Comprehensive evaluation study on the maturity of railway construction project management

Mei Tingyu\textsuperscript{a}, Rao Zhiyu\textsuperscript{b}, Liu Xiangze\textsuperscript{c}, Wu Jiacheng\textsuperscript{d}

Jiangxi Science and Technology Normal University Nanchang City, Jiangxi Province, China

Abstract - With the reform and opening up, China's rapid economic development and the growing demand for passenger travel, high-speed railway projects are booming. China's railways are renowned worldwide for their high speed, low pollution and technicality, reducing transport costs, increasing the speed of logistics and promoting social and economic development. However, high-speed railway projects are systematic, complex and comprehensive, with difficult construction, extensive use of new technologies and techniques, weak theoretical and technical foundations for managers, corporate reliance on previous experience and deficiencies in traditional management models, resulting in failure to complete properly or frequent accidents. In this paper, a comprehensive evaluation study on the maturity of railway construction project management is conducted to address the shortcomings in the management of large-scale projects such as railways and to enhance the core competitiveness of enterprises.

1. Introduction

At present, with the development of China's economy, various fields are developing rapidly, among which railways play an inescapable role in the process of China's economic development. China's railways started late, from the 1970s and 1980s, and after continuous efforts by experts in research, Chinese railways have systematically mastered railway construction technology in various complex environments and are at the forefront of railway construction in the world. However, in terms of railway management, there is still a significant shortfall compared to Western countries in the management of large-scale projects. Railway project management is a complex and arduous process involving many departments such as construction, supervision and exploration, and at the same time needs to meet multiple objectives such as investment, schedule and safety, placing high demands on the level of railway management. Project management in China started late in China and is currently relatively low-level in terms of management, with large management systems that are too young and confusing and have conflicting instructions. Management on large projects such as railways is not only limited to the construction phase, but for the whole life cycle a set of standard management is required. Efficient project management can improve the efficiency of the use of resources, optimise the allocation of resources, achieve the project objectives under the specified conditions for the successful completion of the project, to mention China's railway enterprises in the market competitiveness.

The article examines current railway construction and project management, and through reading relevant Chinese and foreign literature, conducts a study on the maturity of railway project management and makes some recommendations for project management.

2. Status of project management maturity research

In 1987, in the software industry, Paulk M not only introduced the software capability maturity model, but also elaborated on the model, as well as on the key activities of management, engineering and organisation, which were revised and gradually applied widely\textsuperscript{(1)}. The model identifies problems alongside software assessment and gives good guidance to help in dealing with software related issues.

The Carnegie Mellon University Research Institute (SEI) studied and published the CMM maturity model in 1987\textsuperscript{(2)}, which is divided into five levels: Initial, Repeat, Defined, Managed and Optimised. The model integrates software development, monitoring and transforming software development and maintenance in real time, making its management more scientific and standardised. In 2003, the US introduced the Project Management Maturity Model OPM3\textsuperscript{(3)}, which allows for the systematic evaluation and development of successful projects. The model is a three-dimensional model containing four gradients of maturity, standardised, measurable, controllable and continuously improved. In this way, the model shows how closely the best practices are linked to the organisation's project management maturity before.
In order to improve the efficiency of the project, the enterprises gradually absorb foreign project management experience. By combining the theoretical knowledge of project management and construction projects, enterprises have achieved better results through practice, greatly improving the project management process, reducing high-risk and other unfavourable situations, improving the utilisation of various resources and enhancing the production capacity of enterprises.

3. Status of railway development and management

3.1 Railroad Management Status system

Railways are an important infrastructure in the process of regional economic development. With over 500,000 trains operating daily, China's railways have developed into the world's largest railway operating network. It greatly facilitates the long-distance travel of the Chinese population and the transportation of goods. Railways are difficult to ensure profitability even for China's population of more than one billion due to their large workload, duration, investment and long capital recovery time. Taking the year before the epidemic, the earnings of some of China's home railways are shown in the table below. It can be seen that with the exception of a few railways, most railway companies are in the red, see table 1 in the table below.

