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Study on the Costs of Steel Reinforcement on the Construction of Subway Station

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In order to study the cost of the steel reinforcement construction in the subway station, through the analysis of the correlation between the costs of labour and ancillary equipment on the process of subway station construction, and the analysis of the correlation between the cost and the duration, and then established mathematical model of the correlation between the costs of labour and ancillary equipment and the correlation between the cost and the duration, which were based on the statistical analysis. So that it has been on the positive direction of controlling the cost and the duration on the subway construction. By the theory of coupling coordination degree model, explored the coupling mechanism of the costs of labour and ancillary equipment, and the coupling mechanism of the cost and the duration, at last established coupling mathematical model based on the data of statistical analysis. Those statistical data included No. 1 and No. 12 section of the Changsha Metro 3rd Line, and No. 6 and No. 7 section of the Changsha Metro 4th Line. Model results showed that the standard coordination degree of coupling coefficients in No. 1 and No. 12 section of the Changsha Metro the 3rd Line, and No. 6 , No. 7 and No. 8 section of the Changsha Metro the 4th Line. By calculating the value of the degree of coordination were 0.9852, 0.9414, 0.9668, 0.6515 and 0.5383. Besides, the result of analytical computation showed that the duration decreased with the increase of the coefficient of the coordination degree. When the proportion of the cost of labour and ancillary equipment was 1, the total cost was minimum. Besides, when the proportion of the cost of labour and ancillary equipment was 1, the duration was the shortest time. So when on the process of subway station construction, we should adjust to the best value of the proportion between the cost of labour and ancillary equipment.

1. Introduction

By the end of 2014, 95 metros had been build throughout 22 cities in China, and the mileage reached 2900 km was in motion and do business.

By 2020，it was estimated that more than 45 cities will be built subway in China. However the cost of Metro construction achieved a staggering 5.8 billion yuan per kilometer. So the control of the cost of subway construction was particularly important.

Reinforced concrete structures is not only the most structural forms used in the modern construction engineering, but also the most important part measurement in the engineering construction. Investment in construction of Metro stations, the proportion of the material investment of steel material was 70%-80% in the total investment of construction of subway station. Furthermore, steel bar construction was a concrete skeleton or embedded parts, and it was also hidden works. And steel bar construction and install was the most cumbersome step in subway engineering project. Steel bar binding played an important part in connecting, fixing and constraining vertical and horizontal steel bar and stirrup. Commonly, the rebar way included the sequential fastener and Pigeon - toed buckle (As indicated in Figure.1). Besides, steel bar binding should ensure the effectiveness of the steel rigid frame and function. So the technology of steel welding, assembling and installation was directly related to the safety, quality and cost of the construction of Metro stations.

For a long time, Steel bar construction in construction industry mainly relied on manual work in China. And steel bar binding and install were not only tedious but also very low productivity, which seriously restricted the level of modernization in China. Therefore, it was needed to study on subway coupled relationship between materials, labor, machinery and ancillary measures in steel bar construction of subway station construction, which achieved the control of the cost subway station construction.

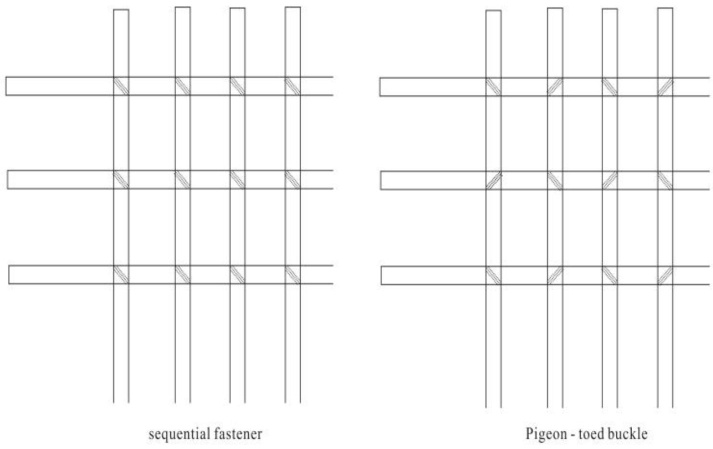

Figure 1: Common methods of steel bar binding

2. Model of coupling coordination degree for steel bar construction in metro station construction

2.1 Format model of coupling coordination degree

Coupling was described as the physics concept about electronic components and the correlation, division of labor and cooperation, and the information or energy transmitted of the networks. And later, the physics concept has been widely used in geography, economics, biology, agronomy and other fields.

