Refined cost control and management methods for high-speed railway signal projects

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Abstract. The paper concentrates on a cost control and management problem of high-speed railway signal systems when the project managers require to organize, implement, and assess the project cost. When it comes to the existing issues of implementing railway signal project, the management process's actual performances are presented, including the weak awareness of refined management and the lack of the financial management information system. Aiming to reduce project cost and safe operation of the signal systems, the refined cost control and management methods and concrete measures are presented during the concrete stage involving project bidding, preparatory, implementation, and completion.

1. Introduction

The operating mileage of Chinese high-speed railways (HSRs) has exceeded 37,900 kilometers by the end of December 2020. China has established the most modern railway network and the most developed HSRs network around the world. It seems to be a world miracle that the HSRs of China has been developed from scratch, from weak to strong, from accumulation, introduction to independent innovation, and from domestic to foreign. China has become a country with the fastest-growing HSRs, longest operating mileage, largest scale under construction, largest number of HSRs trains in the world.

As one of three cores of the HSRs transportation system with high-speed rail fixed equipment (lines, bridges, tunnels) and mobile equipment (locomotives, vehicles), the communication signal system is a key to ensure the safe and efficient operation like the center and nerve of HSRs [1]. China's HSRs communication signal system technology has achieved 100% localization of core technologies and products, which effectively guarantees the safe and orderly operation of China's 37,900-kilometers high-speed railway network, and also makes important contributions to the construction of intelligent railways.

According to the 2019 World Bank Research Report [2], the average cost, including signal systems, electrical systems, and facilities of China's HSRs with a speed of 350 km/h, 250 km/h, and 200 km/h are about 139, 114, and 104 million yuan per kilometer respectively. The average cost of the HSRs signal system accounts for about 10% of the sum. The construction cost of China's HSRs network averages 17 to 21 million dollars per kilometer, which is about two-thirds of the construction costs of other countries.

Cost control and management are the fundamental issues of some projects to identify, manage, and satisfy the client needs, project scope, and project cost [3]. It plays a significant role in the construction of large projects to reengineer the process [4], widely applied in different scenarios such
as software time control [[5]], risk analysis [[6]] and project scheduling [[7]]. Aiming to refine project management and save project composition costs, the paper introduces the new methods for cost control and management in high-speed railway signal projects. The rest of the paper is organized as follows. Section II introduces existing problems of cost control and management in actual railway signal projects. Refined methods and concrete measures of cost control and management are listed in section III, and section IV gives a conclusion.

2. Refined cost control and management of railway signal project

The quality of communication signal engineering and the smooth operation of communication signal devices are related to the safety of trains with a significant role. The refined cost control and management of railway signal project (RCCMRSP) are responsible for making an effective organization, implement, control, track, analysis and assess for project cost, strengthening business management, and improving financial cost management. Consequently, it realizes corporate profits and improves system quality, thereby ensuring the safety of railway signal systems, which is an inevitable choice for enhancing corporate competitiveness. The existing problem of RCCMRSP can be summarized as follows.

2.1. Existing problems

Firstly, the entire process of implementing the railway signal project lacks cost control. At present, many departments lack prior control of cost during the construction process. They merely calculate the incurred costs when the project ends or at a considerable stage. However, it is so late that the effect of cost control cannot imagine. As part of project cost management, cost accounting, which is the main content of ex-post control, only records, categorizes, and calculates the actual costs incurred, reflecting the actual implementation results. The focus of RCCMRSP should be shifted to the process control of pre-control and in-process.

In addition, cost equality lacks control and management. As a consequence, it is unable to handle the relationship between quality and cost, construction period, and cost.

Then, the system of RCCMRSP is not in a sound phenomenon that the "responsibility, power, and benefits" of the project leader are generally not implemented in all business departments in the implementation of project management. There is no specific and clear cost management responsibility for each position in the engineering project, which is difficult to assess the strengths and weaknesses. Project costs are not linked to the economic interests of project managers, and the responsibilities and rights of the cost management system are not organically combined. Therefore, project managers are often satisfied with the completion of indicators such as output value, schedule, quality, and safety and are less concerned about the saving and control of labor, materials, and mechanical use that are directly related to the cost. Even though the higher-level departments force them to carry out cost management, project managers and on-site management personnel are still passive and more superficial.

Finally, due to information security issues, collecting data is difficult in RCCMRSP even though several companies have begun to integrate this work with management models.

2.2. Actual performance

The actual performance can be listed as the following points. On the one hand, the awareness of fine management of internal finances is not strong. At present, small and medium-sized enterprises have serious problems in terms of economic losses. Due to the weak of internal financial management awareness in the enterprise, the standard of fine management cannot be achieved. Especially in this increasingly competitive market, a small and medium-sized enterprise with an unsound financial management model cannot resist the actual situation. Even in this situation, many companies are unwilling to break the traditional management concepts and still adhere to backward thinking. They cannot understand the importance of refined management in finance. As a result, their financial
management cannot keep up with the pace of the times and lack management experience, and it is unable to meet the standard of refined financial management.

