Research on Construction Progress Management and Control of Municipal Road and Bridge Engineering Based on BIM Technology

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Abstract: The municipal road and bridge engineering project has long construction period, many participate subject, complex spatial environment. Management of progress through the traditional means of 2D drawings and Excel spreadsheets suffers from poor coordination, poor quality management and supply chain inefficiency causing severe delays and cost overruns. This paper is based on the practical engineering problems in municipal road and bridge engineering, and studies the application path of BIM technology in construction progress management of such projects. The developed technology assists the effective enhancement of progress management efficiency, shortening project duration and frictional losses from delays through BIM technology, which provides practical references for implementing capital-intensive municipal road and bridge engineering projects.

1. Introduction

As an important part of the urban transportation network, the construction quality and progress of municipal road and bridge engineering directly affect the efficiency of urban operations and residents' travel experiences. BIM technology, as the core technology of digital transformation in the construction industry, features visualization, parametrization, and collaboration. They allow the integration of full life-cycle data from road and bridge projects into 3D models—and new opportunities for managing progress. So the in-depth study of BIM technology for specific application methods and key practical problems to be solved in the construction progress management and control of municipal road and bridge engineering have important practical significance to improve project management level, guarantee delivery time.

2. Problems in the Construction of Municipal Road and Bridge Engineering

2.1 Inadequate Construction Organization and Coordination Mechanisms

Municipal road and bridge engineering is a project that has a number of participating parties, such as: construction organization, designing organization, supervision engineer and material supplier. The pace of construction progress is directly influenced by the efficiency of organization and coordination among these parties. In the current phase of utilizing some projects during the building organization, there's no consistent design. Most construction plans concentrate on the technical organization of work processes with little attention to the allocation of rights and responsibilities or the design for joining processes among participants. The absence of a regular channel of communication between design and construction units is an example. Once design plans are delivered, construction units often discover during on-site implementation that the designs do not match actual site conditions (structural dimensions cannot fit in available space, material requirements cannot be met with local supply capabilities, etc.) All of these are communicated, and bounced few times for confirmation to adjust & modify which delays the work procedure. At the same time, the coordination and supervision role of supervision units is poorly used In some supervision work, supervision is limited to the sampling inspection of construction quality, and issues such as cross-operation conflicts and resource allocation contradictions in construction

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progress are not actively coordinated. Supervision does not play a role in coordinating key content between participating parties during construction handover process, and often acts independently. In addition, there are some shortcomings in the internal organizational management of the construction unit. The project department does not dynamically adjust the task assignment among construction teams. It fails to quickly transfer resources from other teams and, due to the technical deficiencies, delays construction progress. Furthermore, if teams are not technically clear in their disclosures of information, it can lead to rework due to misunderstanding construction standard and increase time-and-cost consumption.

2.2 Substandard Construction Technology Management and Quality Control

Construction technologies for municipal road and bridge engineering must have higher requirement in professionalism and standardization, and the emphasis of work items is also different. On the other hand, in some projects the management of technology has already performed poorly delivering obvious loopholes. On the one hand, the preparation of technical plans lacks pertinence and operability. Especially in engineering design and construction, some construction units blindly copy general technical templates without optimizing the plan based on actual factors such as project location geological conditions, climate environment types, traffic environmental conditions and other factors. As an example, a special reinforcement way can not be made in terms of compressibility and water content according to the construction of soft soil foundation sections. Instead, conventional compaction methods are used which may leave the subgrade uneven once opened to traffic and require remediation later on. In contrast, there is a disconnection between the technical disclosures and the on-site guidance. Many technicians transferred technical requirements to construction teams either orally or in a simple written form without consolidating it with visualization tools ensuring complete understanding from the team mentos. As a result, the construction involves technical discrepancies. Quality Control: Some projects have weak quality inspection system. The number and frequency of inspections are not regulated; the recording and analysis of inspection data is lacks systematicness. You can only identify quality problems on the surface, and it is difficult to recognize possible hidden dangers in concealed works. In addition, construction labor has different levels of technological competence. Other front-line workers never received structured technical training and are unfamiliar with operating new construction equipment. Not only will this affect construction efficiency, but operational errors may lead to quality accidents that increase rectification costs and schedule pressure on the project.