Coordination expressed that the relationship and trends between system elements was virtuous circle and healthy development, and each system elements made a concerted effort and matched properly.

But the degree of coordination was the metrics of the characterization of phylogenetic status, which was the metrics of describing the dynamic process of sustainable development between the system elements.

In order to study the relationships between system elements, described the interaction between the various elements of the subsystem or system function, and the dynamic relationship of interdependence and mutual influence by "coupling" and "coordination". And the degree of coupling coordination described a whole system change or evolution. Therefore, the degree of coupling coordination model was not only described the overall evolution of the system of measurement, but also was a diverse, comprehensive and overall aggregate analysis of mathematical methods. Based on the above theory, this definition of the costs of labor and machinery were two subsystems, and expressed system dynamic development trends and the overall trend by the degree of coupling coordination model (As indicated in (1)).

$$C = {(U_i^k \times S_i^k)} \Big/ {(\alpha U_i + \beta S_i)^{2k}} \tag{1}$$

In the formula: ***C*** was the coefficient of the degree of the coupling coordination, α and β were undetermined coefficients, $\alpha + \beta = 1$, k was adjustment factors, and $2 \le k \le 8$.

2.2 Model of coupling coordination degree for steel bar construction in metro station construction

The technology process of steel bar binding and install were cumbersome，which not only needed manual measures，but also needed mechanical assistance. Besides manual and mechanical virtuous interaction not only provided good production efficiency, but also saved construction costs. Because traditional analysis method of construction process could not dynamically described the balance relationships and trend between steel artificial measures and mechanical assistance. In order to analyze the dynamic development and overall trends of the manual measures and mechanical measures, based on statistical data of the cost of the manual measures and mechanical measures in the subway station construction in Changsha city, and applied coupling coordination degree model for study the dynamic development and overall trends of the manual measures and mechanical measures, which was the feedback of dynamic development trends and the overall trend.

Supposed U_i as subsystems function that was the cost of artificial measures in subway station construction, and supposed as subsystems function S_i that was the cost of mechanical assistance in subway station construction, and the two subsystems were equally important, $\alpha+\beta=1$, and selected the adjustment coefficient $k=2$.

3. Example analysis

In the process of metro station construction, artificial measures and mechanical measures were mutual relationship of collaboration. While the cost of artificial measures was too much, it would cause production efficiency reduced and cost rose. And while the cost of mechanical was too much, although it improved production efficiency but the cost would significantly rose. So in order to makes the cost of artificial measures and mechanical measures reached a good of balance state in metro construction process, used coupled coordination degrees model to analysis the dynamic relationship.

According to the model of coupling coordination degree for steel bar construction, U_i expressed the cost of artificial measures and S_i expressed the cost of artificial measures in subway station construction. Besides, these parameters were known, $\alpha=0.5$, $\beta=10.5$, $k=2$.

$$C = {(U_i^2 \times S_i^2)}\Big/{(0.5*U_i + 0.5S_i)^4} \tag{2}$$

In the formula: ***C*** was the coefficient of the degree of the coupling coordination. U_i as subsystems function that was the cost of artificial measures in subway station construction, and supposed as subsystems function S_i that was the cost of mechanical assistance in subway station construction

When c=*1*, the formula (2) showed

$$1 = {(U_i^2 \times S_i^2)}\Big/{(0.5*U_i + 0.5S_i)^4} \tag{3}$$

By calculating, the formula (3) showed

$$(U_i + S_i)^4 = 16(U_i^2 \times S_i^2) \tag{4}$$

The result of analytical computation shows that while the value of U_i and S_i was equal, the value of ***c***- the coefficient of the degree of the coupling coordination was 1.

So in order to establish the mathematical model to research on the relationship between the cost of artificial measures and mechanical assistance and the duration, statistical data included total cost, the cost of steel bar, the cost of labour, the cost of machinery and the duration, which were the project budget from the statistical data in No. 1 and No. 12 section of the Changsha Metro 3rd Line, and No. 6 , No. 7 and No. 8 section of the Changsha Metro 4th Line(As indicated in Table.1, Table.2, Table.3, Table.4& Table.5).

