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Technological innovation and operational efficiency among healthcare services

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Abstract

Driven by the global digital transformation of healthcare, diverse technological innovations have become critical levers for improving operational performance in tertiary-level hospitals. Targeting five leading tertiary hospitals in Hebei Province, China, this study explores the intrinsic links between three digital technologies (big data, artificial intelligence, and blockchain) and hospital operational efficiency covering service-process optimization, resource allocation and cost control. By means of purposive-convenience sampling, 200 hospital practitioners with hands-on job experience were recruited for questionnaire-based investigation. A descriptive research design was adopted for empirical analysis, and SPSS 28 was utilized for overall data processing. Reliability tests yielded Cronbach's α values ranging from 0.840 to 0.899 across all dimensions, confirming satisfactory internal consistency of the measurement instrument. As the Shapiro-Wilk test indicated non-normal distribution of sample data, Spearman's rank-order correlation was applied to examine correlations among variables. Survey findings suggest respondents gave affirmative evaluations of both on-site technology implementation and overall operational efficiency. Among the three technologies, artificial intelligence and blockchain earned equally high scores, whereas the perceived practical outcomes of big-data transformation were comparatively weaker. For operational efficiency, cost control achieved the best rating, while service-process optimization still held substantial room for improvement. Statistical tests reveal strong positive correlations between each of the three technologies and all sub-dimensions of operational efficiency ($p < 0.001$), with artificial intelligence showing the most prominent correlation with resource allocation ($\rho=0.885$). This study verifies that digital-technology adoption can substantially boost institutional operational performance. It also identifies practical deficiencies within sampled hospitals, including insufficient translation of big-data insights and inadequate refinement of operational workflows. Grounded in empirical outcomes, actionable measures are proposed. This paper delivers local-context evidence for hospital administrators and health-policy makers to advance healthcare digitalization, and lays foundations for future long-term follow-up research.

Keywords: technological innovation, big data, artificial intelligence, blockchain, operational efficiency, tertiary hospital, healthcare service delivery, Hebei Province

Technological innovation and operational efficiency among healthcare services

1. Introduction

The integration of technological innovations to enhance operational efficiency in healthcare, particularly within tertiary hospitals, is a global phenomenon. Digital health innovations are widely recognized as a transformative force, bridging gaps in healthcare delivery worldwide and presenting significant opportunities (Ahmed et al., 2025; Cascini et al., 2023). The World Health Organization actively supports this trend with its "Global strategy on digital health 2020–2025," aiming to improve health outcomes through advanced medical diagnosis, data-driven treatment decisions, digital therapeutics, and enhanced professional competence (Cascini et al., 2023, p. 2). Within this context, the digitization of health records, telemedicine, and data analytics significantly enhance operational performance by streamlining administrative tasks and improving care coordination ("International Journal of Multidisciplinary Research and Growth Evaluation," 2021; Ng'andu & Haabazoka, 2024, p. 1136).

Technology innovation in medical services is increasingly defined by the interconnected dimensions of Big Data, Artificial Intelligence, and Blockchain Technology, each revolutionizing distinct aspects of healthcare delivery and management. Big Data technology provides the foundation for multi-dimensional assessments, personalized treatments, and improved decision-making by enabling the organization and analysis of vast, complex datasets to enhance patient diagnostics, facilitate rapid epidemic recognition, and optimize patient management (Dıcuonzo et al., 2021; Khan et al., 2021; Waghodekar & Bewoor, 2025). Complementing this, Artificial Intelligence innovations are transforming healthcare by providing advanced solutions for medical imaging analysis, predictive analytics for patient outcomes, and clinical decision support systems, thereby enhancing diagnostic accuracy, treatment planning, and overall patient care (Chatterjee et al., 2024; Naqvi et al., 2023; Silcox et al., 2024). Finally, Blockchain Technology introduces dimensions of enhanced data security, privacy, transparency, and data management, crucial for safeguarding electronic health records, streamlining health data sharing, facilitating remote patient monitoring, and securing pharmaceutical supply chains, thereby addressing critical challenges of data integrity and interoperability within the healthcare ecosystem (Abuhalimeh & Ali, 2023; Bathula et al., 2024; "Blockchain Applications - Transforming Industries, Enhancing Security, and Addressing Ethical Considerations," 2022; Chaudhary et al., 2023; Cheikhrouhou et al., 2025; Kasyapa & Vanmathi, 2024; Liu et al., 2024; Quazi et al., 2024).

