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Key Pathway Analysis of Hospital Engineering Cost Control Based on Whole-Process Management

Yongbo Xu

The Second Affiliated Hospital of Wenzhou Medical University, Wenzhou, Zhejiang, China

Abstract: ***This paper proposes a full life cycle management system in view of the common problems existing in the current hospital engineering management. Combined with the characteristics of hospital engineering management in the decision-making stage, design stage, bidding and tendering stage, construction stage and completion acceptance stage, it builds the key point identification and control of the full life cycle and proposes a system guarantee system. The research suggests that hospitals should enhance the identification and construction of risks throughout the entire process, and establish a more complete engineering management database to form a collaborative mechanism in terms of systems, so as to promote the effective management of various risks. The cost management throughout the entire life cycle requires hospitals to break through the traditional static thinking when conducting cost project control, form a dynamic control pattern, eliminate the binary opposition model between Party A and Party B, form a collaborative management system, reduce the negative impact brought by construction changes, and improve the accuracy of cost management.***

Keywords: Hospital Engineering Full life cycle Cost management Process control**.**

1. Introduction

With the deepening of the reform of China's medical and health care system and the upgrading of people's health demands, hospital engineering construction has transcended the traditional infrastructure scope and become an important carrier for providing public medical services and promoting the balanced development of regional medical resources. Its particularity lies in having both significant attributes of people's livelihood and complex engineering attributes: On the one hand, hospitals, as public welfare infrastructure, are directly related to public health security and the level of social well-being, and the construction quality and efficiency directly affect the accessibility of medical services; On the other hand, modern hospital projects generally exhibit characteristics such as large scale, diversified functional systems, and high levels of technological integration. The investment in a single project often reaches the level of several billion yuan, and it involves the deep integration of professional fields such as medical processes, clean engineering, and intelligent systems, resulting in complex factors influencing the cost. Against this backdrop, how to effectively control the project cost through scientific management methods is not only a practical demand for improving the efficiency of public financial fund utilization, but also an inevitable choice for promoting the high-quality development of medical infrastructure. The traditional project cost management model often focuses on cost accounting and post-audit during the construction stage, which has drawbacks such as fragmented management stages, insufficient risk prediction, and lagging dynamic control. The theory of full-process cost management emphasizes starting from the perspective of the entire project life cycle, and through systematic collaboration in stages such as decision-making, design, bidding, construction, and completion, achieving the optimal allocation of resources and precise control of costs. Most of the existing studies at present focus on cost control in the decision-making stage, while the control of situations such as investment deviations, positioning errors, and budget overestimates is not in place enough. The whole-process management of cost control based on the characteristics of existing hospital projects can improve the actual benefits of optimal resource allocation in the construction process of hospitals, enhance the economic value of investment, promote the efficiency improvement of public services, and has obvious strategic significance.

2. The Framework for the Entire Process Management of Hospital Project Cost Estimation

2.1 Decision-making Stage

The decision-making stage of hospital engineering is the logical starting point of cost control. Its core task lies in clarifying the necessity, feasibility and economic rationality of the project through systematic argumentation. Exploring the feasibility of hospital engineering management from the perspective of the entire life cycle can reduce and control the mistakes caused by investment deviations. Maintain an effective balance between the dynamic evolution and the static investment model of engineering construction to avoid insufficient research in the early stage, which leads to positioning failure or repeated engineering changes in the later stage, resulting in overall management failure. Feasibility studies need to fully take into account the particularity of medical processes and the adaptability of the cost index system, pay attention to the special costs of specialized projects such as clean engineering and radiation protection systems in hospital management, and avoid causing systematic cost management deviations. Integrate the concept of flexible planning in the demand analysis stage, reserve the functional expansion space to adapt to the iteration of medical technology, and at the same time, establish a dedicated cost index library covering medical process parameters through multi-disciplinary collaboration to achieve the transformation from extensive estimation to structured modeling. During the decision-making stage,

hospitals also need to assess their overall functions from the perspectives of the demands of medical functions and the direction of specialized development. Understand the differentiated demands of different specialties for diagnosis and treatment processes, equipment configuration, and hospital infection control, thereby adjusting the way of building plan combination and improving the overall setting of the mechanical and electrical system. For example, the radiotherapy area of the oncology specialty needs to have an independent shielding structure, while the combined operating room has higher requirements for the laminar flow purification level. If the early planning fails to precisely anchor the development direction of the hospital's specialization and distinctiveness, it may lead to different risks such as functional redundancy or functional absence, forcing the construction plan to be adjusted during the construction stage. Therefore, in the decision-making stage, the hospital needs to clarify the priority and scale threshold of specialized construction based on the regional health planning and the hospital's strategic goals. Through medical process simulation and deduction, quantify the resource allocation standards of each functional unit; The value analysis method is applied to eliminate non-essential functional modules and achieve cost optimization on the premise of meeting the supply of medical services.