On the other hand, the financial management information system lacks integration. Aiming at making the financial management information system more effective in applying big data technology, it is essential to strengthen the integration of the financial management information system. Only in this way can it play an active role. Some companies have not yet realized this, and the integration of financial management information systems is not strong, especially the failure to effectively integrate and connect various information systems, resulting in the failure of the financial management information system to play its role effectively. For example, although some companies have established big data platforms and have strong pertinence and comprehensiveness in data resource collection and other aspects, the lack of integration of financial management information systems directly leads to the insufficient application of big data, especially the collection and analysis of external data is relatively small, which directly leads to the failure of the overall function of big data to be effectively utilized. Another example is that some companies do not pay attention to the effective integration of financial management information systems and enterprise resource planning systems. This directly leads to the data resources of financial management information systems. Only financial information itself and other related information resources cannot be effectively used, which is not conducive to the implementation of financial strategy.

3. Main components of RCCMRSP

The main components of RCCMRSP, whose structure can be depicted in Figure. 1 involves cost control and cost management in four different project stages. The details of the two methods will be introduced in the next section.

3.1. Cost control

Cost control is a process of calculating, adjusting, and supervising various costs incurred in the production and operation of an enterprise using the principles of systems engineering. It is also a process of discovering weak links, tapping internal potential, and finding all possible ways to reduce costs. Cost control refers to the absolute amount of cost reduction, so it is also called absolute cost control. Specifically, cost reduction includes the overall arrangement of the relationship between cost, quantity, and revenue, so that the increase in revenue exceeds the increase in cost and achieves relative cost savings, and it is also called relative cost control.

The dialectical relationship between cost management and guaranteeing equipment quality refers to the long-term habit of emphasizing quality and neglecting cost control. Although quality has improved, the marginal relationship between quality and cost is disproportionate, which affects the economic benefits and long-term development of the enterprise. On the contrary, it will increase the additional cost of failing to meet the quality standard and even affect the qualification and reputation of the enterprise.

The principles of cost control can be summarized as cost minimization, overall control, and dynamic control. The fundamental purpose of project cost control is to achieve the lowest possible target cost through various means of cost management. When implementing the principle of cost minimization, attention should be paid to the possibility of cost reduction and reasonable cost minimization. The overall control of project costs is to prevent cost control from being everyone's responsibility and everyone's care. With the gradual development of the various stages of the railway signal project, each part of the content cannot be omitted, nor can it be tight or loose, and the cost of the construction project must be under effective control from beginning to end. Although the railway signal project is completed at one time, the cost control should emphasize the intermediate control of the project, that is, dynamic control, because the cost control in the preparation stage is only based on the specific content of the signal design to determine the cost target, prepare the cost plan, and formulate the cost control plan. As the content of each stage continues, the content requirements of the project may change, and the corresponding costs need to be dynamically controlled.
The methods of cost control can start from different aspects, including institution, construction period, contract management, and technical personnel management, and equipment and materials procurement. For example, the formulation of the procurement budget is an estimation and prediction of the project procurement cost before the specific implementation of the project procurement behavior with a rational plan for the entire project funds. It not only reasonably allocates and distributes project procurement funds but also establishes a standard for the use of funds so as to monitor and control the use of funds in the procurement implementation at any time to ensure that the use of project funds is within a certain reasonable range floating within. To control the project procurement costs, implementing procurement budget constraints can improve the efficiency of using project funds, optimizing resource allocation, finding some exceptions in the use of funds, and controlling the flow of project funds. Cost procurement should focus on the reduction of the total cost of the entire project, rather than a single price for purchased goods or services.

Deviation control is the common method that depicts the deviation and change between planned value (PV) and actual cost (AC). PV shows the cumulative increase in the total budget activity cost at the beginning and end of a given baseline plan. AC usually refers to the actual cost of the work performed, which is the cumulative actual cost spent at a given point in time. The two kinds of deviation in cost control are actual deviation $d_a$ and planned deviation $d_p$, which can be described as

$$d_a = c_a - v_e$$

$$d_p = v_e - v_p$$

where $c_a$, $v_e$ and $v_p$ represent AC, earned value (EV) and PV in cost control respectively. EV describes the amount budgeted for performing the work completed at a given time. The objective in cost control is to reduce the objective deviation, which is defined as

$$d_o = c_a - v_p$$

With the objective deviation as the controlled member, deviation control is responsible for observing the above three deviations by comparing AV and PV every day or week regularly.

Compared to the basic schedule, the current performance on time and cost objectives requires to be measured in a railway signal project. Schedule performance index (SPI) in cost control depicts the time performance as a percentage in a scheduled baseline, which can be defined as:

$$i_{sp} = \frac{v_e}{v_p}$$

In Eq. (4), if $i_{sp}$ is smaller than 1, it means the signal project is later than the scheduled progress. Instead, the project is ahead of scheduled when $i_{sp}$ is larger than 1. Besides, the cost performance index (CPI) describes the cost performance like SPI, as presented by

$$i_{cp} = \frac{v_e}{c_a}$$

In Eq. (5), when $i_{cp}$ equals to a value smaller than 1, it represents the budget of the signal project is over than the scheduled. If the budget is utilized under the scheduled cost, $i_{cp}$ is larger than 1. The two performance indexes play a significant role in determining an action in time and cost during actual cost control.
3.2. Cost management

Cost management is comprehensive, in-depth, and meticulous work that not only requires the attention and support of the company's management but also requires the active cooperation and coordination of employees. It is necessary to establish and improve various rules and regulations to ensure the implementation of these systems. The main methods of cost management consist of six aspects.