2.3 Inefficient Resource Allocation and Supply Chain Management

Due to their long construction period and high consumption of resources, municipal road and bridge engineering projects have greater demands on the rational distribution of human, mechanical, and material resources as well as operation stability in the supply chain. On the other hand, present projects demonstrate huge room for improvement in terms of resource management. There is no scientific demand forecasting and dynamic allocation mechanism in human resources. One of the major factors leading to labor shortages in key work processes during early construction stages may be insufficient estimation of peak-period labor demands. However, in the off season of construction, labor idleness exists which make labor cost waste. On the other hand, there is also a serious shortage of technical talents needed in construction projects with such needs, like professional capabilities on BIM technology application and special mechanical operation qualifications. This restricts the full play of some construction technologies and equipment, thus limiting the improvement of construction efficiency. In mechanical equipment, management has been found to have unreasonable equipment selection and insufficient maintenance. Reduced rates of equipment utilization: Some construction units select lower performance level equipment so as to cut down on costs or do not match the equipment reasonable with regards to needs for construction method. In addition, there is no well-organized daily maintenance and repair plan for the equipment. Maintenance performed just after breakdown, which leads to delay in construction process and excessive repairs cost for equipment. Long-term stable cooperation mechanism of suppliers is absent in material supply chain management. The short-term, fragmented material procurement with a lack of a systematic approach When there are changes in market material prices, delays in material supply happen to be when supplies become tight. Secondly, storage and managing materials once they are on the site can also be random. Certain moisture and spoilage sensitive materials are not very well protected, resulting in excessive material losses. Not only does it increase material costs, but it may also lead to interruptions in the construction industry due to a lack of materials that can further extend delays.

3. Application Paths of BIM Technology in Construction Progress Management of Municipal Road and Bridge Engineering

3.1 Construct a 4D Progress Integration Model to Achieve Precise Association between Progress Plans and Physical Projects

Integrating two-dimensional progress plans with three-dimensional physical models to build a complete 4D progress integration model with time dimension is the core first step of BIM technology application in progress management, breaking through the traditional disconnect between progress plans and engineering entities. It is necessary to fully carry out the accurate construction of three-dimensional physical model in every structural unit of road and bridge project, such as subgrade, pavement, bridge pier, cover beam and prefabrication component initially during the process for establishing model so that their geometric parameters and material properties are completely consistent with those of actual projects. Then the time information of progress plan should be tightly bound to structural units in three-dimensional model. Each structural unit is assigned the relevant construction start time, end time and duration and work procedure logical relationships through BIM software to establish a complete 4D progress model by using its parametrization function.

The entire construction sequence and the spatial arrangement of road bridge projects in all stages from start to finish can be intuitively reflected by this model. By visualizing procedural relationships and spatial distribution ranges, construction managers can easily understand the sequential connection relationships of various work procedures, thus avoiding progress delays caused by chaotic work procedure logic or spatial conflicts. Meanwhile, the 4D progress model enables dynamic simulation capabilities. Hence, through the construction simulation, we can unravel the key route work procedure nodes and get their core work procedures affecting the total project duration, which lays a foundation for define the subsequent progress control focus. It also contains a progress visualization query functionality in the model. After clicking on any structural unit, managers can quickly get the construction time plan, corresponding resource requirements and associated work procedure information of it, which is convenient for the real-time verification of progress execution during construction and timely detection of progress deviation in its embryonic stage to buy enough time for adjustment of progress [1].

3.2 Build a Collaborative Management Platform to Open Up Information Transmission Channels among Multiple Participating Parties

Many parties participate in municipal road and bridge engineering, so information barriers between them are an important factor contributing to the low efficiency of progress management. BIM technology can build a collaborative management platform, in which the progress information necessary for project management can be shared and transmitted between multiple participating parties in real time. Using the BIM model as the core carrier, integrate the information needs of design parties, construction parties, supervision parties, construction enterprises and material supply parties into one. Set up operation ports with different rights to make sure all parties involved can complete loading, looking at, feedback and collaborative process of progress-related information within the platform.

In-platform operation, design units can timely upload design change documents and model adjustment content, and scope of influence and impact degree on relevant working procedure progress caused by changes to help construction units quickly evaluate the impact of changes on overall progress. Construction unit shall upload the on-site construction progress information once a day, and mark the completed structural units in the BIM model, synchronously upload problems encountered during construction to provide a basis for supervision and construction units to grasp progress dynamics. Supervision units can perform progress deviation checks based on the progress plans and actual progress data in the platform. If discrepancies are found, they will be able to quickly trigger alerts in the platform and offer corrections. The platform can summarize the progress information of all participating parties for construction units, so that they can fully understand the overall progress of the project. Quickly organizing coordination meetings for major node progress delays, and the collaborative management platform has a traceability function of progress information that can record the operation traces and information transmission times of each participating party. It can make the responsibility determination clear according to evidence and avoid the management inefficiency in low progress caused by delayed information transmission or undefined responsibilities [2].

