Analysis on Multi-factorial Risk Coupling Effect of Construction schedule of Large Construction Projects

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Abstract: This paper aims at researching on multi-factorial risk coupling effect on construction schedule of large construction projects. Combined with related data of construction industry in China and with the means of $N-K$ model and Matlab simulation, the paper has got the effective value of multi-factorial risk coupling . The result shows that personnel is the key factor in multi-factorial risk coupling which leads to project accident and schedule delays. Therefore, paying attention to multi-factorial risk coupling, especially including personnel factor to make early measures can narrow risks down and reduce losses.

Introduction

In recent years, the relevant research have been proven that the most prominent problems in the large-scale construction projects are mainly concentrated in the construction schedule, quality and safety, among which the proportion of schedule has reached to 49%[1]. After adopting of a large number of theoretical analysis and empirical findings some researchers have found that factors which affect construction schedule permeate all aspects of the project. However, these factors always couple to each other instead of impacting on schedule lonely, besides, after coupling the harm of scope will expand and losses will be also increase. So there'll be great importance to study multi-factorial risk coupling to guarantee the smooth construction of large-scale construction projects.

Risk factors and coupling in construction schedule

A large number of theories and practices shows that personnel、materials、equipment and environment is the major risk factors which affect schedule greatly in large-scale construction projects. The details of these factors have been shown in Table 1.

First Factors	Code	Weight (%)	Second Factors	Weight(%)	Code
Personnel	A	29.4	Low management level in personnel	20.5	A1
			Few experience of technicians	18.9	A2
			Shortage of construction personnel	19.9	A3
			Poor physical quality of construction personnel	20.1	A4
			Low speed in submitting design drawing of design personnel	20.6	A5
Materials	B	24.9	Supply with delay	23.0	B1
			Proper quality	23.3	B2
			Using inappropriately	20.0	B3
			Storage unreasonably	16.1	B4
			Unsuitable technical parameters	17.5	B5
Equipment	C	24.5	Inappropriate selection	25.7	C1
			Storage unreasonably	21.8	C2
			Operating inappropriately	27.9	C3
			Maintenance not in time which leads to aggravation of wearing and aging	24.7	C4
Environment	D	21.4	Changes of relevant policy、laws and regulations of nation and industry	25.7	D1
			Culture diversity in different territory	24.1	D2
			Natural disaster of typhoon、flood and earthquake	27.4	D3
			Noise and air pollution in the process of construction	22.8	D4

Table1 Risk Factors in construction schedule

However, the first factors and second factors always couple with each other instead of taking place lonely, effect schedule, extend the risk scope and evolve into a new kind of risk[2]. For example, as important participants in the projects, construction workers often operate inappropriately, work in low efficiency because of fatigue and with weak safety awareness; besides, due to lack of professional knowledge and work experience, the technicians can not adopt corresponding methods timely when risk happens, which will also lead to enlarging the risk scale, increasing losses and delay schedule in some extend. The relationship of coupling in these factors has shown in Fig.1.