Operational efficiency in medical services is a crucial objective, especially given rising healthcare costs and the demand for high-quality care (Rella et al., 2023, p. 2). This overarching goal is underpinned by several key dimensions. Service Process Optimization focuses on streamlining workflows and activities to eliminate waste and enhance value for patients, ultimately leading to improved patient satisfaction by reducing waiting times and improving communication (Allabbas et al., 2024; Amati et al., 2022; Mast et al., 2011, p. 1097). Methodologies like Lean healthcare are widely implemented to improve work processes, accelerate productivity growth, and optimize resources (Anuar et al., 2018). Efficient process design can also involve sophisticated techniques, such as integer linear programming, to improve the work efficiency of medical professionals and reduce patient waiting times (Li et al., 2023, p. 1). Another critical dimension is Resource Allocation Efficiency, which involves the optimal deployment of human, capital, and material resources to maximize output and avoid waste (Asamani et al., 2021; Farzianpour et al., 2016, p. 43; Nepomuceno et al., 2022). Misallocation of resources can significantly impact productivity, highlighting that how money is spent is as important as how much (Chandra et al., 2023). Strategic resource allocation, informed by data analytics and aligning with patient needs and organizational priorities, is essential for cost-effective care without compromising quality (Owolabi et al., 2024, p. 959). Lastly, Cost Control strategies aim to limit healthcare expenditures by eliminating inappropriate use of services and identifying the best practices to optimize resource utilization and reduce overall costs (Doshmangir et al., 2022, p.

2; Rella et al., 2023, p. 2). This can involve measures such as reducing service duplication, decreasing the use of expensive inputs, and fostering organizational mergers to achieve economies of scale (Doshmangir et al., 2022, p. 2).

The present study aims to explore the multifaceted relationship between technology innovation and operational efficiency within tertiary hospitals, specifically focusing on healthcare services in the Hebei Region of China. While the introduction highlights the global recognition of digital health innovations as transformative forces, this research grounds itself in the particular context of the top five tertiary hospitals in the Hebei Region. Despite the general acknowledgment of technology's potential, a notable research gap exists in comprehensively understanding how specific technological dimensions, such as Big Data, Artificial Intelligence, and Blockchain Technology, are optimally integrated to systematically enhance operational efficiency across diverse tertiary hospital settings, particularly considering varying global implementation challenges and successes. Therefore, the problem of the study centers on the imperative to identify, analyze, and synthesize effective strategies for leveraging these innovations to overcome existing operational inefficiencies and optimize service delivery within tertiary hospitals in the Hebei Region of China, ensuring sustainable, high-quality, and cost-effective healthcare in an increasingly digitalized global landscape. This local focus contributes to the broader understanding of these dynamics within a specific healthcare context.

This study holds multifaceted significance, offering crucial insights for various groups. For researcher, it contributes empirical data from tertiary hospitals in the Hebei Region of China, helping to fill a geographical research gap and providing insights into the relationship between IT deployment and healthcare performance, calling for more empirical research in this domain (Enam et al., 2022, p. 210; Ingvaldsen et al., 2022, p. 26). The findings will aid in refining theoretical frameworks, understanding regional variations in technology impact, and supporting future research on efficiency and productivity analysis that accommodates the sector's complexity (Andrews & Emvalomatis, 2024). For hospitals, particularly those in the Hebei Region, this research offers practical guidance for informed decisions on technology investments and implementation strategies across Big Data, AI, and Blockchain. By highlighting their impact on service process optimization, resource allocation, and cost control, it enables hospitals to strategically deploy technologies to improve patient care, streamline processes, and enhance operational effectiveness (Hung-Xin, 2024, p. 10; Mukherjee et al., 2023, p. 8; Remondino, 2020, p. 116). For stakeholders, including patients, policymakers, and technology providers, the study implies better quality of care and increased efficiency through digital technologies (Heidlund, 2023, p. 6; Lahmann & Hampel, 2020, p. 756). Policymakers can leverage these findings to develop evidence-based healthcare policies and optimize resource allocation. Technology providers gain a clearer understanding of the perceived needs and impacts of their solutions, guiding future product development to meet the specific demands of the Chinese healthcare system and integrate early health technology assessment into the innovation process. Finally, for future researchers, this study establishes a foundational groundwork for longitudinal and comparative studies, inviting deeper investigation into the mechanisms of IT deployment and healthcare performance (Enam et al., 2022, p. 186; Ingvaldsen et al., 2022, p. 26), the challenges of integrating new technologies like 5G in hospitals in Western China (Zhou et al., 2024), and the optimal use of Big Data for managerial decision-making in Chinese public hospitals (Wu & Khalid, 2024, p. 24424), thereby facilitating a deeper understanding of digital transformation in healthcare and contributing meaningfully to theory and practice (Abbate et al., 2022, p. 3306).