3.3 Implement Dynamic Progress Monitoring and Deviation Correction to Ensure Progress Objectives are Controllable

Based on the real-time data collection, progress deviation analysis and dynamic plan adjustment functions of BIM technology can achieve the function of dynamic monitoring and deviation correction of municipal road–bridge engineering construction progress, and keep the goal of progress control in a controllable range. This phase utilizes the BIM system, which can be combined with Internet of Things technology to automatic collection of various kinds of on-site progress data such as human input, mechanical operation, material arrival and work procedure completion without manual statistical entry. It can effectively reduce the lag time for data collection process and its error rate. The collected progress data is transmitted to the BIM model in real time, and is automatically compared with the preset participation plan data to form a dynamic visual report of execution. The report enables managers to easily understand key information like the completion percentage of the progress, and the number of days delayed or ahead of each work procedure. If a progress deviation is detected, the system will automatically start a deviation analysis process and trace the cause of deviations across multiple dimensions including technology, resources as well as management. And the analysis of road and bridge network is that if a certain construction work procedure related to a foundation are behind schedule, then it can make an analysis to check whether material supply delayed by checking anyway on the record or not, analyze whether mechanical failure or technical deviations had happened using its data output/inputs. Regarding the impact of deviation assessment, combined with the logic of progress network plan, the degree of impact on future work processes and total project duration after deviation can be simulated in BIM system, distinguishing whether it will cause key route transfer or total project duration delay; this provides a scientific basis for formulating deviation correction plans. During the dynamic adjustment of plan, managers can make use of the progress optimization function of BIM software to work out accurate corrective plans according to the deviation analysis results. If the deviation is due to resource shortages, resource allocation plans can be adjusted appropriately to shorten the duration of work procedures; if the deviation is caused by technical problems, it can coordinate construction personnel to jointly organize and optimize construction processes while improving efficiency; if this network has a great impact on total project duration (mlt), then logical relationships of subsequent work procedures can be created only when strictly following quality requirements such such as changing some non-key working procedure into parallel operation so as to compress total key route time. In order to achieve the ideal variant of progress management with dynamic closed-loop control and to ensure that the project is controlled in accordance with plan, it shall be ensured that the relevant parties obtain timely latest updated information from the adjusted progress and this adjustable progress plan is automatically synchronized to both collaboration platform as well as the BIM model.

3.4 Conduct Construction Simulation Analysis to Proactively Avoid Progress Risks and Construction Conflicts

There are many work procedures and cross-operations in municipal road and bridge engineering projects. It is predictable that during the construction, work procedure conflict or safety accident will occur without fully predicting the risks in advance and it will directly lead to slow down of the construction progress. BIM technology through construction simulation analysis can be proactive to identify risks and formulate corresponding response measures. Construction simulation, which is based on the BIM model and integrates the construction process, site environment, resource allocation, etc. of a project to simulate the overall construction procession in a virtual environment and predict potential persisting risks and conflicts [3].

In risk prediction, first check whether the logical sequence of work procedures has risks through simulation. It checks if there is a rationality between the order of different kinds of work procedures through the BIM model, and whether there are conditions such as backward or missed work procedures. For example, it verifies whether road surface paving is arranged after the completion of subgrade construction or cover beam construction before bridge pier casting has achieved a strength that meets design standards and technical requirements to determine compliance with the work procedure logic. Second, in spatial conflict risk, it simulates the discipline and work processes during construction. It, for example, checks overlap between the space that bridge prefabricated beams are lifted over and ground pipeline construction space or road construction with following excavation of surrounding underground pipe networks. In case any spatial conflicts are found, the construction sequence is adjusted beforehand or the construction scheme is optimized for preventing on-site conflict and thus avoiding stagnation of the work.

4. Conclusion

To sum up, combined with the historical construction data to achieve 4D progress modeling for plan visualization, collaborative management on information barriers across actors; real-time data collection providing basis for dynamic monitoring; and simulation analysis of construction status to help in risk aversion during construction show that BIM technology holds promise to address the pitfalls of inadequate coordination mechanisms, subpar quality control and inefficient supply chain management besetting traditional progress management. This presents a structured mechanism for effective monitoring of the project progress. With the further penetration of digital technologies in the construction industry, BIM technology will play a bigger role in the construction progress management of municipal road and bridge engineering at that time, providing stronger technical support for guaranteeing on-time project delivery and enhancing urban infrastructure construction quality.

References

[1] Li Huijun. Research on the Management and Control Strategies of Construction Progress in Municipal Engineering [J]. Juye, 2024(7): 190-192.

[2] Zhang Yuyao. An Exploration of Construction Progress Management and Control in Municipal Engineering [J]. China Building Materials, 2020(1): 121-123.

[3] Zeng Fanquan. An Exploration of Construction Progress Management and Control in Municipal Engineering [J]. Doors and Windows, 2019(17): 75.