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

Feiz D. MD[1], Rastgar A. A. MD[1], Basirat A.[2*]

Abstract:

<u>Background and Objective:</u> The primary aim of this research is to examine the role of artificial intelligence in innovation and investment strategy for the development of smart surgical services within Iran's healthcare system. The study focuses on identifying the barriers, opportunities, and strategies for advancing this technology in the Iranian healthcare environment.

<u>Materials & Methods:</u> This study was conducted using a mixed-methods approach (qualitative-quantitative). In the qualitative section, 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 and NVivo software. In the quantitative section, data from 30 hospitals equipped with smart surgical technologies, primarily located in major cities of Iran, were gathered and analyzed using linear regression and economic modeling.

<u>Results:</u> In the qualitative section, three main categories were identified: barriers to investment (such as financial and infrastructural constraints), opportunities for innovation (increased surgical precision and reduced operation time), and inter-organizational collaboration (partnerships with technology companies and support from policymakers). The results showed that artificial intelligence has a significant impact on the efficiency of surgical services ($\beta = 0.750$, $p = 0.007$) and the 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 reality.

<u>Conclusion:</u> The results of the research indicate that realizing the full potential of artificial intelligence in smart surgery requires strategic investment, policy support, and the development of technological infrastructure. An operational framework based on open innovation theories and dynamic capabilities can assist decision-makers in charting a path for the sustainable development of smart technologies within Iran's healthcare system.

***Keywords:* Artificial intelligence, smart surgery, investment, technology innovation, Iran's healthcare system**

[1]Professor, Department of Business Administration Faculty of Economics, Management, and Administrative Sciences, University of Semnan, Semnan, Iran

[2*]PhD Student in Business Administration, Marketing Concentration Faculty of Economics, Management, and Administrative Sciences, University of Semnan, Semnan, Iran

Received: 22/04/2025

Accepted: 27/09/2025

Corresponding Author: Atena Basirat

Tel: 09127742261

E-mail: atenabasirat@semnan.ac.ir

Background and Objective

Recent advancements in artificial intelligence have been recognized as one 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 provision of innovative solutions in medical fields. Smart surgery, as one of the most advanced applications of artificial intelligence, utilizes 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 that 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 for the scalability of smart surgical services, which has not yet been thoroughly examined.[3] This problem statement seeks to investigate the role of artificial intelligence 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.

The focus of this research is on how to utilize artificial intelligence 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, artificial intelligence 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 artificial intelligence 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]

In the past three years, extensive research has been conducted on the application of artificial intelligence in smart surgery, linking it with key theories in technology innovation and strategic management. According to the open innovation theory, which emphasizes the importance of collaboration between organizations for the development of new technologies, studies from 2023 have shown 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 focuses on organizations' ability to reconfigure resources in response to environmental changes.[7] Additionally, research from 2024, referencing resource-based strategic management theory, has demonstrated that artificial intelligence can reduce logistical costs by up to 35% by optimizing the supply chain for surgical equipment.[2]

While these studies emphasize the potential of artificial intelligence in improving operational efficiency, they have paid less attention to how to attract investments for scaling these technologies. Strategic investment theory, which focuses on resource allocation for creating 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 concentrated 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 artificial intelligence can act as a catalyst for

innovation and investment attraction; however, the lack of integrated models for guiding financial resources and prioritizing innovations remains a significant challenge.[8]

Despite remarkable advancements in the application of artificial intelligence in smart surgery, there are still considerable research gaps that hinder the full exploitation of this technology. Most recent studies have focused on improving artificial intelligence 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 how financial resources are allocated 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 can integrate 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 needs to accelerate the development of smart surgical services.[8]

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

Technological advancements in recent decades, particularly in the field of artificial intelligence, have redefined traditional processes in the healthcare sector. One area significantly impacted by this technology is medical surgery, which has undergone fundamental transformations with the introduction of AI algorithms into decision-making, training, execution, and outcome analysis. Smart surgery, as an emerging subset of digital medicine, not only contributes to improved clinical outcomes but also creates opportunities for targeted investments in healthcare by relying on data-driven approaches and predictability.[10]

Materials and Methods

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

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

Smart surgery, as a platform for innovation, necessitates the establishment of a technology-driven ecosystem where constructive interactions occur among universities, hospitals, tech 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 viewed not just 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 relies on a balanced combination of technological knowledge, 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 at the level of development and investment strategies.[5]

Numerous studies in recent years have examined the applications of artificial intelligence (AI) in surgery, reflecting the increasing growth of this technology in modern medicine. Chen and colleagues conducted a systematic review exploring the evolution and applications of AI at various stages of surgery, including pre-operative planning, intraoperative navigation, and postoperative follow-ups. They demonstrated that AI can improve the accuracy, safety, and outcomes of surgeries; however, challenges such as costs, data security, and the need for professional training still remain.

In line with improving surgical performance from a skills perspective, Yangi and colleagues, by focusing on tracking hand and surgical tool movements through deep learning algorithms, demonstrated that since 2018, artificial intelligence has increasingly contributed to surgical training and the enhancement of surgical quality.

