

RESEARCH

# A Novel Implementation on Intelligent Digital Transformation Towards Smart and Sustainable Healthcare

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## ABSTRACT

**PURPOSE:** This paper proposes a secure and intelligent digital transformation framework for healthcare, focusing on heart-specialised centres. The aim is to enhance diagnosis, treatment, and monitoring through an ensemble of the Internet of Things (IoT), Artificial Intelligence (AI), and Blockchain (BC) technologies.

**DESIGN/METHODOLOGY/APPROACH:** The framework integrates IoT for real-time monitoring, AI for predictive analysis, and BC for secure data management. Comprehensive experimentation was performed using real-time datasets. Quantitative evaluation employed performance metrics including accuracy, precision, recall, and F1 score, while the qualitative assessment involved a few domain experts. Security analysis was conducted using NIST standard tests.

**FINDINGS:** Results show improvements of 40% in diagnostic accuracy and 30% reduction in processing time. Three hypotheses were tested at a 5% significance level. The system supports personalised treatment, predictive analytics, and seamless communication with strong security measures.

**ORIGINALITY/VALUE:** The study highlights how digital transformation can address security and precision challenges in healthcare, shaping sustainable and future healthcare ecosystems.

**KEYWORDS:** *Sustainable healthcare Artificial Intelligence; Digital Transformation; Blockchain; Internet-of-things.*

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## INTRODUCTION

Digital revolutions have a significant part in elevating the traditional domains into a strong and intelligent environment. These systems enable the incorporation of many states of the art (SOTA) frameworks, fostering participatory governance and data-driven decision-making processes. These platforms support agile governance and knowledge distribution process (Andriushchenko *et al.*, 2020). In accordance with the global surveys, nearly 60% of the organisations believe digital transformation can enhance productivity and operational efficiency.

In this context, healthcare, which plays a prominent role in the economic growth of the country, needs rapid transformation by integrating revolutionary technologies like Internet of Things (IoT), Artificial Intelligence (AI) and Advanced Wireless Communication (AWC). Digitally transformed healthcare systems offer many advantages such as Telemedicine (TM), Predictive Analysis, Comfort Treatment process using Wearable devices and improved patient care systems (Nambisan, 2017). This sector's market size is expected to attain USD 86.03 billion in 2025 and is predicted to rise at a CAGR of 14.5%, approaching USD 351.71 billion by 2035 (Taques *et al.*, 2021; Kraus *et al.*, 2021; Ning and Xiong, 2024).

The integration of AI, big data analytics, and the IoT within the healthcare sector is transforming clinical services, enhancing operational efficiency, and advancing treatment results. Cloud-based infrastructures facilitate real-time exposure to medical data, strengthen collaboration between healthcare providers, and support more effective decision-making (Xu *et al.*, 2022; Khan *et al.*, 2023). In addition, government initiatives towards digital healthcare and the growing demand for patient-specific and digital health services are further driving market expansion.

The increasing adoption of AI-powered diagnostic tools, telemedicine platforms, and health wearables is improving clinical services and supporting early disease prediction. Cloud computing is revolutionising healthcare data management by allowing universal access to patient records and facilitating real-time information exchange among medical professionals (Alojail and Khan, 2023; Doran *et al.*, 2024; Alojail *et al.*, 2023). Additionally, big data analytics is enhancing diagnostic reasoning by processing vast volumes of patient information to uncover trends and tailor treatment approaches.

This research study therefore aimed to fill these gaps by answering the following research questions (RQ).

**RQ1:** What is the impact of Digital Transformation (DTs) on diagnosis and decision support processes in healthcare organisations?

**RQ2:** What are the main determinants of the adoption of DTs for intelligent diagnosis in healthcare organisations? The study used the Decision Delphi methodology to examine seven areas of DTs: IoT, AI, machine learning (ML), big data, business analytics, cloud computing, and blockchain (BC). These DTs were selected from previous studies as the most relevant for healthcare.

**RQ3:** How does digital transformation influence patient engagement, trust and satisfaction in the healthcare diagnosis system?