<table>
<thead>
<tr>
<th>Railways Bureau</th>
<th>Net profit for 2018</th>
<th>January - June 2019 Net profit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Taiyuan Railway Bureau</td>
<td>95.58</td>
<td>63.57</td>
</tr>
<tr>
<td>Shanghai Railway Bureau</td>
<td>17.09</td>
<td>77.07</td>
</tr>
<tr>
<td>Xi'an Railway Bureau</td>
<td>16.89</td>
<td>10.87</td>
</tr>
<tr>
<td>Nanchang Railway Bureau</td>
<td>14.27</td>
<td>-4.42</td>
</tr>
<tr>
<td>Jinan Railway Bureau</td>
<td>-6.72</td>
<td>1.56</td>
</tr>
<tr>
<td>Huhehaote Railway Bureau</td>
<td>-20.05</td>
<td>-10.21</td>
</tr>
<tr>
<td>Qinghai-Tibet Railway Company</td>
<td>-23.01</td>
<td>-12.41</td>
</tr>
<tr>
<td>Guangzhou Railway Bureau</td>
<td>-26.05</td>
<td>14.47</td>
</tr>
<tr>
<td>Nanning Railway Bureau</td>
<td>-35.72</td>
<td>-14.53</td>
</tr>
<tr>
<td>Urumqi Railway Bureau</td>
<td>-42.69</td>
<td>-14.09</td>
</tr>
<tr>
<td>Lanzhou Railway Bureau</td>
<td>-57.48</td>
<td>-31.82</td>
</tr>
<tr>
<td>Beijing Railway Bureau</td>
<td>-61.39</td>
<td>-15.44</td>
</tr>
<tr>
<td>Shenyang Railway Bureau</td>
<td>-113.56</td>
<td>-66.95</td>
</tr>
<tr>
<td>Harbin Railway Bureau</td>
<td>-125.88</td>
<td>-65.17</td>
</tr>
<tr>
<td>Chengdu Railway Bureau</td>
<td>-126.75</td>
<td>-50.57</td>
</tr>
</tbody>
</table>

3.2 Railway project management maturity

The Project Management Maturity Model is a scientific approach that can be used to achieve desired objectives in order to achieve increased project success. It provides a quantifiable framework that can help organisations progress from low to high project management capability, and thus from beginner to advanced. The model is not a mathematical solution or chart, but a systematic and scientific approach that enables organisations to continuously improve and enhance their project management capabilities. Referring to the SEI-CMM model, the different stages of project management are characterised by five levels, Initial, Awareness, Optimisation, Relevance and Refinement.

\[ M = m + (T-t) \phi \]

M; denotes the final ripeness, m; denotes initial maturity, and T; denotes the target maturity ripeness, and t; for time saving, and \( \phi \); denotes maturity coefficient.

3.2.1 Initial Level

At the initial stage, the project management capacity of railway construction enterprises is weak. The project management capability is limited by the influence of personnel transfer, and no stable internal operation mechanism and external development environment has been formed. Management work is haphazard, lacking standardised management documents and experience, and unable to systematically collect and analyse relevant management data. There is almost no project management knowledge, management seems to have no rules and clear directions, highly dependent on individuals, lacking systems and mechanisms; management is arbitrary, lacking norms and standards; information is not kept, making it difficult to accumulate experience. This makes the continuous progress and innovation of enterprise project management face greater obstacles, and the improvement of project management level mainly relies on the efforts of individual personnel, and the overall level is difficult to be improved significantly.

3.2.2 Cognitive level

With the help of accumulated project management experience, the company uses informal and incomplete management methods, adjusting and monitoring and correcting deviations through the pre-project management process, facing problems such as unclear project status reports, lack of systematic measurement of project progress and estimation calculations limited by the project manager's knowledge and experience. The organisational structure of the enterprise is generally effective in its application, and overall it is able to meet
the basic requirements of project management work. In railway construction, the enterprise relies on its many years of experience to achieve control and control of the current relevant projects through moderate adjustments to the railway project management process in the early stages.

