The Key Transfer Essentials From Construction to Operation in Urban Rail Transit

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Abstract: Urban rail transit construction and operation transfer process involves a large number of management and technical interfaces, including territorial management rights, equipment use rights and dispatching command rights handover between construction unit and operation unit as short time as possible. This paper focuses on operation transfer characteristics, important works and key lines. At the same time, using the multi-objective planning method, analyses the effective solution about transfer to provide theoretical and practical reference data for the relevant personnel in construction and operation of Urban Rail Transit.

1 OVERVIEW

At present, China is in a period of rapid construction and development of urban rail transit, as of the first half of 2017, 31 cities opened urban rail transit with a total mileage of 4,400 kilometers on urban railways. The total scale of construction is 5770 kilometers. After 2015, the new urban rail cities include Nanchang, Lanzhou, Qingdao, Huai'an, Fuzhou, Dongguan, Nanning, Hefei, Shijiazhuang, etc. The structure of urban operation line system is shown in figure 1. The rapid construction and diversification of urban rail transit have set higher requirements for the construction and operation. In particular, the transfer management from construction period to operation period is paid more and more attention for the construction unit and operating unit. The transfer processes play a crucial role to guarantee the commissioning acceptances, improve the quality and safety of operation, and reduce the post-maintenance costs, etc.

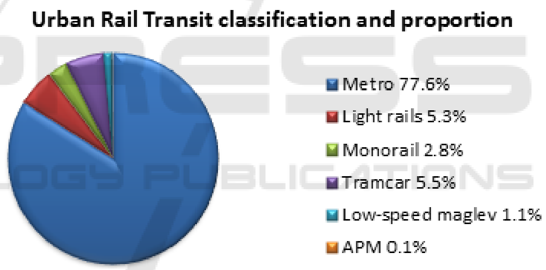

Figure 1: Urban rail transit lines operating standard chart

2 THE TRANSFER CHARACTERISTICS FROM CONSTRUCTION TO OPERATION

The urban rail transfer from construction to operation is an important part of urban rail transit life-cycle management. It marks that the construction focus of urban rail transit including installation, commissioning and acceptance is transferred to the operation center including total joint test, operating exercises, test run and trial operation management (General Administration of Quality Supervision, 2013). The important landmark event is the transfer of territorial management rights,

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equipment using rights and dispatching command rights.

The transfer of territorial management rights mean that the site management of stations, control centers and depots will no longer be undertaken by the construction unit, but belong to the operation unit. The project plan such as the unfinished construction, sub-projects and unit project acceptance so on will be arranged by the operation unit, but not construction unit any more. For each participating unit, construction should be completed before this node time, otherwise, the construction time cost will increase substantially.

The transfer of the equipment use rights mean that the construction unit shall transfer the maintenance and overhaul of the equipment to the operation unit. And the equipment starts to be put into normal use after the node time. The equipment contractor can apply for the payment of the settlement of the equipment, and the equipment enters to the quality warranty period.

The dispatching command rights mean that Inter-area traffic command and station equipment comprehensive using began to be charged by the operation unit. After this node time, the operation unit starts to take charge of coordinating and comprehensive application of equipment to ensure driving reliability and safety during trial operation.

3 THE TIME PERIOD BACKGROUND ANALYSIS OF THE TRANSFER FORM CONSTRUCTION TO OPERATION

According to the lifecycle relationship between urban rail transit construction and operation, the transfer from construction to operation involves three stages: the pre handover stage, the handover stage, and the later handover stage.

The main tasks in the pre handover stage include the intervention management of construction project, operation external and internal preparation, single system debugging and acceptance of different specialties.

The main tasks in the handover stage include the operation of the stationing management, temporary management operations, transfer of three rights and other work.

The main tasks in the later handover stage include alignment joint-test, Operating practice, safety assessment, full map sports car, Commissioning assessment and defect rectification, trial operation and unfinished construction work (Ministry of Construction of the People's Republic of China, 2009), the timing of the specific work plan shown in figure 2:

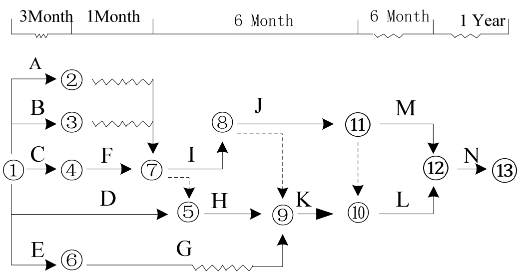

Figure 2: Urban rail transit construction and operation of the transfer of the main work timing diagram

In the figure, A - Power supply system debugging; B – Signal & Communication system debugging; C - Vehicle system debugging; D - Electromechanical system debugging; E - Operation preparation; F - Cold and hot slide; G - Operational involvement; H - Total joint test; I - The transfer of the three powers; J - Reliability test; K - Full map sports car; L - Pilot run; M - Security assessment; N - Trial operations and unfinished construction work. Solid arrows line - the adjacent work has a real overlap relationship; Virtual arrow line - the adjacent work has logical relation; Wave line - wait time.