Objectives of the Study - This study aimed to assess the Technological Innovation and Operational Efficiency in the Healthcare Services in China. Specifically, it aims to determine technological innovation in terms of bigdata technology, artificial intelligence and block chain technology; assess the level of operational efficiency in terms of service process optimization, resource allocation and cost control; test the significant relationship among Technological Innovation and Operational Efficiency; and to propose a plan of action to improve the Technological Innovation.

2. Methods

Research Design - A descriptive research design were used in this study to provide an adequate and precise interpretation of the findings regarding resource allocation efficiency and cost control in tertiary hospitals. Descriptive research systematically describes populations, events, or phenomena by delineating their key characteristics, frequencies, trends, and classifications—proving especially valuable for probing understudied domains like hospital operational efficiency, where baseline insights inform subsequent explanatory or experimental approaches (Subaie, 2019, p. 4). This approach is well-suited here, as it enables a comprehensive profiling of current practices, inefficiencies, and patterns in complex healthcare settings, aligning with established methodologies for initial efficiency assessments in hospitals.

Participants in this study - The selection of participants for this study is meticulously designed to ensure the collection of relevant and reliable data from a representative group within the specified healthcare context, employing a purposive convenience sampling approach. This method was chosen because it combines the strategic selection of participants based on predefined criteria (purposive) with the quota of 40 for each company, ensuring that the insights gathered are both relevant and feasible to obtain. The study involved 200 employees drawn from the top five tertiary hospitals located in the Hebei Region of China. This institutional focus on tertiary hospitals is crucial because these facilities are typically at the forefront of adopting technological innovations and are characterized by complex operational structures, making them ideal settings to examine the interplay between technology and operational efficiency. Furthermore, limiting the selection to the top five hospitals ensures that the participants are from institutions with potentially higher levels of technological integration and established operational frameworks, providing a robust sample for analysis within the Chinese healthcare landscape. A minimum employment duration of six months for each participant is stipulated to ensure that all respondents possess sufficient institutional knowledge and experience with the hospital's operational procedures and technological implementations to provide informed insights.

Beyond the institutional and tenure requirements, the selection criteria further specify that participants must have direct involvement in hospital operations and demonstrable experience in using technology in their job roles. The requirement for direct operational involvement is essential to gather perspectives from individuals who actively contribute to the daily functioning and service delivery within the hospital, as their experiences are directly tied to the study's focus on operational efficiency. Concurrently, the prerequisite that employees must have utilized technology in their professional capacity is paramount for a study exploring technological innovation. This ensures that the data collected directly reflects the practical application and impact of technological tools, such as Big Data, Artificial Intelligence, and Blockchain Technology, on their work processes and the hospital's overall efficiency. By adhering to these stringent selection criteria, combined with the practical accessibility of these individuals, the study aims to capture nuanced and empirical insights into how technology innovation influences operational effectiveness in the targeted Chinese tertiary hospital setting.

Instruments - To collect the data, the researchers designed their own questionnaires. It was based on previous literature and research conducted in the field. The researchers properly validated and tested the questionnaires. The questionnaire was divided into two parts. Part 1 is used to analyze the impact of technological innovation on healthcare services. It is divided into three subfields (big data technology, artificial intelligence technology, blockchain technology). This section requires respondents to answer a total of 15 questions. Part 2 is used to analyze the impact of operational efficiency on healthcare services. It is divided into three subareas (service process, resource allocation efficiency, cost control). In this section, they answered another 15 questions. To ensure the effectiveness of the data collection tool in terms of relevance, clarity, and applicability, we submitted the data collection tool to a panel of three experts for surface and content validation. These experts were selected based on their expertise in the field. The judges' feedback, including comments, suggestions and opinions, was incorporated into the final draft of the tool.