2.2 Design Stage

During the design stage, hospitals should carry out effective limit design and conduct value engineering calculations to enhance the effectiveness of design management and implement full life cycle management. The effect of the constraint mechanism is enhanced through limit design. The goals of investment estimation are decomposed step by step into each professional design module to ensure that the upper limit of investment is consistent with the goals of the hospital, meet the functional standards of hospital construction, and achieve the upgrade of the technical path. Hospitals also need to approach from an engineering perspective, meet the systematic requirements of hospital construction, ensure that hospital functions are consistent with economic goals, achieve dynamic balance, and build a two-way functional drive system. From the perspective of value coefficient analysis, the space for elastic optimization is screened out. Through the demonstration involving multiple parties such as building structure, medical process, and equipment, the actual production cost is reduced and redundant functions are eliminated. Overall, during the design stage, hospitals should ensure hierarchical control, achieve dynamic balance, and implement cost management for all specialties. This can not only avoid functional deficiencies caused by limited design but also prevent system imbalance due to excessive pursuit of cost-effectiveness in value projects. During the design stage of a hospital, the management should ensure the effectiveness of the division of specialized processes and civil engineering interfaces. The spatial layout of different key departments such as operating rooms, imaging departments, and laboratory centers should be effectively designed. Through three-dimensional simulation of spatial layout, equipment positioning, and pipeline routing, quantifiable design parameters should be formed to avoid losses caused by disassembly and modification due to mismatch of process requirements after the completion of civil engineering design. During the process of professional management, hospitals need to clearly define the responsibility boundaries of different parts, carry out effective management of composite interfaces involving multiple professional intersections, formulate interface technology introduction principles, issue task books, achieve precise connection of each module, and reduce the cost of later repairs. Converting the technical specifications of medical professional engineering into the influencing factors of calculable costs not only meets the current medical process requirements but also leaves room for adaptation for future technological iterations. Thus, the risk of cost overruns can be eliminated at the source, and the possible passive changes during the construction stage can be transformed into active and controllable technical solutions.

2.3 Bidding and Tendering Stage

The effectiveness of cost control in hospital project bidding and tendering should first focus on whether the bidding and tendering documents are complete and whether the technical descriptions are accurate. Compared with conventional public buildings, the construction of medical projects involves related contents such as purification engineering and protective systems. These projects are embedded with the main body, with ambiguous technical boundaries and abstract requirement parameters, which can easily lead to omissions and construction rectifications in the subsequent construction process. Therefore, during the bidding and tendering stage, hospitals should transform requirements into precise and controllable parameters to avoid ambiguous expression of requirements. In the dimension of interface management, it is necessary to clearly define the physical junction points between specialized projects and the civil engineering and mechanical and electrical systems, form technical connections, and eliminate the scope vacuum of cross-professional projects. In the dimension of risk control and management, it is necessary to pre-block the possible high-frequency omitted risk points. During this process, hospitals need to build a cross-professional collaborative review platform to ensure the integrity of demands through multi-perspective cross-validation and expose potential hidden risks in advance. Identify risks through effective technical standards in advance. In terms of management, hospitals still need to establish a linkage review mechanism for technical bids and business bids of bidding units, break the binary opposition relationship between technology and economy, and achieve effective unity between the two through the value transmission model.

2.4 Construction Stage

During the construction phase, hospitals need to break through the limitations of traditional static cost control, form a data collection system covering all elements and the entire cycle, and digitally map the costs of labor, materials, machinery, etc. Match the spatial vectors properly and carry out phased risk prevention and control. Through methods such as Monte Carlo model artificial intelligence analysis, a comprehensive prediction is made for uncertain factors such as design changes and construction claims, forming a deep coupling of technology and monitoring indicators. The payment review mechanism is combined with the project entity and progress control mechanism, and the prediction is initiated for progress payment applications that exceed the

