

EVALUATING THE FEASIBILITY OF THE HIGHWAY ENGINEERING SCHEDULE USING SIMULATION TECHNIQUE

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ABSTRACT : In the highway engineering, the performance, quantity and status of machines available for the project have direct impact on the project time. For instance, the status of machines, such as working or in trouble, have great influence on the activity execution. Therefore, while scheduling the project, the project manager always increases the spare machines or prolong the activity time to avoid delaying the project time when some of the machines are in trouble in construction site. However, how many are the spare machines and how long are the prolonged activity time, which are estimated subjectively by the manager. This subjective estimation has been criticized for systematically overestimating or underestimating quantity of the machines and the activity time. In the paper, we propose and prototype a model to simulate the status of the machines in construction site, and then to evaluate the schedule feasibility considering the performance, quantity and statuses of the machines involved.

Key words : engineering management, feasibility of the schedule, evaluation , simulation

1. INTRODUCTION

In the highway engineering, the schedule feasibility has direct impact on the project successful execution. How to evaluate the schedule feasibility considering various factors in the actual project condition, and find the shortcomings and problems in the project schedule, and make steps to adjust and improve the schedule to raise the feasibility of the project schedule, which are extensively studied by lots of researchers. Zhang Jianping(2003) constructs a 4D model by linking a 3D model of a project with the project schedule to evaluate the schedule feasibility. Koo(2000) finds out the problems in the project schedule using a 4D model. Akinci(2000) proposes a method to handle with the conflict between the schedule with the construction space. Ingalls(2000) evaluates the feasibility of the schedule with limited resources using the qualitative simulation.

In China, in order to ensure the project continual execution when some of the machines involved are in trouble, the project manager always increases the spare machines or prolongs the activities duration according with his experience while scheduling the project. Using this scheduling method with experience can raise the schedule feasibility. However, at the same time which may reduce the efficiency of machines involved and increase the project cost. In this paper, using computer simulation technique, we propose a model to evaluate the schedule feasibility considering the performance, quantity and status of machines involved. By performing a lots of simulation trials, we gain a group of data of the project schedule in various status of the project construction. After analyzing the group of data, we can gather appropriate statistics, such as the average duration of each activity and the average duration of the project, etc.. These statistics can help to scientifically

evaluate the feasibility of the schedule with limited machines.

2. SIMULATION EVALUATION MODEL

2.1 Problem statement

In the construction processes of the highway engineering, there are the followings: (1) the performance of machines involved are different. For instance, the performance of a new excavator is better than the used excavator of the same model. (2) the performance , quantity and status of machines involved have direct impact on the activity time. (3) lots of random factors have influence on the machines in the construction site. The machines involved may be in trouble , and some of the troubled machines may be repaired in the construction site but the others may be beyond repair in the construction site. Considering the foregoing situation, the project manager always increase the spare machines or prolong the activity time when scheduling the project. This study constructs a model to estimate the activity time with limited machines involved and then to evaluate the schedule feasibility considering the performance , quantity and status of machines involved.

2.2 Hypothesis

In the simulation evaluation model we constructed, there are two hypothesis: (1) The machines, which are not in the construction site when constructing the project, cannot be invested into the construction site. (2) For a mechanized activity, there is only one kind of machine whose quantity have determined the activity time directly. That is, the quantity of the machine has an inverse proportion to the activity time.

2.3 Terms

In the construction processes, the activity time will vary with the performance, quantity and status of the machines involved. In order to present this condition, in this model, we define three terms: (1) Standard machine: the performance of machines of the same model are different because of the different producer and used time. In the machines of the same model, one is appointed as the standard machine of this type of machine, the others are converted to the standard machine using the conversion coefficient. (2) Standard time: with specified quantity of the standard machines, the time that completes a activity to need is the standard time of the activity. (3) Conversion coefficient: the performance of a machine to its standard machine is the conversion coefficient of the machine.

The model uses the standard machine to define the performance of machines, and uses the standard time to define the activity time, and uses the conversion coefficient to convert the machine to the standard machine.