As can be seen from the figure 2, there are two key lines for the transfer form construction to operation: ①④⑦⑧⑪⑫⑬ and ①⑤⑨⑩⑫⑬, which need to be noticed in the actual work.

4 THE KEY TRANSFER ESSENTIALS FROM CONSTRUCTION TO OPERATION

The key essentials of the transfer from construction to operation can be divided into two parts: construction unit and operating unit. From the perspective of the construction unit, the focus of the operation transfer includes the realization of the system functions, the management of the three rights, the unfinished project construction plan. For the operation units, the focus includes the management of personnel, machines, production goods articles, and some key woks such as total joint test, operating practice, full map sports car; Pilot run and trial operation management, etc. The focus of transfers includes the following six aspects:

(1) The function of each equipment system to achieve the situation

Equipment system includes vehicle system, power supply system, communication system, signal system, integrated supervisory control system, fire alarm system, automatic fare collection system, screen door system, escalator system, ventilation and air conditioning system, water supply and drainage system, power lighting system, etc. Each system's functional acceptance is divided into master project acceptance and general project acceptance. under normal circumstances, the acceptance of each system must be completed before the transfer from construction to operation.

(2)Internal preparations of operation unit

Internal preparation of operation unit mainly includes personnel preparation, organization preparation, material preparation and data preparation (Lin, He, 2015). Personnel preparation mainly includes: The level of technology and management personnel backbone is in place, their service quality and ability can meet the job needs and they have obtain qualification certificates.

Organizational preparation mainly includes: institution is already set up reasonable, organization can effective operate, business process is clear, and plan implementation is accurate;

Material preparation mainly includes: Passenger cars and construction vehicles is completed on schedule and delivered to use, critical equipment and spare parts is delivered on-time, warehousing and transportation works well;

Data preparation mainly includes: Contract, design drawings and other technical documents are completed, operation programs are seasonable and accurate, rules and regulations prepared are scientific and perfect.

(3) The process control of operation transfer

The main processes include the advance intervention of the operation unit, entering the station by operators, the management of the station and the interval, the transfer of the three rights, etc.

The main control work includes unit project acceptance, limit checking, vehicle cold slide and hot slide test, temporary operation management for the station and interval, formal transfer of territorial management rights, equipment using rights, dispatching command rights and other works.

(4) Total joint test and operation exercise smooth implementation

The total joint test mainly includes the commissioning of the mechanical and electrical equipment system led by the comprehensive monitoring system in the station (other system have geomantic electric system, escalator system, screen door system, tickets system of selling and checking, disaster alarm system, etc.) , and anther commissioning led by vehicle system (other system have signal system, communication system, and track system) (Yanjun, Xiao, 2014); Operational exercises include operational exercises in normal mode, doing it in abnormal modes, and emergency drills in emergencies. Construction units and operation units need to cooperate closely to complete this part.

(5) Trial operations assessment and defect rectification

The main works include each system reliability test, vehicle full map sports car, opening station and existing line transfer, station and interval tuning and testing of the full participation, control center system access and test program, ticketing system test. This stage of operation units strictly enforced commissioning of various programs, at the same time need construction units combined with rectification.

(6) Disposal situation of the unfinished construction work

After the transfer from construction to operation, until the opening of the line, there will be projects left over by construction unit for various reasons. This requires the operation unit reserve the skylight time for the construction unit, the construction unit shall timely construction and acceptance in the skylight time; for really unable finished construction before opening of the line, the construction unit should formulate construction plan according to the trial operation plan; At the same time, according to the construction situation, the operating unit draw up the trial operation and vehicle driving protection measures, which include measures to stop stopping and measures for subsection opening of line.