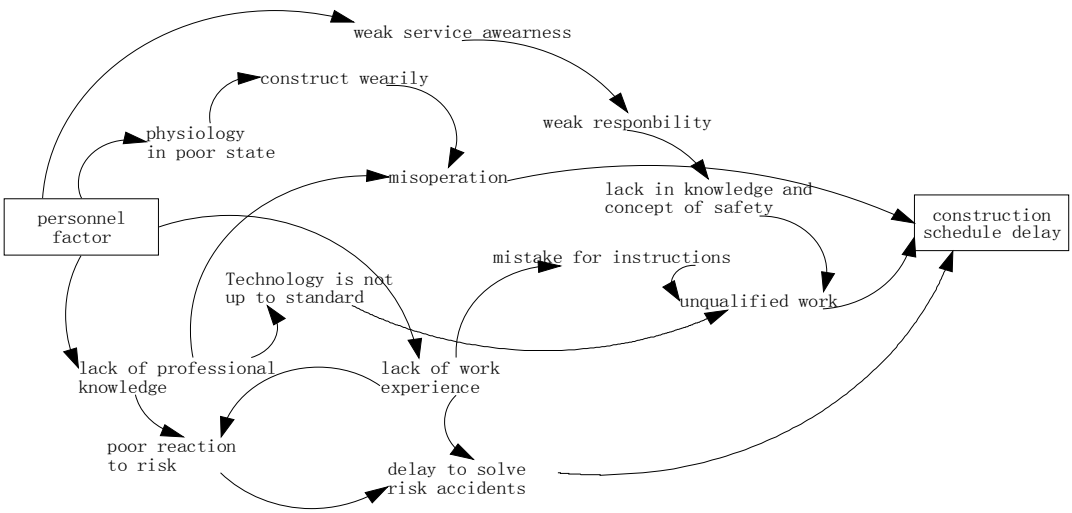

Fig.1. Cloud relationship of coupling in personnel factor

Besides risk of personnel, factors of equipment, materials and environment also have the relationship of coupling. For example, there are potential risks such as whether or not the equipment and materials place in the right place, or if they are operated appropriately and if they are maintained in time during the construction.

In addition to the researches of type and coupling on risk factors, there are also researches on coupling level. There'll be a conclusion of the state of risks through the result of level which is helpful to change the plan timely to avoid the occurrence of risk or reduce losses.

Analysis of Risk Coupling Effect based on $N-K$ model

In recent years, there are many models and methodologies to analyze the effect of multi-factorial risk coupling , however, because of the complex and a great lot of calculation, it is not convenient for the analysis of multi-factorial coupling problems when using these methods. What's more, they are poor practicability in the project[3]. So, after referring to a lot of scientific theories, there is a method called $N-K$ model which can convert complex problems to simplification and reduce quantity of calculation when comes to multi-factorial coupling[4]. This method is based on all data and the most mature classical probability theory to obtain results of coupling. Therefore, combining with the four risk factors of personnel, equipment, materials and environment in construction schedule, there is the model shown (1) as follow based on the means of $N-K$.

$$T(\mathrm{A},\mathrm{B},\mathrm{C},\mathrm{D}) = \sum_{h}^{H}\sum_{i}^{I}\sum_{j}^{J}\sum_{k}^{K} P_{h,i,j,k}\cdot lb[P_{h,i,j,k}/(P_{h...}\cdot P_{.i..}\cdot P_{..j.}\cdot P_{...k})] \qquad (1)$$

$$h = 1,\mathbf{L},H;\ i = 1,\mathbf{L},I;\ j = 1,\mathbf{L},J;\ k = 1,\mathbf{L},K$$

In above formula, N is the number of integral component and the minimum value of K is 0 and the maximum value is $N-1$. A, B, C, D is the code of personnel, equipment, materials and environment. $P_{h,i,j,k}$ is coupling probability that personnel is in the status of h, equipment in the status of i, materials in the status of j and environment in the status of k . T is the value of quantitative risk assessment which influences construction schedule. The higher the value, the more influence it is on the schedule.

Empirical Analysis

In order to research the effect on schedule when there is multi-factorial risk coupling, this paper combines the relative data from National Bureau of Statistics in recent 6 years(from 2009 to 2014) [5] with the software of MATLAB to analyze the count and frequency between factors with the help of $N-K$ model, there is the probability when single factor, double-factor coupling and multi-factor coupling takes place. The result has been shown in Table2. The value of T has shown as follows:

$$T_{ABCD}=0.1783, T_{ABC}=0.0834, T_{ABD}=0.1389, \quad T_{ACD}=0.0874, \quad T_{BCD}=0.1211, \quad T_{AB}=0.0542,$$

$$T_{AC}=0.0659, \quad T_{AD}=0.0724, \quad T_{BC}=0.0264, \quad T_{BD}=0.0818, \quad T_{CD}=0.0285$$

$$T_{ABCD} \ \mathbf{f}\ T_{ABD} \ \mathbf{f}\ T_{BCD} \ \mathbf{f}\ T_{ACD} \ \mathbf{f}\ T_{ABC} \ \mathbf{f}\ T_{BD} \ \mathbf{f}\ T_{AD} \ \mathbf{f}\ T_{AC} \ \mathbf{f}\ T_{AB} \ \mathbf{f}\ T_{CD} \ \mathbf{f}\ T_{BC} \qquad (2)$$