- Strengthen engineering change management. If the design is changed in the HSRs signal construction process, it will have a great impact on the construction plan and schedule of the project department. The project manager should organize the personnel of the relevant departments of the project department to carefully study the new drawings and make corresponding adjustments to the previous construction plan and schedule. At the same time, they should also investigate the current market labor, materials, and mechanical equipment rental prices and compare the price of research and bid. If the price exceeds the reasonable range of increase, the project department should communicate, coordinate, and negotiate with the owner unit in a timely manner to adjust the contract unit price to reduce losses.

- Strengthen original record management. The project department ought to keep records of the working days of production personnel, mechanical personnel, material procurement personnel, and management personnel. Materials and records of various income and expenditure vouchers should be filled in as required, and the procedures are complete. What’s more, the project department should also make a record of issuing materials and establish consumption accounts according to accounting objects and receivers (contractors). It is necessary to make the records involving operation, repair, shift, and spare parts consumption according to stand-alone machines and trains.

- Cost forecast of labor, materials, and machinery. The project management personnel should analyze the labor cost of the project, and then analyze the labor wage level and social labor market conditions, and analyze whether the labor cost is covered in the project contract price according to the construction period and the number of personnel to be invested. The material fee focuses on analyzing the difference between the specifications specified in the quotas of main materials, floor materials, and auxiliary materials and the actual specifications, and re-approving the supply location, purchase price, transportation method, and loading and unloading fees of materials.

- Cost forecast of the construction plan. After the project won the bid, a technically advanced, feasible, and economically reasonable implementation group was established combined with the actual situation of the high-speed rail signal project. The construction method adopted by the implementation group was compared with the difference between the bidding documents to make the correct prediction.

- Risk prediction of out-of-control costs. The risk analysis of the project cost target is the pre-analysis of the factors that may affect the realization of the target during the implementation of the project. The four steps of risk analysis are determining the baseline schedule, defining the uncertainty of time and cost, simulating process and giving a sensitivity analysis.

- Handle the relationship between quality and cost, construction period and cost, supervise the implementation of costs, and discover the deviation of actual cost from a plan in time. The concrete method has been provided as Eq. (1) to Eq. (5) in cost control.

\[
f_{TV} = \frac{(V_o - V_p) \cdot T_{pl}}{c_p}
\]

Notably, the forecast of time variance (TV) and cost variance (CV) are two key indicators measuring the accuracy and stability. TV \( f_{TV} \) can be defined as
where $v_e$ and $v_p$ are the earned and planned value for project time cost. $t_{pd}$ and $c_p$ are the planned duration and planned cost of the railway signal project. As a consequence, three approaches of the estimated cost in the end are given as

$$
\begin{align*}
C_{ea}^{PF1} &= t_{pd} - f_{ev} \\
C_{ea}^{PF2} &= \frac{t_{pd}}{i_{sp}} \\
C_{ea}^{PF3} &= \frac{t_{pd}}{i_{sc}}
\end{align*}
$$

where $C_{ea}^{PF1}$, $C_{ea}^{PF2}$ and $C_{ea}^{PF3}$ are the estimated cost under three different earned value. $i_{sp}$ and $i_{sc}$ are the schedule performance index and schedule cost index. Respectively, CV is provided as

$$
f_{cv} = c_a + \frac{c_e - v_e}{PF}
$$

In Eq. (7), $c_a$ and $v_e$ are actual cost and earned value of cost in the project. PF is the possible factors that evaluate the cost performance in the future. The PF can be calculated in two approaches, including SPI equaled by Eq. (4), and the new earned schedule based on SPI. The approaches estimate the total cost at the end of a project and provide an upper and lower bound about what the manager hopes to cost.

4. Conclusions
The paper introduces the refined cost control and management method by analyzing the main problems involving the entire process of finances management, information system integration in the high-speed railway signal project. Several improving methods of cost control are presented in the institution, reasonable marginal model of quality cost, construction period, contract management and so on. In addition, some measures of cost management are also given in the stage of project bidding, preparatory, implementation, and completion to ensure the safe and efficient operation of high-speed railway systems.

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Method of FCCMRSP

- Project bidding
- Project preparing
- Project implementation
- Project completion

Cost Control
- construction period
- contract management
- technical personnel management
- equipment procurement

Cost Management
- engineering change management
- original record management
- Cost forecast of materials
- Cost forecast of the construction plan
- Risk prediction
- Relationship between quality and cost

Stage

Project departments
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Figure 1. Structure of the refined cost control and management of railway signal project
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