scope. Check whether there is any false reporting in the existing engineering links, effectively control the duplicate pricing behavior, ensure that the economic closed loop and the technical closed loop form a synergy effect, create a chain reaction, and promote the construction unit to automatically optimize resource allocation and meet the compliance requirements. Throughout the entire life cycle of cost control, hospitals should introduce value analysis tools to precisely align progress payments with the process of project cost creation, effectively manage core technical paths, and also ensure the priority of different payments. For non-critical path processes, a lagging payment strategy is adopted to achieve the dual-objective optimization of cost control and project schedule. Hospitals should also manage visa changes effectively and establish an effective control mechanism for the impacts such as cost, function and security caused by the changes. Submit relevant professional assessment reports and manage important changes, major changes and general changes in a classified manner. For instance, for general changes such as the replacement of decoration materials, a standardized fast-track approval channel can be adopted to reduce the channel resources occupied by general changes. When it comes to major contents such as the re-examination of drawings, hospitals need to make comprehensive judgments from the perspective of the process in construction management. Through an effective engineering database construction mechanism, the cost impact caused by a single change can be incorporated into the process management. The standardization level of hospital engineering construction can be continuously improved through knowledge accumulation methods.

2.5 Completion Acceptance Stage

During the completion acceptance stage, hospitals mainly verify the authenticity of the cost of various concealed works, which is also a key link in cost control. The physical entity of hospital projects is highly complex, so it is necessary to effectively identify the contradictions between invisible data and settlement data during the completion acceptance stage. For instance, hospitals can use spatio-temporal traceability technology to search for the timestamps and geographic coordinate information of various image materials, establish mapping models covering key construction nodes such as pipelines and pre-embedded waterproof layers, and form a data penetration system. Hospitals should also embed construction logs, supervision records, settlement statements, etc., to ensure the consistency of material specifications and construction techniques. Through methods such as logical mutual verification, probability simulations should be conducted for unconventional additional items in the settlement of concealed works to identify false declaration behaviors that violate construction logic. Throughout the entire process, hospitals can conduct data analysis on immutable engineering archives through blockchain technology, BIM reverse modeling technology, and artificial intelligence image recognition technology. Timely detect the deviations in the design model, conduct a comprehensive analysis of the construction details in the image data and the technical features described in the settlement list, and transform the verification process that relies on subjective judgment into an objective verification process that is quantifiable and traceable, thereby curbing settlement risks such as false reporting of engineering quantities and duplicate pricing.

3. Critical Path Identification and Optimization Strategies

3.1 Process Control of Price and Cost Management

The cost engineering management of hospitals needs to form a precise system under the work decomposition structure, build a professional system based on the functional modules of each part, focus on technical cores such as clean engineering and intelligent systems, improve the effectiveness of management, and give higher weight to the core links related to the realization of hospital functions. Breaking away from the traditional perspective of progress management, it conducts a comprehensive analysis of project progress, project cost and other contents from the perspective of resource management. Form a dynamic and sensitive system to resolve conflicts in process logic, enhance the efficiency of quality-cost conversion, and implement quality-cost control for high-risk processes. A series of external variables such as the price trends of bulk materials and changes in labor policies are incorporated into the early warning model to form a path blocking mechanism for risk transmission and a key method for coordinated prevention and control. Structural safety factors and redundancy in equipment selection are also included in the parameter model. Overall, in the dynamic cost control throughout the entire life cycle, hospitals need to continuously enhance the systematicness and effectiveness of critical path identification, form a dynamic calibration model based on BIM technology, combine spatial verification logic and process simulation and deduction, conduct dynamic analysis of various elements, and form a historical cost database. Combining the evolution laws of material prices and labor costs in different cycles to form an effective guidance system, it is convenient for hospitals to make intelligent decisions in the cost control of the entire life cycle.

3.2 Form a Multi-subject Collaborative Risk Control System

During the project planning stage, the hospital should establish a risk early warning model and organize the construction party, design unit and construction enterprise to conduct a joint risk assessment. By constructing an indicator system that includes dimensions such as technical feasibility, cost fluctuations, and policies and regulations, multi-level risk diagnoses are carried out regularly. Establish a risk classification management system, divide the identified risks into three levels according to the degree of impact, and formulate differentiated control plans accordingly. Implement dynamic tracking and assessment, update the risk list every quarter, and adjust the response plan in a timely manner for newly emerging potential risks. Carry out regular and stratified training for all participating entities. Focus on cultivating systematic risk thinking for the management and establish a project risk responsibility system. Strengthen the education on operation norms for the executive level and embed the requirements of risk prevention and control into job responsibilities. Implement a risk knowledge assessment and certification system, establish a regular rotation training mechanism, and enhance practical abilities through teaching

forms such as case review and scenario simulation.

