RISK EVALUATION IN ROAD CONSTRUCTION WITH NEURAL NETWORKS AND MONTE CARLO SIMULATION

Wu, Tao-Sheng (Doxon), Chou, Hui-Yu

Assistant Prof., Dept. of Cons. Eng., National Yunlin University of Science & Technology, Taiwan, ROC
PhD Candidate, Department of Civil Engineering, National Taiwan University, Taiwan, ROC

Abstract: This study shows the nature of weather risk with a sample project with different networks. The total duration will change by different networks, the starting month, and the different sites. To analyse how to evaluate the risk of weather, by using Mote Carlo simulation and Neural Network to predict potential delay, this study will tackle the risk of weather with proper management skills.

Keywords: Monte Carlo simulation, neural networks, risk management, weather, road construction

1. PREFACE

This paper analyses how the weather conductions affects the schedule of road construction project and presents the new ideal to evaluate the critical degree of construction activities with Taiwan weather data. Unlike most commercial business activities, construction projects are easily affected by weather condition. Taiwan is in the subtropical area, and the schedules of road construction projects are highly influenced by the weather conditions of different locations. How to evaluate the risk of different weather conditions is very important, and contractors can know the costs and risks associated with delay claims by simulation.

A construction project is only executed once, how to know when and where the delay comes from is very important. Some scheduling methods, like PERT, are introduced into construction thirty years ago. The Monte Carlo simulation is used for project schedule estimation for years. With the new development of artificial intelligent, neural networks is another approach to predict the future. This paper will use the Monte Carlo simulation and Neural Networks to evaluate the potential variance of the project schedule affected by weather conditions. With these simulation outcomes, this study will prove that traditional critical path method is unable to allocate the schedule risk properly, and the new method to evaluate the critical degree of activities will be suggested.

The road construction industry needs to develop a new risk management framework to handle the uncertainty of weather conditions in Taiwan. Thus, this paper presents an analysis of road construction projects with weather simulation, and proposes a new evaluation method of schedule risk. The use of these adequate techniques is a key in obtaining a fair risk evaluation for resource allocation and schedule arrangement.

To demonstrate the nature of weather risk, the sample project is sho2wed as figure 1. This sample project simulates some basic properties inherited from road construction, as the same activity repeated many time, site weather affect the final activity duration, and construction schedule is changed by site condition and productivity. There are 22 activities distributed in eight paths. Each activity have same duration ranged form 6 to 16 days with equal chance, with these networks, each path has the same total duration and possibility of critical path. If the arrangement of activity H-O changes by the principle that each activity has only a predecessor, eliminating the asymmetric forms, there will be eight forms of networks.

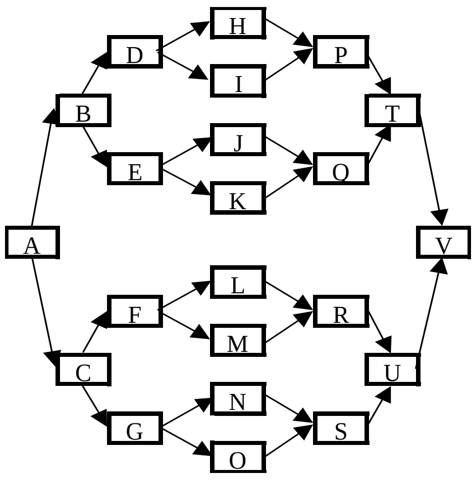

Figure 1. One of the Networks of Sample Project

This particular sample project shows three basic proprieties:

1. If the durations of activities are fixed, the total durations of different paths are the same, and floats of activities, too.
2. If the duration of activities is changed in the range 6-16 days, then each path could be the critical path randomly, but the layouts of different networks will affect the possibility.
3. The real critical path is unpredictable in advance.

2. CONSTRUCTION AND SIMULATION

Many approaches have applied to predict the total duration of construction projects. Construction process simulation theories have been developed for over 30 years [1]. Activity duration relates with a variety of factors, which are not all easily modelled and analysed. Weather is a major factor to affect periodicity in road construction, but which is not included in traditional construction simulation researches until El-Rayes and Moselhi[2].