In order to present the construction processes, we define three activity lists: (1) Animated activity list: it contains all the activity of carrying out; (2) Broken activity list: when performing a activity, some of machines involved in the activity are broken down and there are no substitutes in the construction site. The activity must be broken off and be putted into the broken activity list. (3) Waiting activity list: the activity, which immediate predecessors are finished but there are not idle machines, is putted into the waiting activity list.

The rule entering those lists is FIFO (First-In, First-Out). In the model, the idle machines are in the reserve pool of machines. The broken machines which can be repaired in the construction site are in the reparation pool of machines.

2.4 Simulate the project

We evaluate the project schedule using a discrete-event simulation model with fixed-increment time advance approach. With this approach, the simulation clock is advanced in increments of exactly Δt time units (in this model, $\Delta t = 1d$). After each update of the clock, a check is made to determine if any events should have occurred during the previous interval of length Δt . This model contains the following events:

1) Machine-broken down

The activity in the animated activity list is checked to determine if the involved machine is broken down. If some of those machines are broken down, the model determines if there are substitutes in the reserve pool of machines. If there are enough substitutes, the activity continues to be performed. However, because the performance of substitutes may be different from the broken machines, their conversion coefficients are different. Therefore, the activity remains time should be computed using the formula (1). If there are not substitutes, then the activity enters the broken activity list and releases its right machines to the reserve pool of machines. Next, the broken machine is checked to determine if it can be repaired in the construction site. If the broken machine can be in good repair, then it is putted to the reparation pool of machines. After it is repaired, it can be

used again. If the broken machine is beyond repair, then it will leave the construction site, and cannot used again.

$$t' = \frac{m \times t^o \times \mu}{\sum_{i=1}^N k_i} \quad (1)$$

where: μ is the finished percentage of the activity when his machine is break down. m is the quantity of the standard machine involved in the activity. t^o is the activity standard time according to the standard machine. N is the quantity of the machine actually involved in the activity. k_i is the conversion coefficient of the machine i .

The method to determine if the machine is broken down (or determine if the broken machine can be in good repair) is: if the machine is broken down (or if the broken machine can be in good repair) is a random event and represented as a random discrete variable. This study estimates the discrete variable using simulation. Set the probability of the machine broken (or the machine in good repair) is p . Generate a random number $r : r \sim U(0,1)$. If $r \leq p$, then the machine is broken down (or the broken machine can be in good repair).

2) Broken activity continues to be constructed

The activity in the broken activity list is checked to determine if the activity can continue to be constructed. If there are enough idle machines in reserve pool of machines, the broken activity returns to be constructed. And then, the activity remains time is computed using the formula (1) according to the machines actually involved.

3) Waiting activity begin to be constructed

The activity in the waiting activity list is checked to determine if the activity can begin to be constructed. If there are enough idle machines in the reserve pool of machines, the waiting activity begins to be constructed. And then, the activity time is computed using the formula (2) according to the machines involved.

$$t = \frac{m \times t^o}{\sum_{i=1}^N k_i} \quad (2)$$

where: the meanings of the symbols are the same of the formula (1).

4) Broken machine has been repaired

The machine in the reparation pool of machines is checked to determine if the machine under repair is finished. If the repair of the machine is finished, then the machine is putted into the reserve pool of machines.

The method to determine if to finish the repair of the machine is: its staying time in the reparation pool of machines is longer than the repairing time of the machine.

5) Finish the activity

The activity in the animated activity list is checked to determine if the activity is finished. If there is, the machines what be used in the activity are released to the reserve pool of machines.

The method to determine if to finish the activity is: its staying time in the animated activity list is longer than the

activity time.

And then the activity not in the three lists is checked to determine if it can enter the waiting activity list. If all the immediate predecessors of the activity are finished, then the activity can enter the waiting activity list.

2.4 Program the model

We program this model using Visual Basic6.0. The Procedure flow diagram is showed in Figure 1.

3. EXAMPLE

Basic information of each activity of a highway engineering are presented in table 1.

1) Case 1: Put 6 machines into the project, whose information are presented in table 2. We evaluate the project schedule using the simulation evaluation model. Performing 500 simulation trials, the trial results are show in table 3.

The average project time is 27 weeks, and the variance of the project time is 4 weeks.

2) Case 2: Put 7 machines into the project, whose information are presented in table 4. We evaluate the project schedule using the simulation evaluation model. Performing 500 simulation trials, the trial results are show in table 5.