**RQ4:** How can digital transformation safeguard the healthcare data and maintain security and privacy against growing multiple vulnerabilities?

**RQ 5:** How can digital transformation improve diagnosis accuracy and interoperability of diagnosis systems?

The structure of the manuscript is arranged as follows: The Literature review provides an overview of the relevant studies suggested by multiple researchers. Research Methodology demonstrates the data collection process, AI implementation process and BC deployment Process. Results provide a detailed presentation of the analysis and assessment, with the Conclusion summarising the study and highlighting avenues for future development.

## LITERATURE REVIEW

Alshammari (2023) proposed the AI and BC-Based Predictive Security Framework for Internet of Medical Things Technologies (AIBPSF-IoMT), integrating AI and BC to secure IoMT systems using a four-layer architecture. Machine/deep learning algorithms detect cyberattack patterns, while BC ensures secure verification through cryptographic signatures. The model was validated using the Message Queuing Telemetry Transport (MQTT) dataset, showing high values for evaluation measures. However, the system may face scalability issues and computational overhead during real-time implementation.

Taherdoost (2023) conducted a five-year review on BC in healthcare, highlighting its role in secure data sharing, supply chain management, and EHR interoperability. The study emphasised benefits like data integrity, privacy, and reduced administrative costs. Real-world case studies showed BC's growing adoption and potential in a sustainable healthcare system. Yet, the review noted major implementation challenges,

including high costs and lack of standardised regulations. Alabdulatif *et al.* (2023) presented a secure AI decision-making framework by integrating ML with BC using smart contracts.

Support vector machines and Multilayer Perceptron (SVM and MLP) classifiers were deployed on-chain to protect model decisions, with SVM offering better prediction and MLP providing faster execution. Medical records were used to validate the model's robustness. A key limitation is the increased complexity and resource demands of executing ML decisions on-chain. Stoumpos *et al.* (2023) conducted a systematic bibliographic review analysing digital transformation trends in healthcare across 287 selected articles. They classified the literature into five key themes, including telemedicine, e-health acceptance, and healthcare security, offering insights into the shift towards patient-centric models. The study highlighted the expanding role of wearable and IoT technologies. However, it lacked empirical evaluation or practical deployment of the reviewed models, limiting real-world applicability. AlGhamdi *et al.* (2022) proposed a trusted IoT-based smart healthcare system integrating AI, BC, and Deep Learning (DL) (ResNet152) for COVID-19 recognition from X-ray images. They also introduced a BC-enabled pharmaceutical system and smart clinics without human intervention.

The results showed enhanced security and reliable medical services during pandemics. The major limitation is the high computational demands and scalability issues in low-resource settings. Hameed and Hameed (2023) presented a comprehensive study on digital transformation in healthcare, focusing on stability, safety, BC integration, and design challenges. They emphasised the need for ICT adoption in e-health and discussed BC's role in enhancing privacy and traceability. Their work outlined future research directions and open issues. However, the paper remains conceptual without real-time implementation or validation.

Kerrison *et al.* (2023) developed the Hybrid Channel Healthcare Chain (HC2), combining short- and long-range transmission with blockchain and digital twin models for rural healthcare. Their system reduced long-range data packets by 87× while maintaining secure and end-to-end encrypted transmissions. It improved data integrity and real-time monitoring in low-bandwidth regions.

The limitation lies in device dependency on cloud infrastructure, raising concerns about latency and trust decentralisation. Albakri and Alqahtani (2023) developed a blockchain-assisted smart healthcare system (BSHS-EODL) integrated with IoMT for secure data sharing and disease diagnosis. Their model used SqueezeNet with Bayesian

optimisation and Voting ELM, achieving a maximum accuracy of 98.51%. Image encryption was handled using the Dingo Optimisation Algorithm to enhance privacy. However, the system's complexity and dependency on metaheuristic tuning may limit its deployment in low-resource environments. Alabdulatif *et al.* (2022) designed an AI and blockchain-driven architecture to secure smart healthcare systems from network and malware attacks.