The major two trends of construction process simulation is, the first, the process simulation like CYCLONE[1] and MicroCYCLONE[3]. Some relate issues are also studied like data collection with videotape, information feedback to construction works [4], and resource limits [5].

AbouRizk & Shi apply the techniques of repeated tasks simulation in construction project simulation [6]. Kavanagh combine the ideas of CPM and PERT to develop a project simulation system for repeated activities [7]. Senior and Halpin also propose the PICASSO system for simulating construction project with CYCLONE idea [8].

Ahuja and Nandakumar include some special factor like the weather, worker shortage to forecast the total duration of construction project [9]. After analysing some activities of finished project, AbouRizk and Halpin concluded the statistic distribution of activities' duration should be Pearson distribution [10]. Artificial neural networks (ANN) techniques have been applied to solve construction project simulation problems in last years [11-12]. However, these papers still are focus on duration forecast, not some environmental factors, like weather, tide, and wind.

This paper will combine project simulation technique and neural networks to predict project total duration with weather forecast by neural networks.

3. APPROACHES

This study uses three major research tools: Monte Carlo simulation, Neural Networks, and risk management. The concept of risk management help us to model the system and conclude the management strategy. The Monte Carlo simulation will model the random behaviour of the sample project and weather of the construction sites and the Neural Networks helps us to predict the real weather of the future.

3.1 Monte Carlo Simulation

The method of extracting the weather risk used in this study is similar to previous studies on Monte Carlo simulation of construction process. However, In order to focus on the weather risk and construction planning, the distribution of activity duration is assumed as average distribution.

3.2 Neural Networks

Neural Networks technique has been applied in the research of construction process simulation [11-12]. This study applies the back-propagation training method, which is widely used in prediction problem. The development of software for this method is quite mature. The Vesta Services Company's Qnet 2.23 is used in this study.

By utilizing neural networks to implement the learning, as this research has attempted several network structures, the effects of the prediction on tender price are not as ideal. After 100,000 times of trial runs, RMS (Root mean square) is reduced to 0.00002, while the predicted average rainfall ratio (95% accuracy), based on the prediction of next 12 months, will be about 79%.

Further extracting 30 years rainfall data of four cities, Taipei, and Yilan, this research uses the first 28 years' data to implement the learning study, and the latter 2 years to verify prediction effect. Upon several experiments, the 48-60-20-1 network structure is used to predict the heavy rainfall day(>10mm), while the 48-55-25-1 network structure is used to predict the heavy rainfall ration(heavy rainfall days/month days). With these two predictions, the results of rainfall ratio are better than those of rainfall days.

This paper conducted the learning and prediction with the *step* ideal, it means we use first 24 month data to predict the next month weather, and then add this prediction value to the input case, and so on. It simulates the behaviour of a contractor who is in real decision situation.

3.3 Risk Management

Response to risk is defined as "action that is taken to avoid or mitigate losses arising from project risks". To response appropriately, managers should realize all alternative methods and their contents and effects before making decisions. This study classifies the response methods into four categories, namely risk avoidance, risk transfer, risk mitigation, and risk retention

Risk avoidance

This term describes rejection or change for an alternative to remove some hidden risk, for example by altering working methods.

Risk transfer

This term describes switching risk responsibility between individuals. Contractors commonly use both insurance and subcontracting to offload risk responsibilities.

Risk mitigation

This approach attempts to reduce in advance the probability of a potential risk occurring, or the expected losses should it occur.

Risk retention

This method is appropriate under two conditions: first, unplanned risk retention, where the manager refrains from interfering in the course events despite being conscious of certain risks; second, planned risk retention, where the manager decides to take no action following cautious evaluation.

The response methods mentioned above are the prototypes of contractors' response strategies in the Taiwan road construction cases [13]. Based on the project simulation and weather prediction, the response of contractors to weather risks will involve one or a combination of the multiple approaches described above.

