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The Construction of Infrastructure Management Information Systems for Large Hospitals

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Abstract: This study addresses the practical demands for whole lifecycle management of infrastructure projects in large hospitals by systematically analyzing the inherent limitations in conventional management approaches, including non-standardized processes, information silos, and insufficient decision-making support. Guided by principles of modularity, standardization, and intelligentization, we propose a Hospital Infrastructure Management Information System (HIMIS) that comprehensively covers all project phases from initiation and design to construction and handover. The system features a three-tier architecture, i.e., user interaction layer, application logic layer, and database layer, integrating core modules for project approval, implementation, and handover. Advanced digital technologies, such as blockchain-based data authentication, BIM model collaboration, and AI-driven predictive alerts, are incorporated to enable full-chain data traceability and risk early-warning capabilities. Furthermore, this research delineates technical pathways for deep integration with hospital budgeting and auditing systems, providing a theoretical framework and practical reference for resolving information silos in medical infrastructure management and establishing a digital infrastructure foundation for smart hospitals.

1. Introduction

With the rapid economic development and deepening reforms in China's healthcare system, the public has increasingly higher expectations for both the quality and infrastructure of medical services. Consequently, the renovation and expansion of hospital construction projects have become a focal point in the healthcare industry. Due to the highly specialized functional requirements of hospital buildings and the continuous advancement of medical technologies, coupled with the emergence of new diagnostic and treatment equipment, hospital infrastructure projects inherently demand unique expertise from design and construction to post-commissioning operations and maintenance. Currently, most hospital infrastructure projects in China are still self-managed by hospitals as project owners. In such projects, infrastructure engineers play a critical role, and management practices have evolved from traditional on-site supervision to a hybrid model integrating online and offline approaches. This paper analyzes and explores the development of a hospital infrastructure management information system (IMIS), aiming to provide insights for relevant research and practical applications.

2. Challenges in Conventional Hospital Infrastructure Management

2.1 Lack of Standardized Processes

In traditional hospital infrastructure management, whether adopting Public-Private Partnership (PPP) or Management Contracting (MC) models, hospitals, as both project developers and end-users, remain responsible for overarching project oversight. However, most hospitals lack dedicated infrastructure professionals, and the inherent complexity of medical facilities, characterized by multifunctional design, intricate operational requirements, and stringent technical standards, [1] often leads to ambiguities in critical workflows. These include project initiation, approval, implementation, and final acceptance. The absence of scientifically robust project management tools further exacerbates inefficiencies, resulting in insufficient transparency across stages and challenges in maintaining operational control.

2.2 Information Opacity

Infrastructure engineers often struggle to access real-time updates on critical project metrics, such as budget allocation, progress tracking, documentation status, and contract payments, resulting in cumbersome data retrieval and analytical inefficiencies. Additionally, project teams face systemic barriers in reporting workflow advancements, which directly impedes timely risk identification and resolution.

2.3 Communication Fragmentation

Hospital infrastructure projects involve extensive stakeholder networks and heavy reliance on outsourced contractors. The absence of structured communication protocols, such as automated reminders or centralized platforms, leads to fragmented information flows, hindering the establishment of a cohesive and efficient collaborative framework. Furthermore, decentralized data management practices contribute to delays and inconsistencies in document archiving and retrieval processes.

2.4 Inadequate Decision-making Support

Hospital leadership, distanced from frontline operations, often formulates requirements without grounding in real-time project dynamics or data-driven insights. This detachment leads to decisions disconnected from practical constraints, exacerbating risks of managerial oversight and misalignment with on-site realities.

2.5 Shortage of Multidisciplinary Expertise

Medical infrastructure projects demand managers proficient in civil engineering, urban planning, facility design, and regulatory compliance. However, the scarcity of such cross-disciplinary professionals impedes project efficiency. Concurrently, the absence of homogenized management platforms in hospitals managing multiple projects introduces operational redundancies and systemic vulnerabilities, further complicating coordination and quality control.

3. Development of a Hospital Infrastructure Management Information System (HIMIS)

To address these challenges, this study proposes the design of HIMIS to comprehensively manage the entire lifecycle of hospital infrastructure projects. The system will integrate key phases—from preliminary feasibility assessment and regulatory approvals to mid-term design coordination, construction oversight, and post-completion auditing and financial settlement. Guided by principles of modularity, form standardization, and procedural compliance, the HIMIS aims to transition conventional infrastructure management practices toward data-driven precision and operational refinement.

3.1 System Architecture Design

The HIMIS adopts a three-tier architecture: user interface layer, application logic layer and database layer. User interface layer provides unified foundational services for web portals and mobile applications, including user authentication, account management, and role-based access control. Application logic layer hosts core functional platforms for hospital infrastructure governance, encompassing workflow approvals, contract administration, document control, and real-time collaboration tools. Database layer serves as the centralized repository, utilizing unified form-based data entry interfaces to streamline data storage, retrieval, and cross-module interoperability. All system modules are interconnected with a centralized database, enabling bidirectional data exchange and eliminating redundancies through shared datasets. This architecture ensures data compatibility and consistency across project management functions while maintaining strict version control [2].