3.2.3 Optimisation level

Companies are beginning to focus on the development and application of efficient project management methods, recognising that the organic combination of various management methods within a company can produce greater synergies, with project management playing a key role as a central component. The organisational approach to project management has been strengthened and, with the support of management and the influence of the corporate culture, the level of communication, collaboration and trust between project participants has increased significantly, enabling the formation of a more effective project team. Data on project management processes and results are better collected and analysed, providing important support for project management decisions. Project management tools and methods have become more specialised, and project management theory and practice are being studied and applied in greater depth. The relevant project management system is becoming more and more complete, and the standardisation and standardisation of project management has increased significantly.

3.2.4 Cutting level

A stable organisational structure that enables efficient, highly collaborative and highly profitable project management. The management process permeates every process, with standardised data requirements and collection for effective trend analysis; there is also multi-project planning and control, as well as the development of talent strategies and enhanced departmental collaboration, providing objective and reliable data to support business managers.

3.2.5 Perfection level

The company evaluates and analyses various types of data during project implementation, helps to correct mistakes in a timely manner and gives full play to the team's wisdom and comprehensive strength to develop products that meet market needs and provide a full range of services. The organisational structure is flexible, highly dynamic, flexible, efficient, smoothly running and self-improving, effectively promoting the achievement of objectives and the enhancement of project management capabilities.

4. Application of the project organisational maturity index evaluation system

We know that the project management maturity level is divided into five levels from initial to strategic level. Next, we evaluate the collected data in a comprehensive gray correlation to evaluate the level of the project. Each expert selected for the evaluation, because of his or her background and experience, will lead to different results. In this paper, we divide the evaluation into 5 levels from initial to strategic, i.e.: e=1,2,3,4,5. In this paper, we classify In this paper, we divide the evaluation into 5 levels from initial to strategic, i.e.: e=1,2,3,4,5.

Based on the components of project management, the author has refined and adjusted them to the characteristics of railway construction and reconstructed the components of the maturity system of railway construction project management. These include: pre-project decision-making, design, project investment control and construction fund management, bidding and contract management, material and equipment management, technical management, information management, risk management, organization and coordination, schedule control, quality control, cost control, safety control, environmental management, and post-project management.

The four life cycle stages of a railway construction project - project decision, design, implementation and completion and acceptance - mainly reflect the dynamic changes in railway projects at different stages. By analysing the changes in the indicators of the above 16 elements in different life cycles, the maturity of railway construction project management can be evaluated at each stage.

Project management capability and comprehensive project management capability are the first-level indicators for project management maturity evaluation. In order to assess the maturity of railway construction project management, an evaluation index system needs to be established. At the target level, the management maturity of railway construction projects needs to be taken as the evaluation target. At the criterion level, the sixteen elements of railway construction project management maturity need to be used as evaluation level two indicators. These elements are formed by reference to the traditional nine project management modules and combined with the characteristics of domestic railway construction projects.

Scoring criteria and evaluation indicators are the cornerstones of assessing project management maturity, and can be divided into quantitative and qualitative criteria. Quantitative criteria are easier to define and implement, and the evaluation results are more objective and accurate. Qualitative criteria are more complex to set and evaluate, and are easily influenced by subjective factors such as the knowledge, experience, ability and mastery of the evaluation criteria of the evaluators, and the objectivity and accuracy of the evaluation results are poor. According to different types of indicators,
different methods of assigning values are adopted. Quantitative indicators can be directly quantified or graded into five levels by referring to historical data of railway construction enterprises or the same industry, budget standards (such as railway construction quotas), industry standards or empirical values, and combining with the enterprise project management system. Quantitative evaluation is more objective, unlike qualitative evaluation results which are prone to large biases.