4. PROJECT SIMULATION

First, how many time of simulation is good enough? Figure 1 is the standard deviations of different execution times. Figure 2 is average total duration of sample project of different execution times. By these two figures, this study decides the 1,500,000 times execution will reach 99% confidence level.

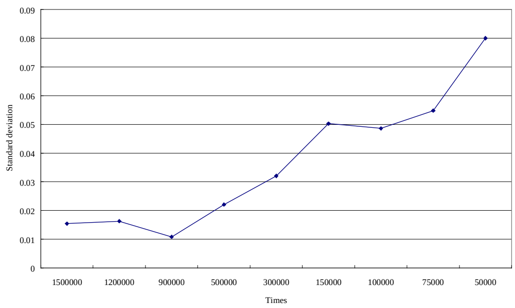

Figure 2. Standard Deviation Changes by Execution Times

Figure 3 shows the distribution of duration of different networks. The 8 networks show the most happened total duration will be about 141 days, only network 6 shows there will be late for about 2 days.

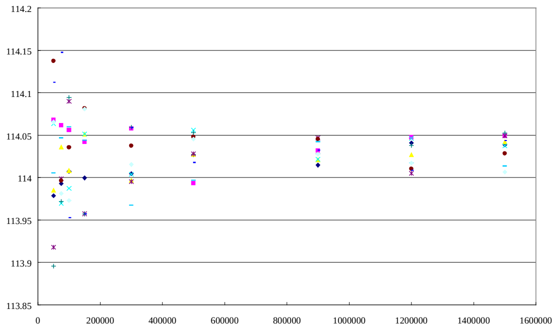

Figure 3. Execution Times and Average Value Range

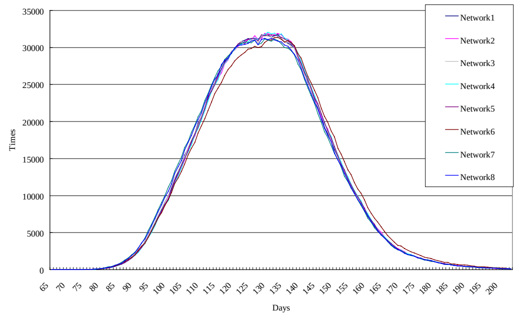

Figure 4. The Distribution of Total Duration of Different Networks

The total duration may not be too much different between networks, but the critical level will be another important issue. This study defines critical level as “the chance to be in the critical path”. Table 1 shows the critical degree of activities; obviously, some activity will have different chance to be critical path by different networks. Considered the same distribution of all activities, the network will be the cause of different critical level. With this technique, project manager can distribute resources and equipment by the possibility of critical activities, not only a single critical path.

Table 1. Critical Degree of Activities

Activity	1	2	3	4	5	6	7	8
A	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
B	0.42	0.51	0.52	0.46	0.40	0.41	0.51	0.51
C	0.60	0.51	0.50	0.56	0.61	0.61	0.51	0.51
D	0.21	0.26	0.26	0.18	0.20	0.21	0.18	0.18
E	0.21	0.13	0.13	0.18	0.20	0.21	0.11	0.12
F	0.19	0.13	0.11	0.13	0.11	0.14	0.12	0.12
G	0.21	0.26	0.26	0.18	0.20	0.21	0.18	0.18
H	0.42	0.51	0.52	0.46	0.40	0.41	0.51	0.51
I	0.09	0.14	0.18	0.11	0.11	0.09	0.18	0.18
J	0.42	0.26	0.33	0.32	0.31	0.35	0.34	0.34
K	0.09	0.13	0.14	0.11	0.11	0.09	0.18	0.18
L	0.22	0.26	0.26	0.28	0.20	0.21	0.33	0.34
M	0.22	0.26	0.26	0.28	0.20	0.21	0.33	0.34
N	0.22	0.13	0.14	0.14	0.20	0.21	0.12	0.12
O	0.19	0.26	0.18	0.25	0.31	0.27	0.18	0.18
P	0.42	0.26	0.33	0.32	0.31	0.35	0.34	0.34
Q	0.09	0.13	0.12	0.14	0.11	0.10	0.12	0.12
R	0.09	0.13	0.13	0.11	0.11	0.14	0.11	0.12
S	0.09	0.13	0.11	0.13	0.11	0.09	0.12	0.12
T	0.19	0.26	0.18	0.25	0.31	0.27	0.18	0.18
U	0.60	0.51	0.50	0.56	0.61	0.61	0.51	0.51
V	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