The system addressed hardware, software, and network vulnerabilities using a case study approach with blockchain stability and dynamic malware assessment. It exposed a knowledge gap in integrating modern security solutions with existing healthcare frameworks. A major limitation is the lack of real-time system deployment and empirical validation on live healthcare data. Srinivasu *et al.* (2021) introduced a blockchain-based encryption model for IoT-enabled healthcare systems over a Fifth Generation (5G) network. Their context-aware approach focused on securing data among non-terminal nodes without overburdening intermediate devices. Performance metrics showed improved results over traditional encryption methods. Yet, scalability issues and integration challenges with existing hospital infrastructure remain unresolved.

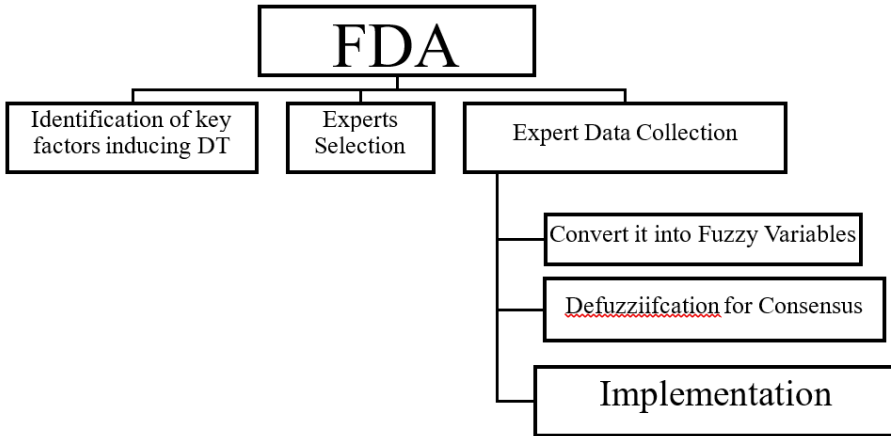
## RESEARCH METHODOLOGY

### Empirical Setup

The research's empirical setting is the ECG healthcare clinic and hospital in Saudi Arabia. The study is a regional-based system adopting the traditional methods of diagnosis and clinical treatment processes.

### Fuzzy Delphi Approach

This research is based on the Fuzzy Delphi Approach (FDA) which is an established information collection and prediction approach to obtain the most trusted consensus from a group of experts. The FDA is an advanced decision-making approach that integrates the conventional Delphi technique with fuzzy rule sets. It is implemented in the research to particularly handle the uncertainties in experts' opinions. In terms of implementing digital transformation in healthcare, the suggested Fuzzy Delphi approach provides a secured and robust framework for achieving the most scalable and secured DT based ECG diagnosis systems. Figure 1 shows the steps involved in FDA for an effective implementation of DT in ECG data signals.



**Figure 1: FDA Deployed for an effective Implementation of DT in Healthcare sectors**  
 Source: The flowchart is developed by author

From Figure 1, the FDA is specifically suitable to address this study’s research questions, since they deal with the current and future implementation in the healthcare sectors. For an effective data collection from experts, there is no fixed agreement, and it purely depends on their expertise levels and involvement. The FDA used in this study is based on interviews with experts. The data was collected by conducting interviews using Google Forms and recording the experts’ voices regarding their opinions on the DT implementation process. For an effective expert data collection, 10 experts were found who were willing to participate. For evaluating the effectiveness of the DT, a semi-structured interview was formulated based on the snowball technique. To ensure comprehensive coverage of all relevant topics, the interview guidelines were validated with the assistance of two experts. Ten experts participated in the interview and expressed their views on DT for healthcare monitoring systems. Table 1 presents the details of experts who participated in the interview process.

