Artificial Intelligence in Innovation and Investment Strategies for the Development of Smart Surgical Services

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Abstract:

Background and Objective: This study aims to investigate the role of artificial intelligence in driving innovation and shaping investment strategies for the development of smart surgical services within Iran's healthcare system. It focuses on identifying the barriers, opportunities, and strategies to advance this technology in the Iranian healthcare context.

Materials & Methods: This study employed a mixed-methods approach, combining qualitative and quantitative techniques. In the qualitative phase, data were collected through semi-structured interviews with 15 key stakeholders, including surgeons, hospital managers, technology developers, investors, and health policymakers. The data were analyzed using thematic analysis with the assistance of NVivo software. In the quantitative phase, data from 30 hospitals equipped with smart surgical technologies, primarily located in major cities across Iran, were collected and analyzed using linear regression and economic modeling.

Results: In the qualitative analysis, three main categories were identified: barriers to investment (including financial and infrastructural constraints), opportunities for innovation (such as increased surgical precision and reduced operation time), and inter-organizational collaboration (partnerships with technology companies and support from policymakers). The findings demonstrated that artificial intelligence has a significant impact on the efficiency of surgical services ($\beta = 0.750$, $p = 0.007$) and return on investment (ROI) ($\beta = 0.680$, $p = 0.009$). However, currency limitations reduce the ROI from 15.3% under optimal conditions to 8.0% in practice.

Conclusion: The research findings indicate that fully realizing the potential of artificial intelligence in smart surgery requires strategic investment, supportive policies, and the development of technological infrastructure. An operational framework based on open innovation theories and dynamic capabilities can assist decision-makers chart a sustainable path for the advancement of smart technologies within Iran's healthcare system.

Keywords: Artificial intelligence, investments, Culturally Appropriate Technology, Delivery of Health Care

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Received: 22/04/2025

Accepted: 27/09/2025

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Background and Objective

Recent advancements in artificial intelligence (AI) have been recognized as some of the most significant transformative factors across various industries, particularly in the healthcare sector. This technology, with its ability to rapidly and accurately process complex data, enables the development of innovative solutions in medical fields. Smart surgery, one of the most advanced applications of AI, employs tools such as machine learning algorithms and medical data analysis to enhance the precision, safety, and efficiency of surgical procedures.[1] However, the development of these technologies requires substantial investments and strategic planning, which depend not only on technical advancements but also on a deep understanding of clinical and economic needs.[2] One of the main challenges is how to direct investments toward the scalability of smart surgical services, a topic that has not yet been thoroughly examined.[3] This problem statement seeks to investigate the role of AI in innovation and the formulation of investment strategies for the development of smart surgical services. The aim is to provide a comprehensive framework that aligns technology, innovation, and investment to ensure that these services are sustainably and effectively expanded on a global scale.

This research focuses on leveraging AI to guide investment strategies in the development of smart surgical services, ensuring that technological innovations align with clinical needs and economic objectives. With capabilities such as analyzing imaging data, predicting surgical outcomes, and optimizing clinical processes, AI can serve as a lever to attract investments in this field.[4] This technology not only has the potential to improve the accuracy and efficiency of surgeries but also creates significant economic value by reducing operational costs and increasing success rates.[2] This study examines how the potential of AI can be harnessed to develop investment models that both accelerate innovation and ensure financial sustainability.[5] In this context, it is essential to consider the needs of various stakeholders, including surgeons, hospitals, and investors, to provide a coherent framework for the development of these services.[6]

Over the past three years, extensive research has explored the application of AI in smart surgery, integrating it with key theories in technology innovation and strategic management. According to open innovation theory, which emphasizes the importance of collaboration between organizations in developing new technologies, studies from 2023 have demonstrated that deep learning algorithms in robotic surgeries have increased diagnostic accuracy by up to 25% and reduced surgical time by up to 20%.[6] These findings align with dynamic capabilities theory, which highlights organizations' ability to reconfigure resources in response to environmental changes.[7] Additionally, research from 2024, referencing resource-based strategic management theory, has demonstrated that AI can reduce logistical costs by up to 35% by optimizing the supply chain for surgical equipment.[2]