Table 1
Reliability test results using Cronbach Alpha and their interpretation

Cronbach Alpha	Quantity of items	Explanation
Technological innovation		
Big data technology	0.851	good
Artificial intelligence technology	0.872	good
Blockchain technology	0.847	good
Operational efficiency		
Service process optimization	0.840	good
Resource allocation	0.850	good
Cost control	0.899	good

Legend: a≥0.9 Excellent; 0.9 > a≥0.8 good; 0.8 > a≥0.7 is acceptable; 0.7 > a≥0.6 is questionable; 0.6 > a≥0.5 difference; 0.5 > unacceptable;

Table 1 presents that the Cronbach Alpha coefficients for each dimension in this study were in the range of 0.840 to 0.899, which is a "good" reliability level, indicating good internal consistency and reliable measurement results for each dimension item. It can effectively reflect the actual situation of each construct of technological innovation (big data, artificial intelligence, blockchain) and operational efficiency (service process optimization, resource allocation, cost control), providing stable data support for subsequent empirical analysis.

Procedure - The electronic questionnaire is applied for via wechat Juxing. After formally submitting written applications to the company, a pilot test was conducted among 30 respondents. The retrieved questionnaires were quickly encoded into Excel format and sent to the school research center via SPSS software for analysis. Once the questionnaire reaches internal consistency, it were finalized and copied and distributed. Researchers distribute questionnaires via Questionnaire Star and collect responses over a period of two weeks. After reaching the sample size within this time frame, follow-up emails and other electronic messages were sent to express appreciation and gratitude for completing the respondents. Finally, the data obtained was analyzed using the relevant statistical methods. Get some descriptive statistics to present the data. It is important to understand the statistics related to the research objective when analyzing the results.

Data analysis - Weighted mean and rank were used to determine technological innovation in terms of big data technology, artificial intelligence and block chain technology; assess the level of operational efficiency in terms of service process optimization, resource allocation and cost control. The result of Shapiro-Wilk Test showed that p-values of all variables were less than 0.05 which means that the data set was not normally distributed. Therefore, Spearman rho was used as part of the non-parametric tests to determine the significant relationship. All analyses were performed using SPSS version 28.

Ethical considerations - As a result, effective privacy protection measures were taken to ensure that the rights of the respondents were protected. During the data collection process, the security of personal information of the respondents can be effectively protected through anonymization processing and encryption technology; In terms of informed consent, the content of informed consent is detailed and the language is easy to understand, allowing respondents to fully understand the relevant information of the study and participate in the study on a voluntary basis. The ethics review committee also made some recommendations for the study, such as strengthening communication and feedback with the subjects during the study and answering their questions in a timely manner; In the process of data usage and dissemination, strict compliance with relevant laws and regulations should be ensured to guarantee the security and legal use of the data.

3. Results and discussion

Table 2 presents the assessment of the respondents on Technological Innovation in terms of Big Data Technology, Artificial Intelligence, and Blockchain Technology. The composite mean of 3.12 indicates that the respondents "Agree" in general. This implies that employees in the top five tertiary hospitals in Hebei Region collectively perceive a positive and integrated role for technological innovations in their healthcare facilities. This general agreement underscores a widespread recognition of these technologies as essential drivers for improving healthcare delivery and management. The consistent "Agree" interpretation across all three dimensions signifies a strong endorsement of digital transformation within these hospitals, reflecting a strategic alignment towards leveraging modern tools. The findings suggest that the surveyed hospitals are actively engaged in adopting and benefiting from the digital transformation in healthcare.