**Table 1: Experts Participated in the Interview Process**

Details of Experts	Designation	Expertise Role	Experience in Field(yrs)	Experience in Organisation(yr)	Total Experience
Technology Background	Data Scientist (Senior)	AI, ML, DL	19.78	12	19.78
	Data Scientist (Senior)	AI, ML, DL	18.6	18.6	18.6
	Data Scientist (Senior)	AI, ML, DL	19.2	9.0	19.2

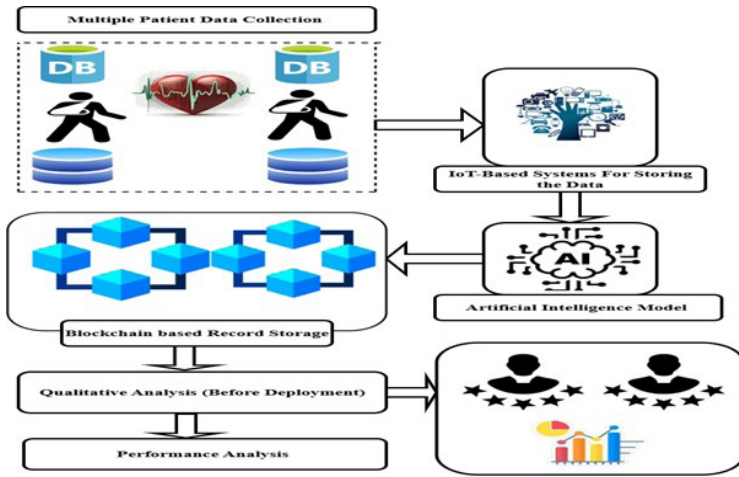
Details of Experts	Designation	Expertise Role	Experience in Field(yrs)	Experience in Organisation(yr)	Total Experience
	Data Scientist (Senior)	AI, ML, DL	19.0	10.6	19.0
	Cloud Engineers	Cloud	10.2	10.2	10.2
	Data Analysts-Senior	AI, ML, DL	9.7	8.2	9.2
	Data Analysts-Senior	AI, ML, DL, BC	17.7	2.9	17.7
Management	CEO	Complete technology	29.9	29.9	29.9
	Chief Technology Officers	Complete technology	28.7	28.7	28.7

Source: Data is collected by author

The panel of experts was engaged to provide insights on the current and prospective effects of deploying the recommended digital technologies on both administrative and technical operations within healthcare service organisations. The proposed questionnaires (RQ1 to RQ5) were conducted by the experts to assess the impact of DT implementation in terms of fuzzy values such as low, medium and high scales in their respective healthcare support systems. To allocate the score to every DT, fuzzy values ranged from 0 to 2. Here '0' corresponds to 'low', '1' impacts on medium and '2' impacts on 'high'. The conclusive score indicates the present and potential effects of the DT on healthcare management facilities. The interviews were carried out using Google Forms/Google Meet during the period from August 2024 to April 2025. The study uses the fuzzification and defuzzification processes to analyse the data collected from different experts.

### Suggested DT Framework Based on FDA Approach

Figure 2 presents the complete model for the digital transformation of the healthcare systems after using FDA techniques. The Wearable IoT systems are used to collect data from the patients and store it in the hospital cloud servers using the Blockchain. Finally, the collected patients' data are then analysed using intelligent learning models to aid for the better diagnosis and treatment processes.



**Figure 2: Suggested DT Framework After FDA Approach**

Source: The flowchart is developed by author

The data collection process using IoT systems has been elaborated. These devices represent a network of interconnected medical technologies designed to gather and transmit data in real time. Examples include heart monitors, glucose trackers, and wearable health devices that deliver continuous insights into a patient’s condition, supporting remote monitoring and timely interventions when necessary. Such connected tools enhance the patient experience by providing a more consistent and detailed overview of the patients’ health.