3.2 Core Functional Modules of HIMIS

The HIMIS is structured around three primary modules aligned with the infrastructure lifecycle: Pre-Approval, Engineering Management, and Project Handover.

3.2.1 Pre-approval Module

This module standardizes project initiation workflows, including background analysis, budget rationale, cost-benefit assessments, and risk evaluations, etc. Approval workflows comprise internal institutional reviews and government-mandated administrative approvals. Internal institutional reviews require multi-departmental collaboration among the following in-house entities: clinical service units (e.g., departments directly utilizing the infrastructure), security office, infection control division, labor union, hospital party committee, etc. Government-mandated administrative approvals tier regulatory approvals based on project scale, requiring validation from provincial or municipal development and reform commissions, health administrations, and financial authorities. Post-approval, cross-departmental oversight (e.g., urban planning, environmental protection, fire safety) ensures adherence to construction codes. During the logical design phase, the module embeds conceptual frameworks (e.g., regulatory compliance protocols, interoperability standards), while automated validation triggers and cross-functional reconciliation mechanisms ensure real-time anomaly detection and data integrity throughout implementation.

3.2.2 Engineering Management Module

The Engineering Management Module establishes a comprehensive governance framework across two lifecycle phases: design phase and construction phase. Design phase governance includes collaborative drafting and auditing of technical specifications, alignment with government-mandated design standards (e.g., energy efficiency, accessibility), bid management, and construction drawing review. Construction phase governance encompasses multifaceted responsibilities, including supervisory contractor procurement (transparent bidding processes for third-party supervision agencies), triple constraint oversight (implementation of cost, schedule, and quality control), contract-safety coordination (dual-focus management of contractual obligations and OSHA-compliant safety protocols). The management framework for this phase demands extended design timelines due to its heightened complexity—characterized by multi-layered content interdependencies and non-linear logical workflows. Effective implementation requires rigorous mapping of temporal sequences and causal hierarchies to ensure deterministic process orchestration. In quality management, hidden danger closed-loop management can be uploaded in real time through the mobile terminal daily and weekly inspection records, the system automatically generates rectification notices and tracking closed-loop, and historical hidden danger data can be analyzed by horizontal comparison. Key processes can also be visualized acceptance, hidden works and sub-parts of the project acceptance, retaining image data and support the five parties responsible for the body online signing, to eliminate the risk of after-the-fact re-signing.

In terms of engineering project schedule management, the information-based platform enables real-time updates, queries, and sharing of construction progress data, allowing timely identification of issues during construction and immediate implementation of corrective measures [3]. For material logistics and cost management, a material consumption database can be established to track incoming materials via RFID technology. Budget-to-actual variance analysis is integrated to strengthen in-process cost control. Building Information Modeling (BIM) is utilized to simulate construction schedules, electronically extract quantity takeoffs, and facilitate investment estimation and review, enabling real-time cost management control. In safety management, contractors put forward specialized safety plans for supervisory review, followed by item-by-item verification during implementation. Additionally, cameras detect violations such as failure to wear helmets or unsafe aerial work, automatically triggering alerts.

3.2.3 Project Handover Module

Upon completion and acceptance of hospital infrastructure projects, the process transitions into the financial closure and operational handover phase. Financial closure comprises two components. One is contractor-led settlement, which involves strict governance of change orders to ensure compliance with predefined contractual clauses. The other is hospital-facilitated financial closure, which requires systematic reconciliation of final accounts against initial budgetary estimates. During the settlement process, strict controls are enforced on change orders, ensuring their execution adheres to predefined protocols, while all audits of engineering quantities and costs must be verifiably documented. All audit processes are digitally traced within the information system to facilitate post-hoc review. Financial closure, as the final phase of hospital infrastructure projects, requires rigorous reconciliation with the initial budgetary estimates established during project initiation. All expenditures must be systematically categorized, archived, and accrued to verify alignment with projected outcomes. In instances of budget overruns, mandatory supplementary approvals must be secured through predefined administrative protocols. Upon completion of financial closure, fixed assets must be promptly capitalized in accordance with institutional accounting protocols.

3.3 Anticipated System Outcomes

After the establishment of HIMIS, it can significantly improve the management efficiency of the project and ensure the compliance of the project promotion procedures. It can also realize real-time mastery of hospital infrastructure projects through the information platform, and effectively help infrastructure leaders make decisions on construction and inputs by using cutting-edge informatization means such as data analysis and AI intelligent assistance. At the same time, it realizes the archive management of the whole life cycle of hospital infrastructure projects, which facilitates internal and external audits and post-evaluation after the completion of subsequent projects.

4. Conclusion

The implementation of HIMIS establishes end-to-end digital continuity across the project lifecycle, from feasibility studies and design to construction and facility operations, enhancing management efficiency while reducing safety incidents. Current hospital management systems, including budgeting, contract administration, auditing, and logistics support, operate as fragmented information silos, failing to achieve synchronized operational coherence [4]. In subsequent phases, our efforts will focus not only on optimizing the system's architectural framework but also on synchronizing its evolution with the hospital's digital ecosystem, thereby progressively enhancing infrastructure governance and monitoring protocols to better align with institutional development imperatives.

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