Table 2
Summary Table of Technological Innovation

Indicators	Weighted Mean	Verbal Interpretation	Rank
Big Data Technology	3.09	Agree	3
Artificial Intelligence	3.13	Agree	1.5
Blockchain Technology	3.13	Agree	1.5
Composite Mean	3.12	Agree	

Legend: 3.50-4.00=Strongly Agree; 2.50-3.49=Agree; 1.50-2.49=Disagree; 1.00-1.49=Strongly Disagree

Digital health innovations are widely recognized as a transformative force, bridging gaps in healthcare delivery worldwide and presenting significant opportunities (Ahmed et al., 2025). The World Health Organization actively supports this trend with its "Global strategy on digital health 2020–2025," aiming to improve health outcomes through advanced medical diagnosis and data-driven treatment decisions (Cascini et al., 2023, p. 2). This proactive embrace of technology, often seen in leading hospitals, indicates a commitment to improving patient care and operational efficiency (Korte & Bohnet-Joschko, 2022). Such a positive attitude from healthcare workers towards new technologies facilitates their adaptation and integration into work processes, seeing technology as a supportive tool rather than a hindrance (Antep & Öngel, 2024, p. 4).

Among the items cited, Artificial Intelligence, ranked first with a mean score of 3.13 and verbal interpretation of "Agree." This implies that the surveyed employees perceive Artificial Intelligence as the most impactful technological innovation among the three evaluated, strongly agreeing with its positive integration. The high ranking of AI reflects its pervasive and transformative influence across various aspects of healthcare, from diagnostics to treatment and operational management. This indicates a strong belief in AI's capacity to deliver advanced solutions that enhance precision and effectiveness in medical therapies. It also suggests that the benefits of AI are tangible and observable in their clinical environments, translating into improved efficiency and quality of care. Artificial Intelligence's capability to process and interpret intricate medical data enhances the precision, effectiveness, and personalized nature of medical therapies, moving beyond human limitations in data comprehension (Tak, 2023). This technology allows for the analysis of vast datasets to uncover complex relationships and generate evidence-based knowledge, which is vital for modern medical practices and decision-making (Faiyazuddin et al., 2025). Furthermore, from automating tasks to driving robotics, AI is systematically streamlining workflows, assisting in diagnostics, and enabling personalized treatment, thereby contributing significantly to improved efficiency and quality in healthcare delivery (Olawade et al., 2024). The strong agreement for AI highlights its accepted role in augmenting medical professionals' skills and enhancing overall healthcare service delivery.

Blockchain Technology, ranked second with a mean of 3.13 and verbal interpretation of "Agree." This implies that respondents similarly perceive Blockchain Technology as a highly impactful innovation, on par with Artificial Intelligence, in transforming their healthcare operations. The strong agreement for Blockchain technology highlights its crucial role in enhancing data management, security, and transparency. This indicates a high level of confidence among employees regarding Blockchain's ability to create a more secure and trustworthy healthcare data ecosystem. The perceived benefits of Blockchain in safeguarding sensitive information are clearly recognized within these facilities, reinforcing its value in addressing critical challenges of data integrity. Blockchain

Technology fundamentally reshapes aspects of data management, security, and transparency within medical services, acting as a crucial dimension of technological innovation. Kasyapa and Vanmathi emphasize that this decentralized and distributed ledger system offers an immutable record-keeping mechanism, thereby enhancing the integrity and trustworthiness of healthcare data (Kasyapa & Vanmathi, 2024). Its core principles of cryptography and distributed consensus are particularly valuable in a sector where data privacy and security are paramount, providing a robust infrastructure to safeguard sensitive information such as electronic health records and medical transactions (Bathula et al., 2024). By enabling a secure and transparent environment, Blockchain aims to resolve long-standing issues of data fragmentation and lack of interoperability that plague traditional healthcare systems (Abuhalimeh & Ali, 2023).

Meanwhile, Big Data Technology, ranked third (last rank) with a mean score of 3.09 and verbal interpretation of "Agree." This implies that while employees acknowledge the positive role of Big Data, its perceived impact is slightly lower compared to Artificial Intelligence and Blockchain Technology. This suggests that Big Data might be viewed as a foundational technology that enables other innovations, rather than a standalone application with direct, highly visible impacts on daily operations. This nuanced perception indicates that there might be opportunities for further optimizing how Big Data's insights are translated into actionable improvements within the hospitals. Despite being fundamental, its transformative potential may be perceived as less direct or immediate compared to its counterparts. Big Data Technology represents a significant innovation within medical services, fundamentally altering how vast amounts of health-related information are processed and leveraged. This capability to derive meaningful insights from large and complex data streams is driving a new era of healthcare delivery and management, enabling improvements that were once unattainable (Weerasinghe et al., 2018, p. 8). This technological advancement yields substantial benefits, enhancing multiple facets of medical care and operational efficiency. By analyzing comprehensive datasets, Big Data provides a robust foundation for more accurate patient diagnostics, supports the rapid recognition and tracking of epidemics, and optimizes patient management strategies (Dıcuonzo et al., 2021). Furthermore, the ability to identify intricate patterns and trends within patient information leads to earlier detection of diseases, the creation of highly individualized treatment plans based on a wide array of data, and the identification of patients at higher risk for complications, thereby revolutionizing therapeutic approaches and advancing medical research (Mazumder, 2024, p. 4).