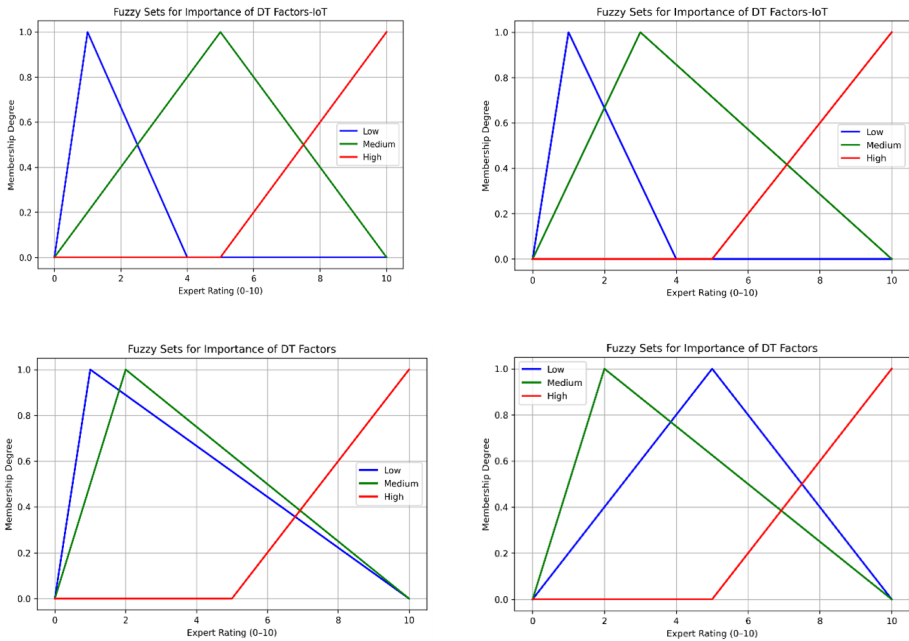
In addition, IoT facilitates more effective healthcare management by minimising the demand for frequent hospital visits and enabling professionals to respond swiftly to changes in patients’ status. When integrated with AI and big data analytics, IoT-generated information allows healthcare providers to develop predictive, holistic perspectives of patient health, encouraging proactive and personalised treatment. For effective operation, a healthcare system relies on six fundamental components: patients, providers, medical devices, sensors, networks, and data processing infrastructure (Aleksashina *et al.*, 2021).

**RESULT**

It is subdivided into two sub-parts, one based on research questionnaires and the other on experimental outcomes. The first part emphasises the influence of the DT on the healthcare sector (specifically in heart diseases) and its barriers to the adoption of DT in ECG-related health centres.

## Impact of DT on the Healthcare Sectors

A semi-structured interview for data collection has been formulated based on the snowball approach. As discussed in the FDA, fuzzy rules are applied to the experts' thoughts. Ten experts participated in the interview and expressed their views on DT for healthcare monitoring systems. Figure 3 presents the fuzzy rule sets based on the experts' opinions regarding DT.



**Figure 3: Fuzzy Rule Sets for the Experts Opinions (Sample Data)**

Source: The flowchart is developed by author

The panel of experts was engaged to provide insights on the current and prospective effects of deploying the recommended digital technologies on both administrative and technical operations within healthcare service organisations. The possible questionnaires were conducted to the experts to assess the impact of DT implementation in terms of low, medium and high scales in their respective healthcare support systems. To allocate a score to every DT, Likert-type scaling ranging from 0 to 2, here '0' corresponds to 'low', '1' impacts on medium and '2' impacts on 'High'. The conclusive score indicates the present and potential effects of the DT on healthcare management facilities. Table 2 presents the different scores for each component of DT.

**Table 2: Likert-Scores for Each Components in Suggested DT Model**

DT	Low	Medium	High	Total Score
IoT	2	5	3	11
IoT with AI	3	2	5	15
IoT with AI and Blockchain	1	1	8	17
Only Blockchain	4	2	4	10
Cloud Storage	4	4	2	08
Data Analytics	2	5	3	11

Source: Data is analysed by author

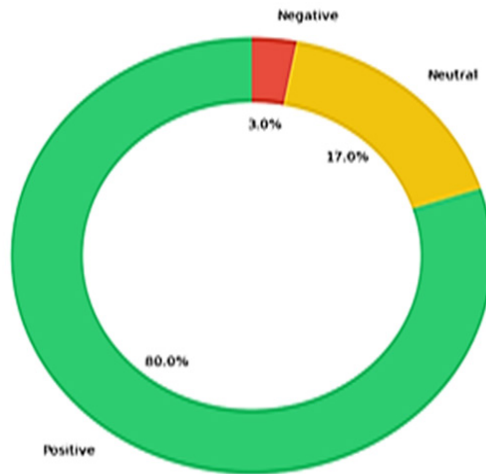
Table 3 presents the different scores of DT implementation in healthcare systems. Experts stated that the ensemble combination of IoT, AI and BC have a high impact on the healthcare monitoring system. The experts highlighted the belief of the experts that this technology can provide effective monitoring, diagnosis, secured transmission and even administrative support for healthcare organisations. The effect of IoT, AI and BC was majorly regarded in enhancing the interactions and remote monitoring of patients. Furthermore, AI Agents integrated with the IoT and BC were considered a major driving force for which staff and management should leverage the benefits.