Therefore, on the basis of the concept and connotation of qualitative indicators, combined with the value orientation of railway construction enterprises and objective environmental requirements, the subordinate factor assignment method of fuzzy mathematics was used to divide the inspection content into five different grades, specifying the specific requirements and basic boundaries of each standard. On the basis of this, a questionnaire survey was conducted and the qualitative indicators were scored by experts on a percentage scale to recommend five grade coefficients: excellent, good, medium, low and poor. The matrix calculation was carried out on the obtained qualitative indicators to derive the maturity level of each secondary indicator module and target level of railway construction project management, so as to improve the scientificity of the evaluation.

At the indicator level, these sixteen guideline level evaluation elements need to be decomposed and refined. These indicators are developed based on the specific content of the railway construction project management elements. Drawing on the evaluation test indicators of existing project management maturity models at home and abroad, they will be transformed, integrated and supplemented, so as to enrich and improve this maturity evaluation system. There are four indicators in the railway construction cost control criterion layer: resource and cost planning capability, the degree of difference between actual and budgeted costs, the level of human, material and machine cost control and the level of non-productive cost control. There are three indicators in the risk management guideline layer: risk identification ability, risk assessment level and risk control ability. There are four indicators in the construction safety control criterion layer: safety management system, safety good work rate, frequency of work-related accidents and degree of work-related accident losses. The establishment of the project management maturity evaluation index system needs to be subdivided from the target layer, the guideline layer and the indicator layer, so as to comprehensively assess the management maturity of railway construction projects. At the same time, the system needs to be continuously supplemented and improved to adapt to the changing project management environment.

Using this system, it is possible to evaluate the maturity level of the project organisation and identify areas for improvement. The evaluation process is as follows: firstly, the project manager scores the indicators and then, using the appropriate calculation methods, obtains an overall rating based on the indicator indices and scores and compares this with the maturity model to determine the maturity level. Next, the expert survey method is used to rank the indicators at each level, and then the hierarchical analysis method is used to determine the importance index of the indicators, using the grey model and the general comprehensive evaluation model to obtain the evaluation matrix, and finally the evaluation results are calculated so as to determine their merit.

5. Conclusion

The purpose of this paper is also to introduce the project management maturity model into the field of railroad construction to provide an idea for the research in this direction. Further work needs to be done in the following areas: key areas of the project management maturity model for railroad construction enterprises and the improvement of the evaluation index system. In view of the limitations of the expert consultation work and the sample taken in the questionnaire survey, more in-depth research is needed to determine how to make the weighting of the evaluation elements and indicators more reasonable and operable.

In terms of project management maturity evaluation methods, the existing methods are mainly qualitative descriptions and quantitative evaluation methods need to be explored more. At the same time, the accuracy and completeness of the qualitative description of each level accuracy, completeness and validity of each level need further research work to solve.

The construction of a project organisation maturity evaluation index system can provide a reliable basis for the evaluation of project organisation maturity, provide evaluation criteria for the operation status of project organisation structure, and then provide scientific guidance to help organisation structure managers to have a deeper understanding of the operation status of project organisation structure and grasp the key control factors, so as to improve the level of project management. China's high-speed railroad projects in the application of fewer research examples, the lack of relevant research data, the subsequent research work, the need to discover and use a more scientific evaluation methods for different construction projects In the future research work, it is necessary to discover and use more scientific evaluation methods and "personalized" model construction for different construction projects, so as to enhance the practicality of the research findings. This can be achieved by increasing the number of network layers, increasing the number of neurons, changing the activation function, increasing the depth of layers, adjusting the dropout probability, adjusting the regularization coefficient, etc.

Acknowledgement

This article is in the Research Project of Practical Innovation Training Program for College Students of Jiangxi Science and Technology Normal University - " Research on Comprehensive Evaluation of Maturity of
High Speed Railway Construction Project Management" (Code: S202111318062)

References