Table 3
Summary Table of Operational Efficiency

Indicators	Weighted Mean	Verbal Interpretation	Rank
Service Process Optimization	3.10	Agree	3
Resource Allocation	3.13	Agree	2
Cost Control	3.21	Agree	1
Composite Mean	**3.15**	**Agree**	

Legend: 3.50-4.00=Strongly Agree; 2.50-3.49=Agree; 1.50-2.49=Disagree; 1.00-1.49=Strongly Disagree

Table 3 presents the assessment of the respondents on Operational Efficiency. The composite mean of 3.15 indicates that the respondents "Agree" in general. This implies that employees in the top five tertiary hospitals in Hebei Region collectively perceive their facilities as demonstrating good overall operational efficiency. There is a general consensus that efforts are being made to optimize processes, allocate resources effectively, and control costs, contributing to a well-functioning healthcare environment. This agreement suggests a positive outlook on the hospitals' commitment to improving patient experience, achieving financial sustainability, and enhancing service delivery. Ultimately, a higher degree of operational efficiency implies a more productive, cost-effective, and patient-centered healthcare delivery system, which these findings generally support (Rella et al., 2023, p. 2).

Operational efficiency in medical services is a crucial objective, especially given rising healthcare costs and the demand for high-quality care (Rella et al., 2023, p. 2). This variable represents the degree to which a healthcare system utilizes its resources to maximize output and achieve desired outcomes while minimizing waste. Achieving operational excellence requires an integrated approach to process improvement, strategic resource management,

and diligent cost oversight (Barros & Díaz, 2023, p. 2). This holistic perspective ensures that all facets of hospital operations contribute to overall effectiveness (Barros & Díaz, 2022, p. 2).

Among the items cited, Cost Control, ranked first with a mean score of 3.21 and verbal interpretation of "Agree." This implies that the surveyed employees perceive their hospitals as particularly strong in managing expenditures and implementing robust strategies to maintain financial health. The high ranking suggests a significant emphasis on fiscal prudence and efficient resource utilization to limit healthcare costs. This indicates a proactive approach to economic viability, ensuring that funds are managed wisely without compromising the quality of patient care. Moreover, regular financial evaluation is likely a key component of these strategies, allowing for continuous optimization and savings (Rella et al., 2023, p. 2).

Cost Control is a vital dimension of operational efficiency, focusing on strategies designed to manage and limit healthcare expenditures in tertiary hospitals, which often face significant operational costs due to complex services (Rella et al., 2023, p. 2). Effective cost control involves a comprehensive approach that ensures appropriate utilization of services and identifies best practices to optimize resource use, thereby reducing overall expenses without compromising patient care quality (Doshmangir et al., 2022, p. 2). Strategic cost analysis and process improvement initiatives are essential for enhancing financial performance and operational efficiency in healthcare organizations (Ong & Vigonte, 2024). This strong emphasis on cost management helps hospitals achieve financial sustainability while delivering high-quality care (Ajam et al., 2020, p. 159).

Resource Allocation, ranked second with a mean of 3.13 and verbal interpretation of "Agree." This implies that respondents perceive a strong and effective management of how human, capital, and material resources are distributed within their healthcare facilities. The favorable ranking indicates that hospitals are generally successful in deploying their resources to meet demands and maximize service output. This suggests a strategic approach to ensuring that vital inputs are available where and when needed, contributing to seamless operations and high-quality patient care. Effective resource allocation is fundamental to sustaining a high-performing healthcare system (Asamani et al., 2021).