This DT study suggested that the combination of IoT, AI, and BC has a deeper impact on the healthcare's administration support processes. Compared with the previous work, the results obtained from the experts are found to be superior and indicate that this combination has the highest impact, distinguishing it from other observational research on assessment and therapeutic procedures in healthcare organisations. On the other hand, Blockchain and Cloud storage occupies the least preference in the healthcare sector especially in developing the ECG monitoring and diagnostic processes.

The use of blockchain in healthcare systems is less pronounced, probably due to its high cost compared with other industries. Stakeholder perceptions influence the implementation of the suggested framework in their healthcare organisations. The patients accounted for 40% of the total responses, highlighting improvements in IoT based telemedicine accessibility, appointment scheduling, and electronic prescriptions. Healthcare professionals contributed 35%, emphasising the need for AI and diagnosis and raising concerns about data integrity. The administrators made up the remaining 25%, with a focus on budgetary constraints, infrastructure readiness, and policy implementation hurdles.

These results suggest that while the suggested digital transformation efforts are broadly acknowledged, experiences and expectations vary widely among stakeholder

groups. Patients were largely positive, while staff and administrators raised implementation concerns. Figure 4 illustrates the proportional contributions of each stakeholder group towards recommending the suggested framework in their respective healthcare systems.



**Figure 4: Sentimental Analysis of Implementing the Suggested Framework**

Source: The figure is developed by author

Figure 3 depicts the sentiments of the different stakeholders for implementing the suggested framework in healthcare centres. From Figure 3, 80% of participants have shown a positive interest in the DT implementation whereas only 2% have shown little interest in the implementation due to its complexity and cost investment process.

### Barriers Identified for an Effective Implementation of EML

The second research inquiry concentrated on recognising the obstacles that hinder the successful adoption of digital technologies within healthcare organisations. Table 3 lists the barriers to effective DT implementation in healthcare systems.

**Table 3: Barriers Identified by Experts for an Efficient Deployment**

Barriers Identified	No of Experts
Skills and Competency	10
Good Attitude	10
Adaptive Learning	08
Economic Resources in DT	08
Level of connectivity	07

Barriers Identified	No of Experts
Level of Available Tools	07
Scalability and Costs Investments	07

Source: Data is analysed by author

From Table 4, it is understood that Skill and Competency with a Good Attitude remain the top priority and the greatest hurdle in implementing DT in healthcare systems. Competencies encompass both the digital literacy of clinicians and the specialised technical skills of employees. A crucial factor is the capacity to collaborate effectively with IT developers. Providing training in digital skills and competencies can play a vital part in encouraging the implementation of DTs.

### Performance Analysis

Table 4 presents the diagnosis performance analysis before and after the implementation of the suggested DT framework in ECG healthcare centres. For this experimentation, 50 participants with different heart disorders participated. They were continuously monitored, and their ECG data was precisely analysed by the AI model. The end outcomes were communicated to both the participants’ mobile devices and the clinicians. In this regard a mobile application developed using Flutter-Flow was developed and installed on their mobiles. From Table 6, suggested DT improved the diagnosis performance with the 24x7 continuous healthcare support.