5 APPLICATION OF MULTI-OBJECTIVE MODEL IN THE TRANSFER FROM CONSTRUCTION TO OPERATION

Solving model with two or more goal decisions is called multi-objective planning model. Transfer in urban rail transit construction and operation of involved the strong professional technology, complex equipment, many units, many decisions interrelated goals belong to typical multi-objective decision problems. For example, in the construction and operation of the transfer, how to choose the right interface solutions, making the transfer smooth, reliable, the highest transfer rate, and spend of the corresponding cost is the minimum? This is the multi-objective decision to be solved.

(1) The main feature of the multi-objective decision

The main feature of the multi-objective decision problem is each target has the contradictory and incommensurability. The contradiction between the objectives is refers to the improvement in a target value, which may make the other target value worse; Incommensurability between objectives means that each objective cannot be directly compared due to the different units of measurement. Urban rail transit interfaces research need to establish a measurable metrics in the multi-objective incommensurability, which can be measured to determine the effect of interface management. For example, the implementation rate of each attribute objective is the standard that can be compared.

(2) The basic elements of multi-objective decision

Multi-objective decision generally includes five basic elements (Zhonggeng, Han, 2009): decision unit, attribute set, objective set, the decision situation and the decision rules. The corresponding way of urban rail transit transfer is shown in table 1:

Table 1: The Corresponding way of multi-objective factors in the urban rail transit transfer

Multi-objective Factors	Correspondence in the construction and operation transfer of urban rail transit
decision unit	Construction unit and operating unit
attribute set	The function of each equipment system to achieve the situation(x_1), Internal preparations of operation unit (x_2), The process control of operation transfer(x_3), Total joint test and operation exercise smooth implementation(x_4), Trial operations assessment and defect rectification (x_5), Disposal situation of the unfinished construction work(x_6).
objective set	the expected value of the achievement rate of each property(a), the deviation of the cost of each property(b)
decision situation	The maximum expected value(a) of the same time the minimum deviation(b)
decision rules	Multi-objective turn into single-objective solution; hierarchical sorting method

(3) Multi-objective decision mathematical expression

From decision situation in table 1, the interface objective of the construction and operation transfer require the indicators of attribute set to achieve the maximum rate, at the same time the minimum cost of their deviation. This multi-objective decision problem can be analyzed using a multi-objective mathematical model.

The expected value of the achievement rate of each property can be used respectively defined as $f_1(x_1), f_2(x_2), \cdots, f_n(x_n)$, the deviation of the cost of each property recorded as $g_1(x_1), g_2(x_2), \cdots, g_m(x_m)$. The decision situation is the maximum expected value of each property, while the minimum cost of their deviation. Making multi-objective transformation into single-objective model, the description model is:

$$\text{n objective functions} \begin{cases} max f_1(x_1) \\ max f_2(x_2) \\ L \\ max f_n(x_n) \end{cases} \quad (1)$$

$$\text{m constraint condition} \begin{cases} min g_1(x_1) \to 0 \\ min g_2(x_2) \to 0 \\ L \\ min g_m(x_m) \to 0 \end{cases} \quad (2)$$

where $n \geq 2$, $m \geq 2$.

If the introductions of vector function, multi-objective decisions can be written in vector form (Guangyan, Shi, 2015):

$$\max F(x) = \left(f_1(x), f_2(x), \cdots, f_p(x)\right)^T \quad (3)$$

$$G(x) = \left(g_1(x), g_2(x), \cdots, g_m(x)\right)^T = 0 \quad (4)$$

6 ARITHMETIC CASE ANALYSIS OF MULTI OBJECTIVE TRANSFER FROM CONSTRUCTION TO OPERATION

The pursuit target of the transfer from Construction to operation is multi-objective coordinated between construction quality, transfer of progress, professional technology, site management and other system technology.

Table 2: Five metro lines p_i and r_i experts score

	p_1	p_2	p_3	p_4	p_5	p_6	r_1	r_2	r_3	r_4	r_5	r_6	$\lambda_{i=1\sim6}$
Line 1	0.88	0.78	0.9	0.83	0.92	0.81	0.05	0.01	0.01	0.02	0.03	0.02	0.167
Line 2	0.92	0.8	0.85	0.90	0.8	0.85	0.02	0.05	0.05	0.03	0.04	0.02	0.167
Line 3	0.95	0.9	0.9	0.85	0.92	0.85	0.03	0.02	0.02	0.02	0.01	0.02	0.167
Line 4	0.85	0.87	0.85	0.89.	0.89	0.80	0.01	0.02	0.02	0.01	0.02	0.01	0.167
Line 5	0.9	0.9	0.92	0.9	0.92	0.88	0.04	0.03	0.02	0.03	0.04	0.05	0.167

The pursuit target of the transfer from Construction There are the contradictory and incommensurability between objectives in urban rail transit, so it is difficult to get multi-objective optimal solution in which all attributes reach their respective optimal values at the same time.