Factor	Probability							
Single	$P_{0...}=0.3285$	$P_{.0..}=0.4336$	$P_{..0.}=0.3392$	$P_{...0}=0.3698$	$P_{1...}=0.7814$	$P_{1...}=0.7814$	$P_{..1.}=0.6363$	$P_{...1}=0.6746$
Double	$P_{00..}=0.058$	$P_{.00.}=0.1120$	$P_{..00}=0.0989$	$P_{0..0}=0.0787$	$P_{0.0.}=0.0796$	$P_{.0.0}=0.1377$	$P_{11..}=0.4073$	$P_{1.1.}=0.3539$
	$P_{1..1}=0.490$	$P_{.11.}=0.3145$	$P_{.1.1}=0.3785$	$P_{..11}=0.3860$	$P_{01..}=0.2042$	$P_{0.1.}=0.1834$	$P_{0..1}=0.1843$	$P_{.01.}=0.3218$
	$P_{.0.1}=0.291$	$P_{..01}=0.288$	$P_{10..}=0.3750$	$P_{1.0.}=0.3294$	$P_{1..0}=0.1979$	$P_{.10.}=0.2272$	$P_{.1.0}=0.2330$	$P_{..10}=0.2503$
Multi	$P_{000.}=0.025$	$P_{00.0}=0.014$	$P_{0.00}=0.0215$	$P_{.000}=0.0291$	$P_{100.}=0.1485$	$P_{10.0}=0.1232$	$P_{1.00}=0.0989$	$P_{010.}=0.054$
	$P_{01.0}=0.0642$	$P_{001.}=0.033$	$P_{.010}=0.1086$	$P_{011.}=0.1500$	$P_{101.}=0.2884$	$P_{110.}=0.2428$	$P_{111.}=0.1645$	$P_{.001}=0.081$
	$P_{.011}=0.213$	$P_{.100}=0.093$	$P_{.101}=0.2057$	$P_{.110}=0.1417$	$P_{.111}=0.1728$	$P_{0.01}=0.0581$	$P_{0.10}=0.0572$	$P_{0.11}=0.126$
	$P_{1.01}=0.230$	$P_{1.10}=0.193$	$P_{1.11}=0.2598$	$P_{00.1}=0.0443$	$P_{01.1}=0.1400$	$P_{10.1}=0.2518$	$P_{11.0}=0.1688$	$P_{11.1}=0.238$

Table2 Probability of Risk Coupling

Conclusion

This paper has analyzed theories and practices of the effect on multi-factorial coupling in the construction schedule and got the conclusions as follows :

(1) The first conclusion is that with the number of factors increasing, damage scale and losses will expend and then delay the schedule. Therefore, the parties involved in the project must develop the corresponding measures and control the risk coupling in the incubation period of risk to reduce the scope of action and reduce economic losses.

(2) The simulation results in formulate (2). has shown that with the number of risk factors increasing, the double-factor and multi-factor effect of risk coupling is greater than single-factor effect. What's more, the effect will be increasing over time. Therefore, in order to avoid the multi-factorial risk coupling, the participants in the project should be taken effective measures as soon as possible to control the expansion of the scope effectively and reduce the losses.

(3) According to the analysis of the phenomenon of multi-factor coupling, the result is that the

effect of the risk coupling including personnel factor is greater than that without personnel factor. Therefore, personnel is the main factor to control the effect of multi-factor risk coupling. To achieve the goal, manager in the project should attach importance to the selection of the personnel, the technical personnel assessment, the construction personnel skills training and the management of the professional training.

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