

Production Rate Regression Model of Railway Construction Project based on Grid

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Keywords: Railway construction project, Time-space grid, Production rate regression model.

Abstract. Project schedule has been regarded as the core work of the project management. Scheduling and using the project schedule scientifically and reasonably is the key to ensure the organization work of construction project orderly. In this paper, the time-location-based division method of influencing factors has been developed according to their time-spatial varying features. The paper has collected the actual construction progress data and taken use of multiple linear regression analysis determining the incidence relation between the production rates and influence factors. Then the regression model with varying production rates based on grids could be developed. Finally, the practical schedule data of railway Wu Caiwan-Jiang Junmiao sectional subgrade engineering has been utilized to verify the validity of the model.

1. Introduction

Due to the uncertainties of construction site condition and environment, the construction production rate of construction engineering is usually not fixed. The prediction of construction rate has become a more and more important part when making project schedule. Simon [1] pointed out that *System Analysis Method* is not suitable for predicting the production rate of earthwork engineering, and he proposed quantifying the impact of each factor by using multiple stepwise regression analysis in 1999. In 2004, Yao [2] pointed out that the inaccuracy of the prediction of construction rate is the main reason to the inaccuracy of duration prediction of CPM. In 2007, based on the historical statistical data and construction experience, Yi [3] found that the temperature and season, geographical position of the site and the road type are the main factors that influence the production rate.

It can be seen that there is still room for improving the method of prediction of construction production rate, and a scientific method of classification of factors that influence the production rate and a suitable method for predicting the construction rates are needed. This paper propose a time-location- based division method of influencing factors according to their time-spatial varying features, and develop a regression model with varying production rates based on grids .

2. Classification of Factors that influence production rates

2.1 Factors that influence production rates

Railway construction progress is affected by many factors because railway construction project has characteristics of long construction duration, continual construction in the wild all year long and so on. The factor of human is the most important interference factor in the railway construction progress control. At the same time, the factor of equipment and materials, money, hydrology, geological and meteorological conditions, social environment should also be analyzed and controlled [4].

In the implementation stage of construction project, *4MIE* method is well used to identify the factors that influence construction quality [5]. This method is also used in the construction safety management. Based on railway construction characteristic and literature discourse [6-9], the factors that influence construction progress are classified into five categories: Man, Material, Machine,

Method, and Environment. This paper inductively arranges factors that influence construction progress by *4M1E* method as figure 1.

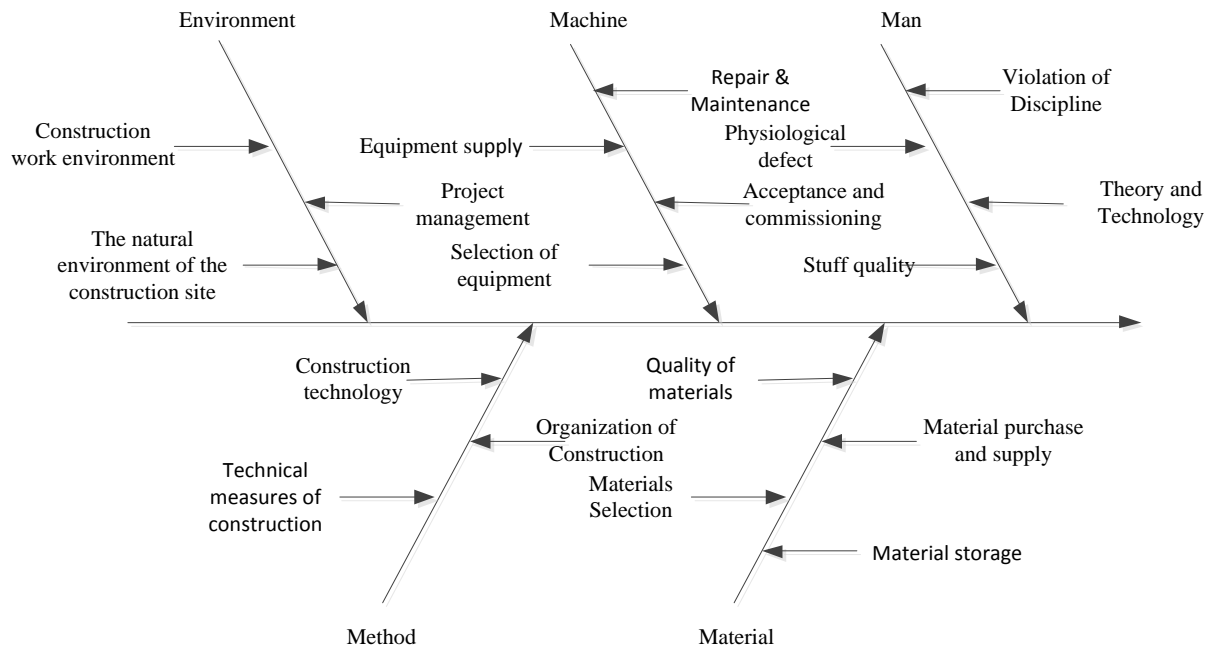


Fig. 1 The main factors affecting the construction progress

2.2 Classification of Factors

In the progress of railway construction, the influence factor varies with time, and from position to position. Most influence factors have close association with construction mileage and time, while the factor classification of *4M1E* method cannot present the time-space characteristic of factors. According to whether factors vary with time and space, influence factors are classified into general factor, time factor, space factor and time-space factor as shown in table 1.