But in a certain condition and range, acceptable efficient solutions or non-inferior solution can be obtained. According to Table 1, find both the maximum expected value of each property and the minimum deviation at the same time, and establish an arithmetic example model, the process is as follows:

Suppose the realization rate of each attribute objective is random variable that is independent of each other, denoted by $R_{i(i=1,2,\cdots,N)}$; the mathematical expectation value (Xiuzhen, Feng, 2011) of each R_i is denoted by $\mathrm{E}(R_i) = P_{i(I=1,2,\cdots,N)}$; the deviation of cost between planned cost and actual cost is denoted by variance$\mathrm{D}(R_i)$, then$\mathrm{D}(R_i) = r_{i(i=1,2,\cdots,N)}$.

Suppose the proportion of the objective achievement rate i to the total objectives achievement rate is λ_i , then the total interface realization rate is $R=\sum_{i=1}^{N}\lambda_i R_i$, the total mathematical expectation value is $E(R)=\sum_{i=1}^{N}\lambda_i E(R_i)=\sum_{i=1}^{N}\lambda_i p_i$, and the total cost deviation is $D(R)=\sum_{i=1}^{N}\lambda_i D(R_i)=\sum_{i=1}^{N}\lambda_i r_i$.

In order to maximize the expected mathematical expectation value for each attribute, at the same time the corresponding cost deviation is minimized, establish the multi-objective decision model, in which ,taking N = 6, and x_1~x_6 in table 1 is put into equations (3) and (4), get:

$$\begin{cases} \max \sum_{i=1}^{6} \lambda_i p_i = p_0 \\ \min \sum_{i=1}^{6} \lambda_i r_i = r_0 \\ 0 \le \lambda_i \le 1 \\ \sum_{i=1}^{6} \lambda_i = 1 \end{cases} \qquad (5)$$

Using expert scoring method, the experts form the construction and operation unit give the empirical values about expectation values p_i and cost deviation values r_i on the five metro lines, at the same time set each target value of $\lambda_i(i=1,2,\cdots,6)$the same. Get table 2.

The p_i , r_i and, λ_i in the table 2 put into the formula (5), get table 3:

Table 3: Five metro lines P_0 and r_0 values calculated

	1	2	3	4	5
P_0	5.12	5.12	5.37	4.26	5.42
r_0	0.14	0.21	0.12	0.12	0.21

According to result(r_o, p_o), do the distribution, show as figure 3:

In the figure 3, for the line ① ② ③ ⑤, ① line interface effect is better than ② ③ ⑤ line, ⑤ line interface effect is better than ② line; For lines ① ③ ④, line ③ is better than line ④, line ① slightly better than the line ③. It shows the line ① is the best transfer interface effect in the five lines construction and operation.

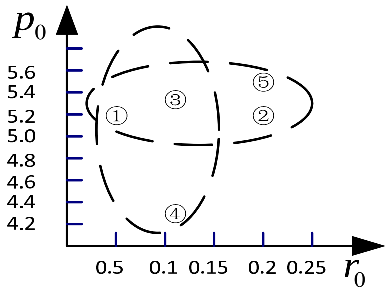

Figure 3 five subway line construction and operation interface renderings

Each interface goal solution in Line ① is not optimal solution, but an effective solution (non-inferior solution), which has important reference significance to solve the corresponding targets of new line.

7 CONCLUSION

(1) The article analyzes essentials about Transfer in urban rail transit construction and operation from six aspects. They are the function of each equipment system to achieve the situation, Internal preparations of operation unit, The process control of operation transfer, Total joint test and operation exercise smooth implementation, Trial operations assessment and defect rectification, Disposal situation of the unfinished construction work. And the key work of each case is given combined with the actual project.

(2) In accordance with the schedule of the transfer form construction to operation, the article analyzes the key lines of the transfer about construction and operation, and points out the key work.

(3) The multi-objective planning and analysis method is used to analyze the handover of five subway lines, and the state of the control data which satisfies both the maximum rate of interface handover and the minimum cost deviation is obtained. Provide a reference for the management and technical personnel in urban rail transit.

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