Resource Allocation Efficiency is a critical dimension of operational efficiency, defined as the optimal deployment of all available resources—human, capital, and material—to maximize service output while preventing waste (Farzianpour et al., 2016, p. 43). This directly influences a hospital's capacity to deliver high-quality patient care effectively and economically (Asamani et al., 2021). The judicious distribution of these vital inputs is crucial for preventing the pitfalls of underutilized assets or overburdened personnel, which can compromise care quality and financial sustainability (Nepomuceno et al., 2022). Therefore, optimizing resource allocation through strategic planning is essential for improving overall hospital performance and patient outcomes (Bravo et al., 2021, p. 640). Hospitals are under constant scrutiny to manage services with limited resources and tighter budgets, making efficient resource allocation paramount (Ordu et al., 2021).

Meanwhile, Service Process Optimization, ranked third (last rank) with a mean score of 3.10 and verbal interpretation of "Agree." This implies that while employees agree that service processes are being optimized, this aspect is perceived as slightly less robust or consistently effective compared to cost control and resource allocation efforts. The lower ranking suggests that there might be opportunities for further enhancing streamlining efforts, reducing wait times, or improving the consistency of standard operating procedures. Despite the "Agree" interpretation, there is potential for further refinement to maximize patient satisfaction and operational flow. A more consistent application of optimal procedures could significantly elevate overall service quality (Allabbas et al., 2024).

Service Process Optimization, as a core dimension, centers on meticulously examining and refining the series of activities involved in delivering healthcare services, crucial for eliminating redundant steps and reducing waste (Allabbas et al., 2024). While systematic streamlining of workflows leads to improved patient satisfaction, primarily through reduced waiting times and better communication (Mast et al., 2011, p. 1097), its impact can be hindered if processes are not consistently optimized. Such optimization is vital for enhancing the overall value

provided to patients and creating a healthcare environment where resources are utilized judiciously (Amati et al., 2022). The application of Lean Six Sigma tools, such as the DMAIC framework, has proven effective in enhancing patient flow and refining operational processes within tertiary care settings (Afriana et al., 2023).

Table 4
Relationship Between Technological Innovation and Operational Efficiency

Variables	rho	p-value	Interpretation
Big Data Technology			
Service Process Optimization	.874**	<.001	Highly Significant
Resource Allocation	.861**	<.001	Highly Significant
Cost Control	.834**	<.001	Highly Significant
Artificial Intelligence			
Service Process Optimization	.883**	<.001	Highly Significant
Resource Allocation	.885**	<.001	Highly Significant
Cost Control	.839**	<.001	Highly Significant
Blockchain Technology			
Service Process Optimization	.871**	<.001	Highly Significant
Resource Allocation	.873**	<.001	Highly Significant
Cost Control	.818**	<.001	Highly Significant

Legend: Significant at p-value<0.01

Table 4 presents the relationship between technological innovation and operational efficiency. The findings demonstrate a strong and highly significant relationship between technological innovation and operational efficiency across all variables examined. For Big Data Technology, the results show very strong positive correlations with service process optimization ($\rho = .874$, $p < .001$), resource allocation ($\rho = .861$, $p < .001$), and cost control ($\rho = .834$, $p < .001$). These values suggest that the integration of big data analytics substantially enhances the institution's ability to streamline processes, allocate resources more strategically, and manage operational costs effectively.

Similarly, Artificial Intelligence (AI) exhibits the strongest correlations among the three technologies, with coefficients ranging from .839 to .885 (all $p < .001$). This indicates that AI-driven tools and systems have a pervasive impact on operational efficiency, particularly in service process optimization ($\rho = .883$) and resource allocation ($\rho = .885$), pointing to AI's capacity to automate tasks, improve decision-making accuracy, and optimize real-time operations. Blockchain Technology also shows strong linkages to operational efficiency outcomes, with correlations of .871, .873, and .818 (all $p < .001$) across the same efficiency indicators. These results underscore blockchain's role in improving process transparency, enhancing resource traceability, and promoting cost-efficient workflows, particularly in functions requiring security and transactional integrity.

Table 4 illustrates the profound relationship between technological innovation and operational efficiency, revealing strong and highly significant positive correlations across all variables. Specifically, Big Data Technology demonstrates robust connections with service process optimization (.874), resource allocation (.861), and cost control (.834). These empirical findings align closely with existing literature. Mazumder underscores how predictive analytics, a core application of Big Data, is crucial for optimizing staffing and managing inventory, directly translating into operational efficiencies and significant cost reductions for healthcare facilities (Mazumder, 2024, p. 2). Akindote et al. further confirm that Big Data analytics optimizes administrative processes and resource allocation within healthcare organizations, leading to tangible cost savings and improved overall productivity (Akindote et al., 2023, p. 1295).