While these studies emphasize the potential of AI to enhance operational efficiency, they have paid less attention to strategies for attracting investments to scale these technologies. Strategic investment theory, which focuses on resource allocation to create sustainable competitive advantages, has also gained attention in recent research. For instance, a study in 2025 showed that data mining-based intelligent systems could optimize financial resource allocation by predicting the demand for surgical equipment.[1] However, this research has primarily focused on technical aspects and has paid less attention to developing investment frameworks for commercializing and expanding smart surgical services. The integration of these findings suggests that AI can serve as a catalyst for innovation and investment attraction; however, the lack of integrated models to guide the allocation of financial resources and prioritize innovations remains a significant challenge.[8]

Despite remarkable advancements in the application of AI in smart surgery, significant research gaps continue to impede the full exploitation of this technology. Recent studies have primarily focused on improving AI algorithms, enhancing the accuracy of surgical tools, and reducing clinical errors;[9] however, insufficient attention has been given to developing investment strategies for the commercialization and expansion of these technologies.[5] This gap is particularly evident in the allocation of financial resources for the development of smart surgical infrastructure on a global scale. Furthermore, the lack of comprehensive frameworks for assessing the financial and clinical risks associated with investing in these technologies has diminished investor confidence.[6] Additionally, the absence of integrated models for collaboration among various stakeholders, including hospitals, technology companies, and investors, has hindered the creation of sustainable ecosystems for the development of smart surgical services.[1] These issues underscore the necessity for research that integrates innovation theories and strategic management to provide a comprehensive framework for guiding investments. Such a framework should address not only technical aspects but also economic and clinical considerations to accelerate the development of smart surgical services.[8]

The aim of this research is to explore how AI can be utilized to formulate optimal investment strategies for the development and scalability of smart surgical services in a way that aligns technological innovations and clinical as well as economic needs.

Technological advancements in recent decades, particularly in AI, have redefined traditional processes in the healthcare sector. One area significantly impacted by this technology is medical surgery, which has undergone fundamental transformations through the integration of AI algorithms in decision-making, training, execution, and outcome analysis. Smart surgery, an emerging subset of digital medicine, not only enhances clinical outcomes but also creates opportunities for targeted healthcare investments by leveraging data-driven approaches and predictive analytics.[10]

Materials and Methods

AI in surgery encompasses a range of advanced technologies, including machine learning, deep neural networks, computer vision, and natural language processing. These technologies are used to analyze clinical data, predict risks, optimize decisions, and control surgical instruments. They have the capability to process vast amounts of complex medical data in real time, facilitating faster and more accurate decision-making. Applications of AI are expanding across preoperative planning, intraoperative monitoring, and postoperative care.[8]

From a managerial perspective, the development of AI-based surgical procedures requires a strategic approach to resource management, infrastructure, and economic models. In this context, the role of technological investments and resource allocation strategies becomes particularly significant. One of the primary challenges in advancing these technologies is developing financial models that align with clinical needs and health system priorities. The use of AI in this process can serve as a valuable tool for economic analysis and investment risk assessment.[5]

Smart surgery, as a platform for innovation, necessitates the development of a technology-driven ecosystem that fosters constructive interactions among universities, hospitals, technology companies, and investors. Concepts such as open innovation, dynamic capabilities, and resource-based investment models provide a solid theoretical framework for analyzing these collaborations. Within this framework, AI is regarded not only as a technical tool but also as a driving force for creating competitive advantages and enhancing investment productivity.[11]

On the other hand, the scalability of smart surgical technologies depends on various factors, including standardization, data security, clinical acceptance, and economic return on investment. Investment strategies must be designed with these components in mind to ensure financial sustainability while allowing for gradual expansion in alignment with national health policies. Furthermore, the role of policymakers and health regulators in facilitating this process is undeniable.[8]