4. Implement the Guarantee System

In the cost management throughout the entire life cycle of a hospital, it is necessary to break away from the traditional mindset of opposition between the client and the contractor. Instead, a joint decision-making mechanism should be established to comprehensively coordinate the demands of all departments in the hospital, strengthen cost control, and form value transmission. Establishing a matrix organizational framework within the entire system not only conforms to the laws of engineering economy but also ensures the flexible scheduling of each module. Respond to the special requirements of medical processes. In the construction of the intelligent guarantee system, hospitals should establish a full life-cycle responsibility traceability system, bidirectional binding of the information of the operation recorder and the person responsible for key links such as design changes, visa approval, and material acceptance. This system helps to implement the responsibility binding mechanism, and any cost decision must simultaneously generate the corresponding supervision list. A long-term responsibility traceability system should be established for concealed works and other links with high lagging risks to facilitate the full life cycle management of cost engineering. In addition, hospitals should also strengthen risk control and provide technical support through different third-party audit intervention methods such as preventive intervention, process intervention, and restorative intervention, to cope with the complex changes in the external market environment. They should not only output risk warnings to the construction entities but also provide analysis reports to the industry regulatory authorities.

5. Conclusion

In conclusion, hospital project cost management based on the entire life cycle should be combined with the actual development of each professional department in the hospital to build a dynamic cost management system. It should be based on the engineering characteristics of different stages such as the design stage, decision-making stage, bidding and tendering stage, construction stage, and completion acceptance stage to form the identification of risk points. During the process, we should strengthen the integrated management of various risks, enhance the systematic level of quality control, further improve the standardization of hospital process management, reduce the impact of construction changes, and increase the precision of cost management.

References

[1] Liu Chi. Research on the cost index of the clean operating department of Shenzhen Hospital [J]. Real Estate World, 2024, (18): 83-85.

[2] Huang Yangyang, Li Lu, Wu Hong. Practice and exploration of quality control of public hospital project audit outsourcing services [J]. China Science and Technology Investment, 2024, (15): 109-114.

[3] Liu Lehui, Xiao Ya, Liu Zhen. Research on the role of full-process cost audit in cost control of public hospital construction projects [J]. Economist, 2024, (05): 252-254+281.

[4] Liu Ping, Zhang Xiu Na. Case study on full-process cost control of large-scale public hospital projects [J]. China Chief Accountant, 2024, (01): 129-131.

[5] Zhang Dapeng. Research on improving the quality of hospital project entrusted audit [J]. Construction and Budget, 2024, (01): 16-18.

[6] Dian Guiwen, Ye Tianfu. A preliminary study on the practice of public infectious disease emergency project management - taking an emergency hospital project in Chaozhou as an example [J]. Construction Supervision, 2025, (04): 19-22.

[7] Weng Zixiao, Wang Nan, Wang Chengwei, Liu Chenhui, Liu Yue, Wang Qiancheng. Application of 5W2H analysis method in hospital sporadic project management [J]. Chinese Hospital Construction and Equipment, 2025, 26 (04): 33-37.

[8] Zhao Yunpeng. Research on optimization strategy and practice of medical radiation protection engineering in hospital construction [J]. Value Engineering, 2025, 44 (10): 135-137.

[9] Franklin Dexter, Richard H Epstein, Anil A Marian, Carlos E Guerra Londono. Preventing Prolonged Times to Awakening While Mitigating the Risk of Patient Awareness: Gas Man Computer Simulations of Sevoflurane Consumption From Brief, High Fresh Gas Flow Before the End of Surgery. [J]. Cureus, 2024, 16 (3): e55626-e55626.

[10] Departamento de Expresión Gráfica, Universidad de Extremadura, Avda. de Elvas, s/n., 06006, Badajoz, Spain, Departamento de Expresión Gráfica, Universidad de Extremadura, Avda. de Elvas, s/n., 06006, Badajoz, Spain, Departamento de Expresión Gráfica, Universidad de Extremadura, Avda. de Elvas, s/n., 06006, Badajoz, Spain, Departamento de Expresión Gráfica, Universidad de Extremadura, Avda. de Elvas, s/n., 06006, Badajoz, Spain. Using an objective measurement model to determine the corrective maintenance demand in the field of hospital engineering[J]. International Journal of System Assurance Engineering and Management, 2019, 10 (6): 1567-1576.