4: Simulated result without risk element

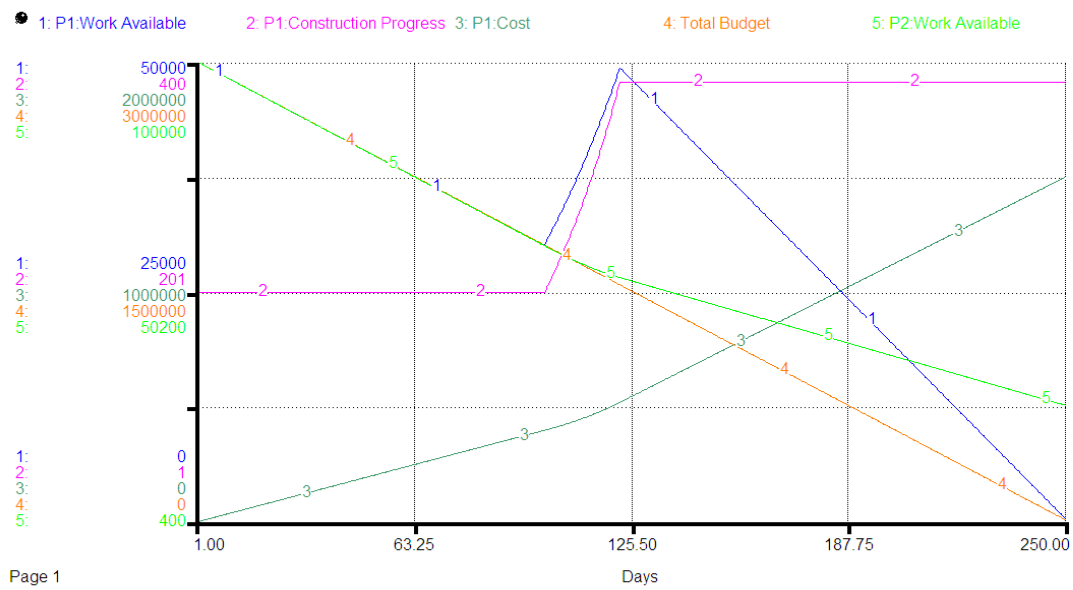

Fig. 5: Simulated result with risk element

From the perspective of risk transmission, the risk element results to increased work of project 1, then the accelerated construction progress of project 1 leads to budget shortage of project 2 through the cost chain between project 1 and project 2. Although there is risk of project 1 and not risk of project 2, the project 1 completes without delay, while the project 2 finally suffers delays, the unfinished 25000 work of project 2 is just the final influence of risk transmission in cost-period chain between project 1 and 2. As to project risk managers, if the economic loss results from the unfinished work of project 2 are more than overruns of project 1, they should interrupt the risk transmission of the cost-period chain, then the project 1 would suffer cost overruns or delays, while the project 2 achieves its cost and period objectives; and if the economic loss results from the unfinished work of project 2 are less than overruns of project 1, they should let the risk transmit from project 1 to project 2 as the model simulated.

CONCLUSION

There are different chains among interacted projects of one enterprise. When the risk element of one project arises, it would transmit to other projects and impact their cost, period and other objectives along with different chains. Based on SD, this study establishes a model of risk element transmission in cost-period chain between 2 interacted projects and then the simulated results demonstrate if the risk element of project 1 transmits to project 2, the project 1 would complete successfully, while the project 2 would suffer delays. According to results, risk managers can take reasonable risk response measures. In addition, SD approach is demonstrated to deal with problem of risk element transmission in project chain among multi projects, therefore SD has a strong potential to research on risk element transmission problems.

ACKNOWLEDGMENT

This work is supported by National Natural Science Funds of China (No. 71071054) and "211 Project" of North China Electric Power University.

REFERENCES

Alejandro, B., B. Raquel and M. Silvia, 2009. Portfolio choice and optimal hedging with general risk functions: A simplex-like algorithm. Eur. J. Oper. Res., 192(24): 603-620.

Cahit, P., A. Amir, K. Hideki, K. Kosuke and S. Masatoshi, 2007. A multi-objective lead time control problem in multi-stage assembly systems using genetic algorithms. Eur. J. Oper. Res., 180(1): 292-308.

Cunbin, L. and Z. Liang, 2009. Research on multi-risk element transmission model of enterprise project chain. Proc IEEE Symp. Inform. Manage. Innov. Manage. Ind. Eng., (ICIII 09), 2: 345-348.

De Beule, M., E. Maes, O.D. Winter, W. Vanlaere and R.V. Impe, 2007. Artificial neural networks and risk stratification: A promising combination. Math. Comput. Model., 46(1-2): 88-94.

Forrester, J.W., 1961. Industrial Dynamics. Productivity Press, Portland OR, USA.

Kash, B. and Y.H. Yacov, 2009. Assessing uncertainy in extreme events: Applications to risk-based decision making in interdependent infrastructure sectors. Reliab. Eng. Syst. Safe., 94(4): 819-829.

Li, C., L. Fan, Y. Guo and Z. Li, 2004. The analytic model and it s application of generalized project risk analysis. Proceeding of International Conference on Construction and Real Estate Management, pp: 229-231.

Li, C.B. and K.C. Wang, 2007. Research on the risk element transmission analytic model of construction network planning project. Chinese J. Manage. Sci., 15(32): 108-113.

Siu, K.A., W. Zhi-Hua and L. Siu-Ming, 2007. Compartment fire risk analysis by advanced Monte Carlo simulation. Eng. Struct., 29(9): 2381-2390.

Tao, Y. and X. Gong, 2008. Applying System dynamics to analyze the impact of incentive factors' allocation on construction cost and risk. Proc. IEEE Symp. Machine Learn. Cybern., (ICMLC 08), 2: 676-680.

Wang, Q.F., X.Q. Ning and J. You, 2005. Advantages of system dynamics approach in managing project risk dynamics. J.Fudan Univ. Nat. Sci., 44(2): 201-206.