Ultimately, existing literature indicates that success in developing smart surgery depends on a balanced combination of technological expertise, managerial insight, and supportive investment mechanisms. This integrated approach can lead to the creation of an innovative and sustainable ecosystem in the field of medical surgery—an ecosystem where AI technologies play a significant role not only at the tool level but also in development and investment strategies.[5]

Numerous recent studies have examined the applications of AI in surgery, highlighting the rapid growth of this technology in modern medicine. Chen and colleagues conducted a systematic review exploring the evolution and applications of AI across various stages of surgery, including preoperative planning, intraoperative navigation, and postoperative follow-up. They demonstrated that AI can enhance the accuracy, safety, and outcomes of surgical procedures; however, challenges such as cost, data security, and the need for specialized training still remain.

In efforts to improve surgical performance from a skills perspective, Yangi and colleagues demonstrated that, since 2018, AI has increasingly contributed to surgical training and the enhancement of surgical quality by tracking hand and surgical tool movements using deep learning algorithms.

Alasiri and Alasmari, focusing on AI-powered surgical robots, highlighted advantages such as improved treatment accuracy, reduced invasiveness, and lower healthcare costs. These findings align with the studies of Mohammadi and Hariri, who applied AI to the design and optimization of surgical robots and emphasized its role in enhancing operational safety.

In the field of orthopedics, Shaddel and colleagues demonstrated that machine learning algorithms and artificial neural networks can help reduce human error, enable precise analysis of surgical images, and support faster decision-making.

On a more specialized level, Sheikhifard investigated the clinical applications of AI in detecting fractures and tumors, as well as in predicting outcomes of orthopedic surgeries, demonstrating that machine learning algorithms improve diagnostic accuracy and lead to more effective treatments. In neurosurgery, Sadeghi Garmaroudi and Rafiei Rad pointed to advances in integrating AI with augmented and virtual reality to minimize complications and enhance surgical precision.

Monafi Nasser and colleagues introduced AI-based biomechanical modeling as a method to enhance the accuracy of medical equipment design.

From a social and human perspective, Khalvati and Karimi examined patients' trust in AI in cardiac surgery, highlighting challenges such as ethical concerns, data security, and transparency in decision-making. Similarly, Kazemi Sahlavani, Ghasemi, and Kiani broadly discussed the role of AI in improving the quality of healthcare services and reducing costs.

The theoretical framework of this study is based on the integration of open innovation theory, dynamic capabilities, resource-based strategic management, and strategic investment. This framework suggests that AI can serve as a key resource for creating a competitive advantage in smart surgical services, provided it is supported by targeted investment strategies and inter-organizational collaboration. According to this framework, the independent variables (AI applications and technological innovation) influence the dependent variables (surgical service efficiency, return on investment, and financial sustainability) through mediating variables (stakeholder collaboration and technological infrastructure). The framework has been designed based on empirical findings from the past three years—including studies conducted between 2023 and 2025—

that confirm both clinical and economic improvements driven by AI.

Findings

This study employed a mixed-methods research design, incorporating both qualitative and quantitative approaches. In the qualitative phase, a phenomenological approach was used to conduct semi-structured interviews with 15 key stakeholders, including surgeons (8), hospital managers (5), and technology developers and investors (2). Purposeful sampling emphasized professional and geographical diversity. Data were analyzed using thematic analysis with NVivo software to identify themes such as investment barriers and innovation opportunities. To ensure validity, data triangulation was performed using relevant documents. In the quantitative phase, hospitals equipped with smart surgical technologies across the country were identified and classified into homogeneous groups based on criteria such as geographic location (province or city) and service level. From each group—particularly major cities such as Tehran, Mashhad, Isfahan, Shiraz, and Tabriz—a number of hospitals were randomly selected to ensure geographical and structural diversity within the study population. The sample size from each stratum was determined proportionally or minimally, resulting in a final sample of 30 hospitals. Data were collected through structured questionnaires and health databases. Statistical analyses were conducted using multivariate regression and economic modeling in R software. Integration of qualitative and quantitative data was achieved through a convergent approach, combining qualitative insights (e.g., collaboration barriers) with quantitative outcomes (e.g., cost reduction), leading to the development of actionable strategies. Ethical considerations included obtaining informed consent, ensuring confidentiality, and adhering to data protection protocols. Grounded in the theories of open innovation and strategic investment, this methodology provides a framework to guide investments and accelerate the sustainable development of smart surgical services.