The average project time is 24 weeks, and the variance of the project time is 3 weeks.

Table 1. Basic information of the activity

	Activity							
	A	B	C	D	E	F	G	H
Immediate predecessor	-	A	A	B	C	C	D,E	F
Count of the standard machines	1	3	3	4	3	4	2	2
The activity standard time (week)	3	4	5	6	4	5	3	3

Table 2. Information of the machines in the project(Case 1)

	Number of the machine involved						
	1	2	3	4	5	6	
Conversion coefficient	1.0	1.0	0.9	0.8	0.8	0.8	
Proportion in good condition(%)	95	95	90	90	80	80	
Proportion of maintenance(%)	100	100	100	100	100	100	
Maintenance time (week)	1	1	1	1	1	1	

Table 3. Trial results(Case 1)

	Activity							
	A	B	C	D	E	F	G	H
Proportion of broken off(%)	0	0.5	1.0	0.5	15.5	0	4	0
Average activity time(week)	3	6	8	9	8	7	5	4

Table 4. Information of the machines in the project(Case 2)

	Number of the machine involved						
	1	2	3	4	5	6	7
Conversion coefficient	1.0	1.0	0.9	0.8	0.8	0.8	1.0
Proportion in good condition(%)	95	95	90	90	80	80	95
Proportion of maintenance(%)	100	100	100	100	100	100	100
Maintenance time (week)	1	1	1	1	1	1	1

Table 5. Trial results(Case 2)

	Activity							
	A	B	C	D	E	F	G	H
Proportion of broken off(%)	0	0	0	0	1	0	2	0
Average activity time(week)	3	5	7	8	6	7	5	3

Based on those trial results, we can analyze the schedule feasibility from the following respects: (1) to ensure the activity are not broken off unreasonably because of the lacking of machines, the count of machines must be putted into the project. (2) the distribution of the activity time and project time can be estimated with the limited machines putted into the project.

4. CONCLUSIONS

In this paper, we propose a simulation model to evaluate the feasibility of the schedule in the highway engineering, which considers the performance, quantity and status of the machines putted into the project. We can evaluate the feasibility of the schedule with the limited machines using this simulation model, and the trial results are the scientific

basis for the manager to improve the feasibility of the schedule.

In China, this model has been applied to a project management system. On the basis of its real operating position, there are the following problems: (1) the two proportion of the machine, the proportion in good condition and the proportion of maintenance, are difficult to be confirmed by some of contractors for lack of the statistic of the machinery. (2) It is difficult to estimate the activity standard time. In order to solve those problems, we set up some databases in the project management system to help users to collect those data related to those parameters, such as the two proportion of the machine, the activity standard time, etc..