Table 1. The classification of the main factors affecting the railway construction progress

Factor Classification	4M1E Factor Classification	Factor
General	Human	Physiological defect
		Stuff quality
		Violation of Discipline
	Material	Material quality
	Machine	Acceptance and commissioning
	Environment	Construction schedule control system
	Method	Construction technology
Time	Man	Theory and Technology
	Machine	Machinery and equipment supply plan
	Method	Construction schedule control system
	Material	Material purchase and supply plan
Space	Environment	The natural environment of the construction site
		Construction work environment
Time-Space	Environment	The natural environment of the construction site
		Construction work environment
	Machine	Repair & Maintenance
	Method	Construction technical measures
		Construction site organization and management
	Material	Material storage

3. Production rate regression model of railway construction project based on Grid

Based on multiple regression analysis method, this model establishes relationship between construction activity production rate and the influencing factors. By inputting the statistical data of influence factors, this model can output the possible construction rates that conform to reality.

3.1 Definition of railway construction project grid

According to the time-space feature of factors that influence railway construction rates [10], railway construction project grid is proposed in this paper. Railway construction project grid means the discretization of the continuous railway construction line, which is divided into many small construction line sections. Meanwhile, the continuous working time is also divided into many small working time sections. The time-space construction region constructed by the line section and time section is named grid unit, and is given an ID (namely grid code). According to the time-space feature of the railway construction project grid, the grid unit is named G_{ij} , in which i represents the column of the grid (the position of construction mileage section) and j means the row of the grid (the position of construction time section). In this way, the time-space position of the grid can be found quickly as figure 2.

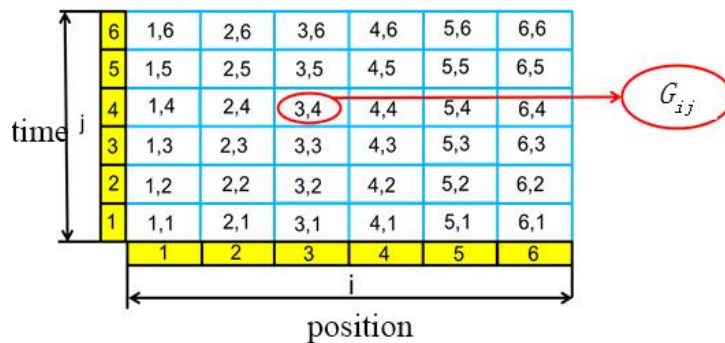


Fig. 2 The railway construction project grid

3.2 The division of railway construction project grid

(1) The division of grid length. The railway is band shaped, and the width is fixed normally, so the length of the railway construction project grid should be divided by the length of the railway line. Referring to many rule and explanation of railway construction project, it is believed that 200m is a suitable length as unit length of railway construction project grid.

(2) The division of grid time. In implementation stage of the project, the schedule management situation varies. For construction companies, implementation schedule usually uses day or week as time unit. On the other hand, day is the smallest unit in railway construction project scheduling in China. Therefore, day is used in this paper as the time unit of railway construction project grid.

3.3 Regression model of construction rate and factor

According to the classification of factors that influence construction rate and research and analysis of relative literatures and historical materials about construction rate prediction, this paper arranges the important influence factors which are usually considered when making construction schedule, and regardless of the change of influence factors in construction progress, as table . To make a better quantify of impact, this paper mainly focuses on the first five factors in the table 2.

In the railway construction production rate regression model, random variable PR represents construction rate of current construction activity, and k variables $X_1, X_2, \dots, X_k (k \geq 2)$ represent the factors that influence construction rate in this research. The multiple linear regression model is shown as blow:

$$PR = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \dots + \beta_k X_k + \varepsilon \quad (1)$$

In which, $\beta_0, \beta_1, \dots, \beta_k$ are $k+1$ unknown parameters, β_0 is regression constant, $\beta_1, \beta_2, \dots, \beta_k$ are regression factors, and ε is random deviation.