1- Qualitative Section: Data Analysis and Findings

In this study, the validity and reliability of both the qualitative and quantitative components were systematically evaluated using standard methods. In the qualitative section, content validity was confirmed through expert review of the questionnaire by specialists in medical AI and digital health investment. Construct validity was assessed by matching 85% of the codes extracted from interviews with the theoretical frameworks of technological innovation and strategic investment. Reliability was confirmed through inter-coder agreement (0.89) and test–retest stability (0.86). Additionally, all processes were transparently documented (auditability) and appended to the report. In the quantitative section, content validity was supported by a Content Validity Ratio (CVR) of 0.91. Construct validity was confirmed through Confirmatory Factor Analysis (CFA) with a Kaiser-Meyer-Olkin (KMO) measure of 0.84 and factor loadings greater than 0.7. Convergent validity was established with a correlation coefficient of 0.76. Reliability was robustly confirmed with an average Cronbach’s alpha of 0.86, test–retest reliability of 0.89, and inter-rater agreement of 0.92 (Tables 1 and 2).

In this qualitative study, key statements (or main meaning units) were extracted through in-depth, semi-structured interviews with 15 key stakeholders—including surgeons, hospital managers, AI technology developers, investors, and policymakers. Each interview lasted between 40 and 50 minutes, was fully recorded, and then meticulously transcribed to ensure that all details of the discourse were preserved.

Table 1- Validity and Reliability of the Qualitative Section

Component	Indicators	Research-Related Details	Value/Results
Validity	Content Validity	- Initial review of the semi-structured questionnaire by three experts in medical AI and two managers specializing in digital health investment. - Question refinement: Adjusted based on feedback until theoretical saturation was achieved.	Final approval by experts
	Construct Validity	- Alignment of codes: Extracted interview codes were aligned with theoretical concepts from models of strategic investment and technological innovation. - Preliminary code validation: Confirmed by seven interview participants.	85% alignment with theoretical foundations
	Face Validity	- Interview form redesign: Conducted following a pre-test with three experts in smart surgery and therapeutic AI.	Final version of the interview form
Reliability	Internal Consistency	- Independent coding: Two coders independently analyzed the interview content. - Inter-coder agreement: Calculated using the Holsti formula.	0.89
	Adaptability	- Re-coding: Conducted four weeks later by the second coder. - Interview recording and archiving: Performed with the participants' informed consent.	0.86
	Descriptiveness	- Comprehensive documentation provided: Includes full interview transcripts, methods for concept extraction, code categorization, and records of research team decision-making sessions.	Complete documentation attached

Table 2- Validity and Reliability of the Quantitative Section

Component	Indicators	Research-Related Details	Value/Results
Validity	Content Validity	- Questionnaire content review: Conducted by five experts in healthcare technology management and AI-based investment, including the calculation of the Content Validity Ratio (CVR).	0.91
	Construct Validity	- Confirmatory factor analysis (CFA): Used to validate the conceptual structure of the questionnaire. Sampling adequacy was assessed using the Kaiser-Meyer-Olkin (KMO) measure and Bartlett's test.	Factor loadings > 0.7, KMO = 0.84
	Convergent Validity	- Correlation analysis: Examined the relationships among extracted dimensions (e.g., technological investment, clinical infrastructure, return on investment, scalability) and the overall performance of smart surgery projects.	0.76
Reliability	Internal Consistency	- Reliability assessment: Cronbach's alpha was calculated for the questionnaire dimensions. For the technology infrastructure dimension, the value was 0.86. Return on Investment: 0.84; Clinical Adaptability: 0.87.	Average Cronbach's alpha: 0.86
	Temporal Stability	- Test-retest reliability: The questionnaire was re-administered to a pilot sample (n = 30) after a three-week interval to assess its stability over time.	0.89
	Inter-Rater Reliability	- Inter-rater agreement: Assessed between two independent statistical analysts who interpreted the initial CFA results and questionnaire scores.	0.92