**Table 4: Diagnosis Performance of Suggested DT and Traditional Healthcare systems**

No of Subjects	Suggested DT		Traditional Framework	
	Diagnosis Accuracy	Patient Engagement Factor	Diagnosis Accuracy	Patient Engagement Factor
10	99.9%	Comfort	99.9%	Uncomfort-Low
20	99.9%	Comfort	98.8%	Uncomfort-Low
30	99.9%	Comfort	98.8%	Uncomfort-Low
40	99.9%	Comfort	98.8%	Uncomfort-Low
50	99.9%	Comfort	98.8%	Uncomfort-Low

Source: Data is analysed by author

### Hypothesis Testing Process

To validate the impact of suggested medical transformation, three hypotheses were tested at a 5% significance level. For H1, a paired t-test comparing pre- and post-implementation diagnosis accuracy yielded  $t=5.903(p=0.00002)$ , indicating a

statistically improved by 40%, showing a significant reduction of 30 minutes. For H2, an independent t-test comparing the operational costs before and after implementation produced  $t=-3.903$ , demonstrating a significant 16% cost reduction in the process. The findings confirm that the suggested AI and BC enabled digital transformation has yielded significant improvements in diagnostic accuracy, service efficiency and operational sustainability. Table 5 presents the hypothesis testing process conducted during the experimentation process.

**Table 5: Hypothesis Testing Results for the Suggested Frameworks**

Hypothesis ID	Test Type	Test Statistic	p-value	A	Decision	Interpretation
H <sub>1</sub>	Paired t-test	t = 5.933	0.0002	0.05	Reject H <sub>0</sub>	The suggested framework significantly improved diagnosis accuracy by 40%.
H <sub>2</sub>	Paired t-test	t = -5.903	0.00002	0.05	Reject H <sub>0</sub>	Average patient waits times reduced by 30 minutes.
H <sub>3</sub>	Independent t-test	t = -3.903	0.00067	0.05	Reject H <sub>0</sub>	Operational costs reduced by 16% after adoption.

Source: Data is analysed by author

## Security Assessment

To examine the security of data stored on the Blockchain, the National Institute of Standards and Technology (NIST) standard test methods are applied to validate the randomness of the encrypted information maintained on the Blockchain server. Table 6 demonstrates the evaluation results of the NIST standard test conducted for the 50-iteration process.

**Table 6: NIST Standard Test Analysis of the Data Stored in the Blockchain technology**

S. No	NIST Test Description	Test Status
1	Universal Statistical Test	Achieved
2	Random Excursion Test	Achieved
3	Lempel-ZIV Compression Test	Achieved
4	Matrix Rank Test	Achieved
5	Linear Complexity Test	Achieved
6	Overlapping Template of all One's test	Achieved
7	Frequency MonoTest	Achieved

S. No	NIST Test Description	Test Status
8	Block Frequency Test	Achieved
9	Frequency Test	Achieved
10	Long Run Test	Achieved
11	RunTest	Achieved
12	DFT Test	Achieved

Source: Data is analysed by author

## CONCLUSIONS

In this study, the adoption of DTs was explored within administrative and managerial processes in healthcare and looked at drivers and barriers for the current research. To the best of my knowledge, this is the first study to examine these issues. It contributes to the debate on determinants of digital transformation, by discussing how drivers and barriers of digital technologies in healthcare administrative and support processes compare with those in other industries and settings, and particularly with those related to clinical processes. The study also contributes through the methodological approach. Previous studies have mainly developed literature reviews, but views of experts were taken to provide a picture of the current situation in healthcare organisations, and the impact of DTs. Furthermore, it also implemented the real time DT for ECG healthcare centres. This shows how new digital technologies have a different impact from previous technologies.

Finally, the study contributes to the literature on digital transformation in healthcare because experts' opinions were used to classify the DTs employed within administrative and managerial processes by macro-category of function: measuring, informing, and knowledge development. Our findings also have practical implications for healthcare service providers, policymakers, and other stakeholders. They highlight the crucial factors that contribute to the successful implementation of digital transformation in healthcare, which will enable organisations to identify strategies that will actively promote digitalisation.

This study provides valuable insights for healthcare service providers to enable them to assess progress towards digital transformation and take the necessary action in each critical dimension to ensure success. Although developments in digital infrastructure seem to enable remote forecasting and blockchain integration, their overall effectiveness depends on the depth of measurement and analysis. This distinction is essential for policymakers aiming to utilise digital transformation as a strategic means to advance the healthcare sector amid emerging application trends.

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