Table 2. The important factors affecting construction progress

No.	Factor	Description	Source
1	Weather condition	Temperature, wind, precipitation	Construction organization planning, construction journal
2	Working window	Time and mileage section out of work	Construction organization planning
3	Terrain slope		Construction drawing
4	Vacation		Construction organization planning
5	Number of workers		Construction journal
6	Rock formation		Construction organization planning, Construction drawing
7	Topography	Plain, desert, etc.	Construction organization planning, site survey
8	Scope of construction land		Construction organization planning, Construction drawing
9	Urbanization	Population density	Construction organization planning
10	Theory and Technology		Experience data

This paper takes the practical data of two activities of railway Wu Caiwan-Jiang Junmiao sectional subgrade engineering (DK96+000~DK115+300) as the source data to build the regression equation. The data is analyzed and proceeded by Excel and SPSS19.0 to get the regression equation.

Production rate regression model of embankment and bottom layer of foundation bed filling activity

The analysis results show that the production rate and the filling layer are related to the lowest temperature, and the production rate regression equation is show as blow:

$$PR_{ij} = 165.519 - 3.251FL_i + 0.286MT_{ij} \quad (2)$$

In which, PR_{ij} ----activity production rate (m/day),

FL_i ----the number of filling layers in working day,

MT_{ij} ----the lowest temperature in working day (°C).

Production rate regression model of surface layer of foundation bed filling activity

The analysis results show that the production rate is related to the lowest temperature and the maximum wind speed, and the production rate regression equation is show as blow:

$$PR_{ij} = 193.123 - 0.545MWS_i + 0.332MT_{ij} \quad (3)$$

In which, PR_{ij} ----activity production rate (m/day),

MWS_{ij} ----the maximum wind speed in working day (m/s),

MT_{ij} ----the lowest temperature in working day (°C).

3.4 Production rate regression model of railway construction project based on Grid

Based on the production rate regression equation in section 3.3, taking the arrangement of working time into account, the working day variable can be added into the equation to present if this day is a

working day or not. Value 1 represents that today is a working day, and value 0 means not, for example, vacation, etc.

According to the time-space feature of factors that influence railway construction rates, corner mark i and j are given to factor variable. Together with the code of time-space grid, a new grid-based production rate regression model is build.

(1) grid-based production rate regression model of embankment and bottom layer of foundation bed filling activity

$$PR_{ij} = WD_{ij} \times (-3.251FL_i + 0.286MT_{ij} + 165.519) \quad (4)$$

In which, PR_{ij} ----activity production rate (m/day),

WD_{ij} ----working day (1 for positive and 0 for negative),

FL_i ----the number of filling layers in working day,

MT_{ij} ----the lowest temperature in working day($^{\circ}\text{C}$).

(2) grid-based production rate regression model of surface layer of foundation bed filling activity

$$PR_{ij} = WD_{ij} \times (-0.545MWS_i + 0.332MT_{ij} + 193.123) \quad (5)$$

In which, PR_{ij} ----activity production rate (m/day),

WD_{ij} ----working day (1 for positive and 0 for negative),

MWS_{ij} ----the maximum wind speed in working day (m/s),

MT_{ij} ----the lowest temperature in working day($^{\circ}\text{C}$).

4. Case study

This paper takes a subgrade engineering of a new-built railway line as example, using production rate regression model to generate project schedule. After that, a comparison between original schedule, real schedule and mode schedule will be made. The original schedule of the construction project is made by the site engineer based on constrains between construction activities and personal construction experience. The comparisons of three schedules of two activities are shown as blow. Embankment and bottom layer of foundation bed filling activity.

Table 3. The time-location information summary table of the three schedules surface layer of foundation bed filling activity

	Mileage	Original Schedule	Real Schedule	Model Schedule
Start Position	SDK1+000	2009-03-05	2009-03-05	2009-03-05
End Position	SDK7+700	2009-04-30	2009-05-13	2009-05-09
Total	6700m	56 days	69 days	65 days

Table 4. The time-location information summary table of the three schedules

	Mileage	Original Schedule	Real Schedule	Model Schedule
Start Position	SDK1+000	2009-04-10	2009-04-10	2009-04-10
End Position	SDK7+700	2009-05-10	2009-05-20	2009-05-17
Total	6700m	30 days	40 days	37 days

From table 3 and 4, it can be seen that the duration of model schedule made is closer to the real schedule than the original schedule in both activities. Therefore, the grid based production rate regression model of railway construction project is superior to the original planning method.

5. Summary

Improving the method of prediction of construction production rate is important for construction industry, and a scientific method of classification of factors that influence the production rate and a suitable method for predicting the construction rates are needed. The main research results of this paper include the following points:

- (1) Develop a time-location-based division method of influencing factors according to their time-spatial varying features,
- (2) Use multiple linear regression analyze the incidence relation between the production rates and influencing,
- (3) Develop a regression model with varying production rates based on grids.

Although the theory and method proposed in this paper have advantage in practical application, there are still some shortages in this paper. For example, the factors considered in this paper are not enough, and the regression model is still needed to be improved. All these need further study in the future.

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