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

In the field of orthopedics, Shaddel and colleagues showed 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 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 combining AI with augmented and virtual reality to minimize complications and enhance surgical precision.

Monafi Nasser and colleagues, in their study, introduced AI-based biomechanical modeling as an approach to improve the accuracy of medical equipment design.

From a social and human perspective, Khalvati and Karimi examined patients' trust in AI in cardiac surgery and raised challenges such as ethical concerns, data security, and decision-making transparency. 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 built upon the integration of open innovation theory, dynamic capabilities, resource-based strategic management, and strategic investment. This framework suggests that artificial intelligence can serve as a key resource for creating competitive advantage in smart surgical services, provided that 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 the 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 the clinical and economic improvements driven by artificial intelligence.

Findings

This study employed a mixed-methods research design (qualitative and quantitative). In the qualitative phase, using a phenomenological approach, semi-structured interviews were conducted with 15 key stakeholders, including surgeons (8), hospital managers (5), and technology developers and investors (2). Purposeful sampling was applied with an emphasis on professional and geographical diversity. Data were analyzed through thematic analysis using NVivo software to identify themes such as investment barriers and innovation opportunities. To ensure validity, data triangulation was performed with relevant documents. In the quantitative phase, hospitals equipped with smart surgical technologies across the country were first identified and classified into homogeneous groups based on criteria such as geographic location (province or city) and service level. From each group—particularly from 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 total of 30 hospitals in the final sample. Data were collected through structured questionnaires and health databases. Statistical analysis was carried out using multivariate regression and economic modeling in R software. Integration of qualitative and quantitative data was conducted 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. This methodology, grounded in the theories of open innovation and strategic investment, 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 parts were systematically evaluated using standard methods. In the qualitative section, content validity was confirmed through expert review of the questionnaire by specialists in medical artificial intelligence 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 verified through inter-coder agreement (0.89) and test–retest stability (0.86). In addition, all processes were documented transparently (auditability) and attached to the report. In the quantitative section, content validity was supported with a Content Validity Ratio (CVR) of 0.91. Construct validity was confirmed through Confirmatory Factor Analysis (CFA) (KMO = 0.84 and factor loadings > 0.7), and convergent validity was established with a correlation coefficient of 0.76. Reliability was strongly 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 carefully 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 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 strategic investment and technological innovation models.* *- Preliminary code validation: Confirmed by seven interview participants.*	*85% alignment with theoretical foundations*
	Face Validity	*- Interview form redesign: Conducted after 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 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; 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 assessed via the Kaiser-Meyer-Olkin (KMO) measure and Bartlett's test.*	*Factor loadings > 0.7, KMO = 0.84*
	Convergent Validity	*- Correlation analysis: Examined relationships among extracted dimensions (e.g., technological investment, clinical infrastructure, return on investment, scalability) and overall performance of smart surgery projects.*	*0.76*
Reliability	*Internal Consistency*	*- Reliability assessment: Cronbach's alpha calculated for questionnaire dimensions:Technology Infrastructure: 0.86* *Return on Investment: 0.84-Clinical Adaptability: 0.87*	*Average Cronbach's alpha: 0.86*
	Temporal Stability	*- Test-retest reliability: Questionnaire re-administered after a three-week interval on a pilot sample (n = 30) to calculate stability over time.*	*0.89*
	Inter-Rater Reliability	*- Inter-rater agreement: Assessed between two independent statistical analysts in interpreting 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 surgery time	*Shorter 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 (i.e., the main themes of the study) were developed through Thematic Analysis. This process was carried out in three stages:

1- Open coding: identifying initial concepts and labeling interview transcripts line by line;

2- Axial coding: grouping similar codes and uncovering 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 by NVivo software (version 12 or higher) to enhance the accuracy of data organization, coding, retrieval, and conceptual relationship analysis. 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 pointed out 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: including financial and infrastructural constraints, mentioned by 87% of interviewees, which aligned with the conditions of public hospitals and budget shortages.**
- **Innovation Opportunities: such as 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, emphasized by 73% of interviewees.**

Table 3 presents the main and subcategories, sample codes, and the frequency of references to each, showing that the qualitative findings are consistent 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 Rate*	*0.62*	*0.015*	*6*

1. Quantitative Section: Statistical analysis and economic modeling

The quantitative section of this research was conducted systematically and in several stages:

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

Second, data were drawn from two primary sources:

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

Third, data were analyzed using R software. Statistical assumptions (such as normality and multicollinearity) were first tested, followed by the application of multivariate linear regression to assess the impact of the independent variable (AI applications) on the dependent variables (surgical service efficiency and ROI). Results indicated that AI had a positive and significant effect ($\beta = 0.75$, $p < 0.01$)(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 about 8%, which is lower than international benchmarks (typically 15–20%).

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 present a realistic picture of the opportunities and challenges of investing in smart surgery in Iran.

The integration of qualitative and quantitative results indicates that, although financial and infrastructural barriers pose serious limitations in Iran, strengthening inter-organizational collaboration and attracting foreign investment can help mitigate these challenges.