5. WEATHER SIMULATION

Traditionally, engineers estimate total workdays in a year in different weather condition, but which month will be the best start point? If this project starts in January, what is the possibility of the project finished in August? It is not easy to answer with traditional CPM/PERT method.

Table 2 and 3 show the average rainy days of four Taiwan cities in last 45 years. In figure 5, engineers can evaluate possible workdays of a project. Usually, these tables and figure will be the major tools in considering how rainfall impacts total duration of projects.

Table 2. The days of heavy rainfall (>10mm) in the four cities

		Taipei	Taichung	Kauhiung	Yilan
Heavy Rain	1	3.00	0.97	0.64	4.59
	2	5.08	2.69	0.54	5.56
	3	5.72	3.03	1.15	4.23
	4	4.62	3.31	1.92	3.59
	5	6.31	5.33	3.90	5.92
	6	7.05	7.36	7.67	5.69
	7	5.46	5.05	5.92	3.10
	8	6.26	6.49	7.69	4.69
	9	5.39	3.08	3.92	7.23
	10	2.97	0.69	1.10	7.46
	11	2.11	0.69	0.46	7.18
	12	2.39	0.62	0.36	5.31

Table 3. The days of small rainfall (<10mm) in the four cities

		Taipei	Taichung	Kauhiung	Yilan
Small Rain	1	6.28	3.77	1.90	8.49
	2	6.23	4.41	2.33	8.21
	3	6.59	5.38	1.56	9.59
	4	5.74	3.97	1.95	7.69
	5	6.28	4.36	3.82	9.54
	6	5.79	4.54	4.87	6.77
	7	4.51	4.54	5.36	4.05
	8	4.54	5.05	6.05	5.18
	9	4.92	3.31	4.46	5.92
	10	5.32	1.46	2.10	8.03
	11	6.42	1.77	1.41	9.26
	12	6.18	2.13	1.33	8.97

This study use last 45years rainfall data to simulate the weather to affect the total duration of a project. When there is one small rainfall in a day, in a simulation execution, the day will be marked as non-working day; in other way, there is a heavy rainfall in a day, the duration of the activity will be add another day. In figure 6, simulating network 1 with Taichung rainfall data, we can observe the difference of duration distributions in different starting months. With this figure, engineers can evaluate the possibility of a specific finish date of the sample project.

With this technique, engineers can input their project networks and site weather conditions to simulate the impact. With the fixed project deadline, this technique can help engineers to decide when to start; in the opposite sides, if engineers can adjust the start date, then the shortest total duration or the stable one should be the best solution.