Table 3- Main and Subcategories, Sample Codes, and Frequency of Mentions

Main Categories	Subcategories	Sample Codes	Frequency (Number of Mentions)	Percentage of Interviewees
Investment Barriers	Financial constraints	Hospital budget shortages	13	87%
	Lack of technological infrastructure	Lack of advanced robotic equipment	12	80%
Innovation Opportunities	Improved diagnostic accuracy	Increased precision with AI	10	67%
	Reduced surgical time	Reduced duration of complex surgeries	9	60%
Inter-organizational Collaboration	Hospital–company partnerships	Need for collaboration with foreign companies	11	73%
	Support from policymakers	Necessity of incentive policies	8	53%

The final structures, representing the main themes of the study, were developed through thematic analysis. This process was conducted in three stages:

1- Open coding: identifying initial concepts and labeling interview transcripts line by line;
2- Axial coding: grouping similar codes and identifying relationships among them to form categories and sub-themes;
3- Selective coding: identifying overarching core themes that provide an integrated explanation of the entire dataset.

This process was facilitated using NVivo software (version 12 or higher) to enhance the accuracy of data organization, coding, retrieval, and analysis of conceptual relationships. The emergence of the final structures was ensured through an iterative cycle of review, constant comparison of data with codes, team discussions, and achieving theoretical saturation (i.e., halting data collection once no new themes emerged). For example, one surgeon referred to the technical advantages of AI in improving the precision of robotic surgeries but identified infrastructural limitations and high initial costs as major barriers. These statements were coded under “technical advantages of AI” and “infrastructural limitations,” which, during axial coding, were linked to subcategories such as “improved diagnostic accuracy” and “lack of advanced equipment.”

Ultimately, three core categories were identified.

· Investment Barriers: Financial and infrastructural constraints were cited by 87% of interviewees, reflecting the conditions of public hospitals and budget shortages.

· Innovation Opportunities: These include improved diagnostic accuracy (67%) and reduced surgery time (60%), highlighting the potential of AI technology in enhancing surgical services.

· Inter-organizational Collaboration: The need for partnerships between hospitals and technology companies, as well as support from policymakers, was emphasized by 73% of interviewees.

Table 3 presents the main and subcategories, sample codes, and the frequency of references for each, demonstrating that the qualitative findings align with the theory of open innovation and reports from Iran’s Ministry of Health.

Table 4 summarizes the results of the multivariate linear regression analysis.

Table 4- Results of the Regression Analysis

Independent Variables	Dependent Variables	Regression Coefficient	p-value	Impact on ROI (%)
AI Applications	Surgical Service Efficiency	0.75	0.007	8
Level of Technological Innovation	Surgical Success Rates	0.62	0.015	6

1. Quantitative Section: Statistical analysis and economic modeling

The quantitative section of this research was conducted systematically through several stages.

First, data were collected from 30 hospitals in Iran equipped with smart surgical technologies, primarily located in Tehran and other major cities such as Mashhad, Isfahan, Shiraz, and Tabriz. These centers were selected based on their access to the required infrastructure and geographical diversity.

Second, the data were drawn from two primary sources:

- Structured questionnaires completed by hospital managers or technology unit staff;
- Internal financial and operational reports of hospitals, including indicators such as return on investment (ROI), operating costs, average surgery duration, and clinical success rates.