According to the model of coupling coordination degree for steel bar construction, their model has been shown in (2), and based on the statistical data in No. 1 and No. 12 section of the Changsha Metro 3rd Line, and No. 6, No. 7 and No. 8 section of the Changsha Metro 4th Line.

Table 1: Statistical table for metro construction in No. 1 section of the Changsha 3rd Line

Statistics Project	Statistics Details	Percentage
Total cost	￥173362838.85	
cost of steel bar	￥56175311.748	32.4%
cost of labour	￥11476111.74	6.62%
costs of machinery	￥13648156.158	7.87%
duration	36 months	

According to the formula (2), the value of ***c*** was 0.9852 by calculating.

Table 2: Statistical table for metro construction in No. 12 section of the Changsha 3rd Line

Statistics Project	Statistics Details	Percentage
Total cost	￥429467288.96	
cost of steel bar	￥131563425.72	33.054%
cost of labour	￥24874046.052	6.252%
costs of machinery	￥35255013.624	8.856%
duration	42months	

According to the formula (2), the value of ***c*** was 0.9414 by calculating.

Table 3: Statistical table for metro construction in No. 6 section of the Changsha 4rd Line

Statistics Project	Statistics Details	Percentage
Total cost	￥226458786.90	
cost of steel bar	￥78807651.58	34.8%
cost of labour	￥16078573.87	7.1%
costs of machinery	￥20834208.40	9.21%
duration	40 months	

According to the formula (2), the value of ***c*** was 0.9668 by calculating.

Table 4: Statistical table for metro construction in No. 7section of the Changsha 4rd Line

Statistics Project	Statistics Details	Percentage
Total cost	￥198826654.56	
cost of steel bar	￥62133329.55	31.25%
cost of labour	￥10259455.38	5.16%
costs of machinery	￥26324649.06	13.24%
duration	44 months	

According to the formula (2), the value of ***c*** was 0.6515 by calculating.

Table 5: Statistical table for metro construction in No. 8section of the Changsha 4rd Line

Statistics Project	Statistics Details	Percentage
Total cost	￥238591985.472	
cost of steel bar	￥78145726.28	32.75%
cost of labour	￥10445678.67	4.38%
costs of machinery	￥32789543.78	13.72%
duration	46 months	

According to the formula (2), the value of ***c*** was 0.5383 by calculating.
So by the model of coupling coordination degree, the results were as follows:

Table 6: Statistical table for the results of calculation

Metro station	Coefficient of the degree of the coupling Coordination
No. 1 section 3RD Line	0.9852
No. 12 section 3RD Line	0.9414
No. 6 section 4TH Line	0.9668
No. 7 section 4TH Line	0.6515
No. 8 section 4TH Line	0.5383

According to the formula (4) and the principle of coupled coordination degrees model, technically speaking, the larger the value of the coefficient of the degree of the coupling coordination was, the better two subsystems was.
While the coefficient was 1, the cost of the manual measures and mechanical measures achieved the best effective balance.
However, in order to study on the cost the relationship between the cost of artificial measures and mechanical assistance and the duration, the data of calculation and statistical analysis were as follows (As indicated in Table 7 and Figure.2).

Table 7: Statistical table for the value of C and duration

Metro station	The value of C	duration(months)
No. 1 section 3RD Line	0.9852	36
No. 12 section 3RD Line	0.9414	42
No. 6 section 4TH Line	0.9668	40
No. 7 section 4TH Line	0.6515	44
No. 8 section 4TH Line	0.5383	46

According to table 7 drew relationship diagrams for the value of C and the duration, which was described the correlation between the two parameters clearly(As indicated in Figure.2)

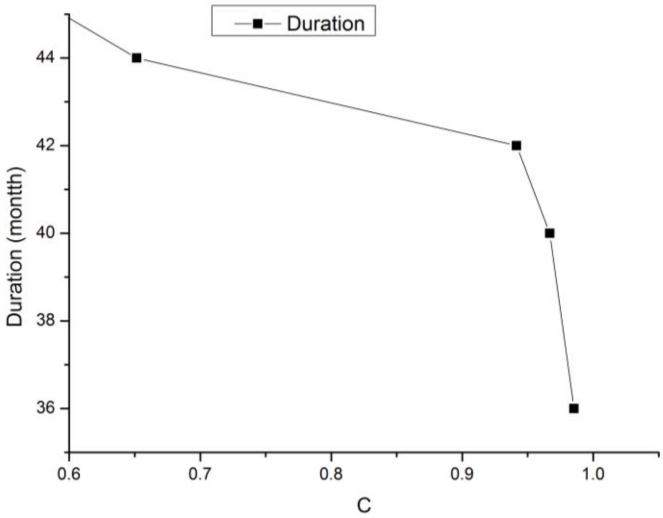

Figure 2: Graph of relation between C and duration

According to figure 2, it was known that while the larger the value of C was, the shorter the duration was. Besides, figure 2 showed that the mathematical relationship between the value of C and the duration was a nonlinear. In addition, the duration decreased more quickly while the value of C approached 1.