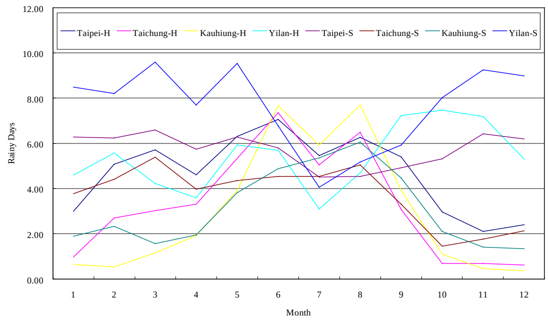

Figure 5. The rainfall days of different month in cities in last 45 years

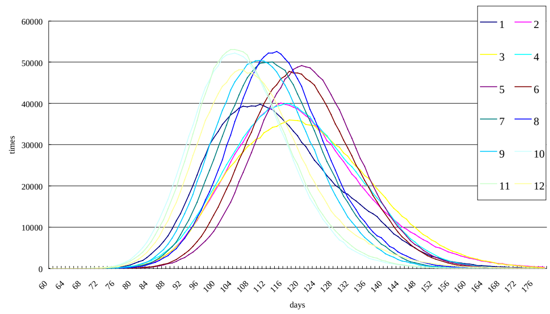

Figure 6. The distribution of different start month in cities

6. WEATHER RISK EVALUATION WITH NEURAL NETWORKS

In above simulation experiments, this study shows the same sample project with different networks executed randomly in last 45 years weather data. By above steps, engineers can evaluate the on-schedule possibility.

In fact, weather forecast is still the art of meteorologist, but the field engineers do not need the precise weather condition in one year ago. In the road construction project, many activities are easily affected by rainfall, and if the engineer can know the number of rainfall day, then the information can help project planning. In the further, if the rainfall days can divide into small rainfall or a heavy one, then engineer can tell some job will be affected just in the rainy day or there will be other reworks task caused by heavy rainfall.

Anyway, if the weather condition could be simplified as rain/no-rain or small/heavy and the forecast information is still helpful, then weather could be predicted by neural networks technique. In fact, this basic forecast could help engineer to evaluate the project schedule in much better information.

We input last 24 months data and predict next month's rainfall days. After that, we remove the first month data and made the new prediction outcome as new input set.

Table 4. The ratio of the predicted heavy rainfall days/real rainfall day in the four cities

Month	1	2	3	4	5	6	7	8	9	10	11	12
Taipei	0.95	0.93	0.94	0.9	0.86	0.75	0.78	0.67	0.72	0.65	0.66	0.63
Taichung	0.92	0.92	0.87	0.76	0.79	0.75	0.66	0.72	0.65	0.62	0.64	0.66
Kauhiung	0.94	0.75	0.87	0.85	0.81	0.78	0.76	0.72	0.83	0.78	0.74	0.71
Yilan	0.89	0.87	0.77	0.81	0.79	0.8	0.76	0.73	0.77	0.69	0.71	0.63

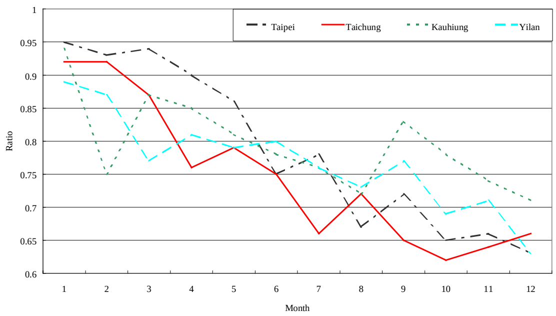

Figure 7. The descending trend of the ratio of the predicted heavy rainfall days/real rainfall day in the four cities

The accuracy of prediction is descending by the time of starting date. This is reasonable by the nature of neural networks. In the other way, we get very good prediction outcome in next three months by last 24 months data.

With these forecasts, engineers can decide the project schedule plan with better information. If we know a project could not meet the deadline by this evaluation skill, we could buy more equipment or resources to catch the deadline in advance; or we can start the project early and meet the deadline with same resources.

7. CONCLUSION

The contractor is the key to project performance, and potential risks dominate the progress of work. Before seeking appropriate risk management methods to enable a project to be completed within time constraints, contractors must recognize their environmental factors, like weather. In this study, we develop some evaluation tools to help engineer to reach the final solution of project schedule plan.

First, by our experiments, the different networks of the same project do change the distribution of total duration, the critical path and the average total duration. We cannot explain why and how the possibility of critical path affected by network layouts, and new scheduling theory could solve this problem. By starting the same project in the different months, the average total duration will changed. The same project with same scheduling network in different sites, the distribution of total duration will change.

Acknowledgments

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