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 artificial intelligence 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 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 show that AI has a significant impact on improving surgical efficiency and success rates, yet financial and infrastructural constraints must be addressed through targeted policymaking and international collaboration. Additionally, since comparing the results with previous studies highlights areas of consistency or divergence, this strengthens both the validity and the 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 present a comprehensive and consistent picture of investment in smart surgical technologies in Iran. On the one hand, the qualitative data clearly reveal that key stakeholders—from surgeons to policymakers—widely acknowledge the transformative potential of AI in surgery, particularly in enhancing precision, reducing operation time, and improving clinical outcomes. On the other hand, they identify structural barriers as the most critical challenges: budget shortages, lack of technological infrastructure, and currency-related constraints, which are especially influential in public hospitals. These findings are consistent with both domestic studies (e.g., Bahrami & Ahmadi, 2022) and international research (e.g., Lee & Choi, 2023), indicating that while Iran is aligned with the global trajectory of medical innovation, its operational context remains underdeveloped.

In the quantitative section, statistical evidence supports and quantifies these

perspectives: the significant impact of AI on surgical efficiency ($\beta = 0.75$, $p < 0.01$) and a 28% reduction in logistical costs attest to 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 internal validity of the study and provides an actionable framework for policymaking.

b) Conclusion

This study aimed to examine the barriers and opportunities for investment 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 examined using multivariate regression analysis and economic modeling.

The results indicate that AI holds substantial potential to enhance efficiency, precision, and quality of surgical services in the country. However, realizing this potential depends on addressing major challenges such as 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 show 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 foster the sustainable development of smart surgical technologies in 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 and domestic and foreign technology companies are encouraged to establish closer cooperation to accelerate knowledge and technology transfer and reduce infrastructural barriers.
2. Support from policymakers: It is essential to develop financial and insurance incentive policies to facilitate investment in AI technologies, particularly in public healthcare centers.
3. Targeted investment in infrastructure: Budget allocation should prioritize the upgrading of 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: Specialized training programs for surgeons and hospital managers are recommended to increase acceptance and effective use of modern AI technologies.

References:

1. Chen G, He Y, Shi Z, Wang L. Artificial intelligence in surgical medicine: A brief review. Ann Med Surg. 2025; 87(4): 2180–2186. doi:10.1097/MS9.0000000000003115.
2. Ghasemi T, Kiani A. Applications of Artificial Intelligence in Medicine and Pharmacy. In: 8th International Conference on Science, Engineering, and the Role of Technology in Modern Businesses; 1403. Available from: https://civilica.com/doc/2251378.
3. Al-Asiri MBQ, Al-Asmari AA. Role of artificial intelligence in supporting the performance of surgical robots: A survey. Computación y Sistemas. 2024; 28(3). doi: 10.13053/cys-28-3-5181.
4. Manafi Nasser M, Mirzaei H, Mirzaei H. Biomechanical modeling based on artificial intelligence: opportunities and challenges in the development of advanced medical equipment. In: The First International Conference on Artificial Intelligence in the Era of Digital Transformation; 1403. Available from: https://civilica.com/doc/2242544.
5. Kazemi Sahlvani Z. A review of the role of artificial intelligence in medical industries. In: Third International Conference on Recent Advances in Engineering, Innovation and Technology; 1403. Available from: https://civilica.com/doc/2213025.
6. Khalvati M, Karimi M. Exploring the challenges, barriers and facilitators of patients' trust in the use of artificial intelligence in cardiac surgery. In: Sixth International Conference on Health, Educational Sciences and Psychology; 1403. Available from: https://civilica.com/doc/2188138.
7. Yangi K, On TJ, Xu Y, Gholami AS, Hong J, Reed AG, et al. Artificial intelligence integration in surgery through hand and instrument tracking: A systematic literature review. Front Surg. 2025; 12: 1528362. doi:10.3389/fsurg.2025.1528362.
8. Sheikhifard F. Applications of Artificial Intelligence in Orthopedic Surgery. In: 22nd International Conference on Information Technology, Computers and Telecommunications; 1402. Available from: https://civilica.com/doc/2009671.
9. Arab Fard M. Artificial Intelligence and Its Role in Health and Medicine with a Look to the Future. In: National Conference on Mobilizing People and National Resources in Sacred Defense; 1403. Available from: https://civilica.com/doc/2254828.
10. Sadeghi Garmarudi M, Rafieirad S. A review of advances in artificial intelligence, robotics, augmented and virtual reality in neurosurgery. In: 14th International Conference on Advanced Research in Science, Engineering and Technology; 1403. Available from: https://civilica.com/doc/2122840.
11. Mohammadi Sh, Hariri A. Investigating the application of artificial intelligence in the design of medical surgical robots. In: 14th International Conference on Information Technology, Computers and Telecommunications; 1400. Available from: https://civilica.com/doc/1444923.
12. Shaddel M, Jamalpour M, Zand M, Yousefi M. An overview of the applications of artificial intelligence and machine learning in orthopedic surgery (challenges, techniques). In: 7th International Conference on Innovative Technologies in Science, Engineering and Technology; 1400. Available from: https://civilica.com/doc/1231676.