Third, data were analyzed using R software. Statistical assumptions, including normality and multicollinearity, were first tested. Subsequently, multivariate linear regression was applied to assess the impact of the independent variable (AI applications) on the dependent variables (surgical service efficiency and ROI). The results indicated that AI had a positive and significant effect (**β** = 0.75, p < 0.01) (Table 4).

Fourth, a cost–benefit economic model was developed, showing that investment in these technologies could reduce logistical expenses, such as preparation time, team coordination, and resource management, by up to 28%. However, financial analyses revealed that currency restrictions and exchange rate fluctuations in Iran limited the actual annual ROI to approximately 8%, which is lower than international benchmarks, typically ranging from 15% to 20%.

Table 5 shows the results of the economic modeling:

Table 5- Results of the Economic Modeling

Scenario	Benefit-to-Cost Ratio	Reduction in Logistical Costs (%)	Annual ROI(%)
Optimal (without currency restrictions)	2.2	28	8
Constrained (with currency shortage	1.8	20	5

Table 6 shows the distribution of costs and benefits.

Table 6- Distribution of Costs and Benefits

Indicators	Amount (million IRR)	Percentage Change with AI
Logistical costs	500	-28%
Equipment costs	1200	-15%
Clinical benefits (success rate)	-	+12%

By combining precise quantitative evidence with context-specific economic analysis, these findings provide a realistic assessment of the opportunities and challenges associated with investing in smart surgery in Iran.

The integration of qualitative and quantitative findings indicates that, although financial and infrastructural barriers present significant challenges in Iran, enhancing inter-organizational collaboration and attracting foreign investment can help alleviate these issues.

Table 7- Comparison of the Present Study's Findings with Previous Studies

Research Aspects	*Findings of the Present Study*	*Previous Studies*	*Alignment Status*	*Comparative Analysis*
Impact of AI on surgical efficiency	*Increased surgical precision, reduced operation time, and improved ROI (return on investment)*	*Lee & Choi (2023): Increased diagnostic accuracy and reduced surgery time using deep learning*	Alignment	*The findings reflect a global trend that can also be implemented in Iran, considering the country's specific infrastructural conditions.*
Infrastructural and financial barriers	*Budget shortages, lack of advanced equipment, and currency limitations*	*Bahrami & Ahmadi (2022): Lack of adequate funding in public hospitals for modern technologies*	Alignment	*Iran's structural barriers are similar to those described in domestic studies, highlighting the need for supportive policymaking.*
Inter-organizational collaboration	*Necessity of partnerships between hospitals and technology companies for knowledge transfer*	*Chesbrough (2003): The necessity of open innovation through technological collaboration*	Alignment	*The theory of open innovation is applicable in Iran, provided it is localized within policy frameworks.*
Role of investment strategy	*Need to develop an investment model to ensure financial sustainability and attract foreign investment*	*Teece (1997): Utilizing dynamic capabilities for optimal resource allocation and market responsiveness*	Partial alignment	*Teece's dynamic capabilities theory is adaptable, though implementation and managerial challenges are more pronounced in Iran.*
Optimization of the surgical supply chain	*Reduction of logistical costs by up to 28%*	*Chen (2024): The role of AI in demand forecasting and optimization of the surgical equipment supply chain*	Alignment	*The alignment of results indicates that data-driven algorithms can also be effective in Iran, given the appropriate conditions.*

For example, qualitative findings regarding inter-organizational collaboration align with quantitative data on reduced logistical costs, suggesting that partnerships with foreign companies could decrease currency dependency and thereby accelerate the return on investment. The results provide an operational framework that aligns AI investment with the needs of Iran's healthcare system and accelerates the development of smart surgical services. Moreover, the findings demonstrate that AI significantly improves surgical efficiency and success rates; however, financial and infrastructural constraints must be addressed through targeted policymaking and international collaboration. Additionally, comparing these results with previous studies highlights areas of consistency and divergence, thereby strengthening both the validity and originality of the research. For this purpose, the comparative findings are presented in Table 7.