Similarly, Artificial Intelligence exhibits even stronger correlations, particularly with service process optimization (.883) and resource allocation (.885), and a strong link to cost control (.839). Suryawanshi et al. affirm that AI technologies streamline workflows, optimize resource allocation through predictive analytics, and automate scheduling to minimize patient wait times, reflecting the high impact observed on service process

optimization and resource allocation (Suryawanshi et al., 2024).

Blockchain Technology also presents strong correlations with service process optimization (.871), resource allocation (.873), and cost control (.818), emphasizing its role in enhancing transparency, traceability, and cost-efficient workflows. These results resonate with findings from other studies. Atadoga et al. highlight that Blockchain's ability to automate administrative and operational tasks through smart contracts minimizes manual errors and overhead, thereby increasing efficiency and reducing costs within healthcare (Atadoga et al., 2024, p. 1609). Alzahrani further notes that Blockchain technology aids in saving resources by eliminating duplicate tests and controlling medication waste through comprehensive patient records, directly impacting resource allocation and cost control (Alzahrani, 2021, p. 72).

Table 5

Proposed Action Plan to improve Technology Innovation

Key Result Area	Strategies	Person/s Responsible	Success Indicator
Improved Operational Decision Support through Big Data Analytics	Conduct workshops and training sessions focused on practical application and interpretation of big data insights for operational staff and decision-makers. Develop clear, use-case specific dashboards and reports that translate complex big data into actionable operational recommendations. Establish a cross-departmental data governance committee to define data-driven decision-making protocols and responsibilities.	IT Department, Data Analytics Team, Department Heads, Hospital Management	Increase in the percentage of operational decisions informed by big data analytics by 15% within 12 months. 20% improvement in key performance indicators (e.g., patient flow efficiency, resource utilization) directly influenced by data-driven decisions. Quarterly feedback surveys show a 10% increase in staff confidence regarding big data's utility in decision-making.
Enhanced Integration of Big Data Tools in Daily Healthcare Operations	Implement user-friendly interfaces and platforms that seamlessly embed big data tools into existing clinical and administrative workflows. Identify and pilot specific operational areas (e.g., patient scheduling, inventory management) for deeper integration of big data tools to demonstrate tangible benefits. Provide ongoing technical support and mentorship to staff to overcome integration challenges and encourage consistent usage.	IT Department, Clinical Informatics, Department Supervisors, End-Users	25% increase in the daily active users of integrated big data tools across relevant departments within 9 months. Reduction in manual data entry and processing time by 15% in pilot areas. User satisfaction scores related to big data tool integration increase by 10% in annual IT evaluations.

Table 5 outlines a comprehensive strategy to integrate advanced technologies within tertiary hospitals in the Hebei Region, China, focusing on leveraging Big Data to elevate operational efficiency and patient care. Below is the proposed action plan focusing on improving Big Data Technology.

4. Conclusion

- The employees generally agreed that technological innovation particularly in Big Data, Artificial Intelligence, and Blockchain Technology, was moderately applied.
- The employees generally agreed on a moderate level of operational efficiency across Cost Control, Resource Allocation, and Service Process Optimization.
- There was a highly significant relationship between technological innovation and operational efficiency.
- A proposed plan of action was developed to improve the technological innovation in healthcare services.

Recommendation

- The IT Department of the Hebei Region Healthcare Services may strategically prioritize the enhancement of Big Data technology integration, particularly focusing on improving the utilization of big data analytics for operational decision-making and its seamless incorporation into daily healthcare operations.
- The Operations Department of Healthcare Services may place a heightened emphasis on refining Service Process Optimization, specifically by reinforcing the consistent adherence to standard operating procedures.
- The Healthcare Services may review and utilized the outlined action plan provided in the study for improving the Technological Innovation.
- Future researchers may extend this study by conducting longitudinal analyses to evaluate the long-term impacts and sustainability of implemented technological innovations and operational efficiency strategies within healthcare services.

5. References

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