While they had not reached effective balance in the civil construction in No.7 and No. 8 section of the Changsha Metro 4th Line. Besides, this calculation suggested that while the smaller of the value of C was, the longer of duration was. So No.7 and No. 8 section should adjust the proportion the cost artificial measures and mechanical measures (As indicated in Figure 2).

4. Conclusions

In order to make the organic balance between production efficiency and cost, analysed the dynamic relationship and trend of the cost of artificial measures and mechanical measures by coordination degree of coupling model .Based on the project budget from the statistical data in No. 1 and No. 12 section of the Changsha Metro 3rd Line, and No. 6 , No. 7 and No. 8 section of the Changsha Metro 4th Line, the model of coupling coordination degree for steel bar construction in metro station construction has been established.

By calculating the degree of coordination were 0.9852, 0.9414, 0.9668, 0.6515 and 0.5383. Besides, the mathematical relationship between the value of C and the duration was a nonlinear. Furthermore, the larger the value of C was, the shorter the duration was. While the degree was 1, the duration and costs were relatively low. So they needed to the proportion of the cost of artificial measures and mechanical measures, so that they achieve the optimized balance.

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Reference

Babu A J G, Suresh N. 1996. Project management with time, cost, and quality considerations. European Journal of Operational Researeh, 1996, 88(2): 320-327. Doi: 10.1016/0377-2217(94)00202-9

Bique A O O, Goryunova A G, Manenti F. 2015. A Comparison of Simulation Techniques for Uranium Crystallization Process. Chemical Engineering Transactions, Vol. 43, 793-798. DOI: 10.3303/CET1543133

Dhahri R, Boughamoura A and Ben N S. 2003. Forced heat transfer for pulsating flow in composite porous fluid system. International Journal of Heat and Technology, vol. 20. No. 2, 193-202.

Hui L D. . 2008. Project Management, Critieal Praxis, and Proeess Oriented- Approach to Teamwork. Business Communieation Quarterly, Vol. 71(2):456 — 471.

Khang D B, Yin M M. 999. Time, cost and quality trade-off in project management: A case study. International Journal of Project Management, Vol. 17(4):249 一 256.

Kima E H, Wells Jr W G, Duffey M R. 2003. A model for effective implementation of Earned Value Management Methodology. International Journal of Project: Management, Vol. 21, 375-382.

Love P E D, Irani Z. 2003. A project management, quality cost information system: for the construction industry. Information Management, vol 40, 649-661.

Mccarthy R. 2007. Understanding project costs and building costs. Managing Library Finances, Vol 17, 6-9.

MeKim R, Hegazy T, Attalla M. 2000. Project performance control in reconstruction projects. Journal of Construction Engineering and Management, Vol. 126(2): 137 — 141.

Nizar L, and Noureddine B. 2007. Heat and mass transfer during fluid evaporation in forced convection with variable thermophysical properties -Soret and dufour effects. International Journal of Heat and Technology, vol. 21. No. 2, 75-81.

Reggente, M., Mondini, A., Ferri, G., Mazzolai, B., Manzi, A., & Gabelletti, M., et al. 2010, The dustbot system: Using mobile robots to monitor pollution in pedestrian area, Chemical Engineering Transactions 23, Vol. 23, 273-278. DOI: 10.3303/CET1023046

Zeghbid I and Bessaih R. 2015. Mixed convection in lid-driven cavities filled with a nanofluid. International Journal of Heat and Technology, vol. 33, No. 4, pp. 77-84, DOI: 10.18280/ijht.330410

Zuorro A, Lavecchia R, Medici F, Piga L. 2014. Chemical engineering transactions/cet guest editors: use of cell wall degrading enzymes for the production of high-quality functional products from tomato processing waste. Chemical Engineering Transactions, Vol. 38, 355-360. DOI: 10.3303/CET1438060