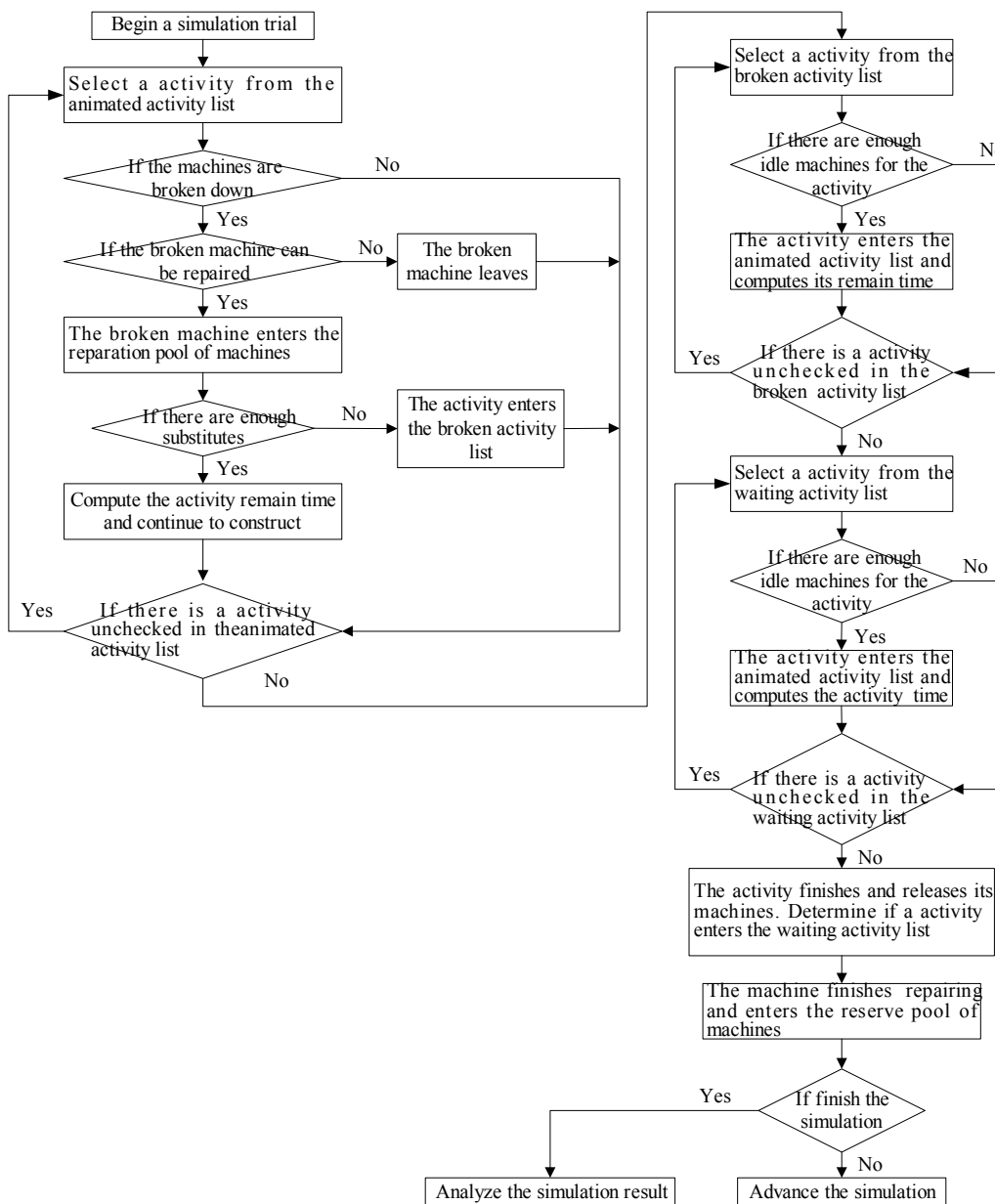


Figure 1. Procedure flow diagram of the model

REFERENCES

- [1]Zhang Jianping and Wang Hongjun, “A 4D site model and 4D management system for construction projects”, *China civil engineering journal* , Vol. 36(3), pp. 70-78, 2003.
- [2]Koo B. and Fischer M.,”Feasibility study of 4D CAD in commercial construction”, *Journal of construction engineering and management*, Vol. 126, pp. 251-260, 2000.
- [3]Akinci B. and Fischer M., “Formalization and automation of time-space conflict analysis”, United State: Stanford University,2000.
- [4]Ricki G. Ingalls., “PERT scheduling with resources using qualitative simulation graphs”, *Proceedings of the 2000 winter simulation conference*,2000.
- [5]Kris G. Mattila and Michael R.Bowman, “Accuracy of highway contractor’s schedules”, *Journal of construction engineering and management*, Vol. 130, pp. 647-655, 2004.
- [6]Hong Zhang and Jonathan Jingsheng Shi, “Application of fuzzy logic to simulation for construction operations”, *Journal of computing in civil engineering*, Vol. 17, pp. 38-45, 2003.
- [7]Mekdam A.Nima,Mohd R.Abdul-Kadir,Mohd S.Jaafar and Riadh G.Alghulami, “Constructability concepts in west port highway in Malaysia”, *Journal of construction engineering and management*, Vol. 128, pp. 348-356,2002.
- [8]Nicola J.Chevallier and Alan D.Russell, “Developing a draft schedule using templates and rules”. *Journal of construction engineering and management*, Vol. 127, pp. 391-398,2001.
- [9]Akbas R., “Geometry based modeling and simulation of construction processes”, United State: Stanford University, 2003.
- [10]Zeigler,B.P., “Theory of modeling and simulation”, London : Academic Press,2000.