Discussion and Conclusion

a) Discussion

The findings of this mixed-methods study provide a comprehensive and coherent overview of investment in smart surgical technologies in Iran. Qualitative data reveal that key stakeholders—from surgeons to policymakers—widely recognize the transformative potential of AI in surgery, particularly in enhancing precision, reducing operation time, and improving clinical outcomes. However, they also identify structural barriers as the most significant challenges, including budget shortages, inadequate technological infrastructure, and currency-related constraints, which are especially influential in public hospitals. These findings align with both domestic studies (e.g., Bahrami & Ahmadi, 2022) and international research (e.g., Lee & Choi, 2023), indicating that while Iran follows the global trajectory of medical innovation, its operational environment remains underdeveloped.

In the quantitative section, statistical evidence supports and quantifies these perspectives: the significant impact of AI on surgical efficiency ($\boldsymbol{\beta} = 0.75$, $p < 0.01$) and a

28% reduction in logistical costs demonstrate the effectiveness of the technology. However, the actual ROI (8%)—limited by currency fluctuations and dependence on imported equipment—remains well below international benchmarks. This gap between technological potential and economic reality constitutes the core policy challenge in this domain. Notably, inter-organizational collaboration—emphasized by 73% of stakeholders—has the dual capacity to reduce costs (as reflected in the quantitative findings) and to mitigate currency dependency through domestic production or technology transfer. This alignment between qualitative and quantitative evidence strengthens the study's internal validity and provides an actionable framework for policymaking.

b) Conclusion

This study aimed to examine the barriers and opportunities for investing in AI technologies for smart surgeries within Iran's healthcare system. The research employed a mixed-methods design. In the qualitative phase, perspectives of 15 key stakeholders—including surgeons, hospital managers, technology developers, investors, and healthcare policymakers—were explored through semi-structured interviews and analyzed using thematic analysis with NVivo software. In the quantitative phase, data from 30 hospitals equipped with smart surgical technologies in Iran were collected and analyzed using multivariate regression and economic modeling.

The results indicate that AI holds substantial potential to enhance the efficiency, precision, and quality of surgical services in the country. However, realizing this potential depends on addressing significant challenges, including financial, infrastructural, and currency-related constraints. The alignment of qualitative and quantitative findings emphasizes that leveraging innovation opportunities and strengthening inter-organizational collaboration—especially among hospitals, technology companies, and policy institutions—can help overcome these barriers.

Quantitative results further demonstrate that the application of AI has a positive and significant impact on increasing surgical success rates, reducing logistical costs, and improving return on investment. Nonetheless, prevailing economic and currency limitations may slow the pace of these returns. Overall, these findings highlight the necessity of supportive policies, strategic planning, and intelligent investment to promote the sustainable development of smart surgical technologies within Iran's healthcare system. Effective resource management and strengthened infrastructure can accelerate the advancement of the national healthcare system in the digital era.

Recommendations

Based on the analyses conducted in this study, the following evidence-based, step-by-step operational recommendations are proposed:

1. Strengthen inter-organizational collaboration: Hospitals, along with domestic and international technology companies, are encouraged to establish closer partnerships to accelerate knowledge and technology transfer and to reduce infrastructural barriers.
2. Support from policymakers: It is essential to develop financial and insurance incentive policies to facilitate investment in AI technologies, particularly within public healthcare centers.
3. Targeted investment in infrastructure: Budget allocations should prioritize upgrading advanced equipment and technological infrastructure, especially in hospitals located in non-central regions.
4. Managing currency limitations: In collaboration with financial institutions and policymakers, strategies should be developed to mitigate the impact of currency restrictions on equipment costs and return on investment.
5. Develop training and awareness: It is recommended to implement specialized training programs for surgeons and hospital managers to enhance acceptance and promote the effective use of modern AI technologies.

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