



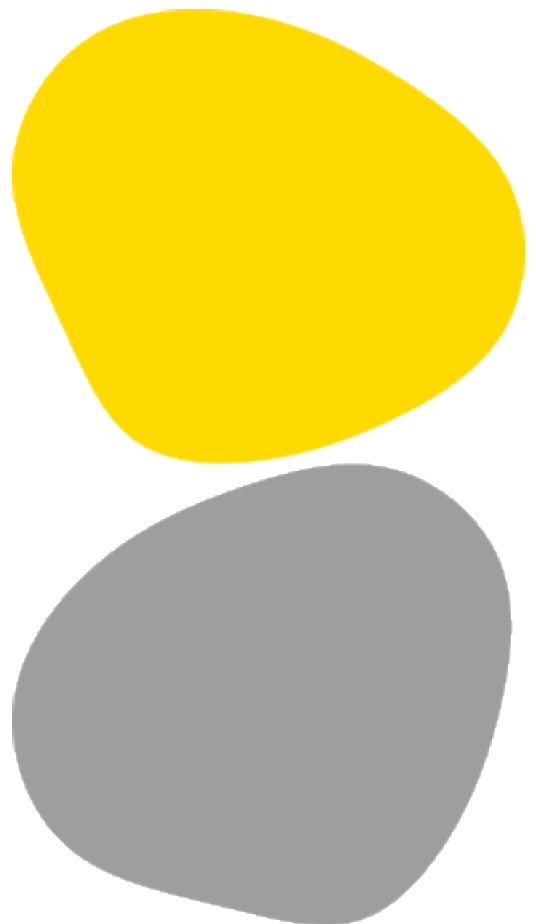
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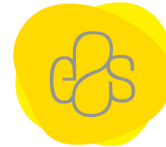
Medical Technology and Healthcare Business (EMMaH)

Mapping Unmet Healthcare Needs in Qatar and Saudi Arabia to Technology and Business Solutions

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Abstract

This dissertation explores the development of scalable modular healthcare architecture tailored to the needs of the Middle East, with a specific focus on Qatar and Saudi Arabia. The study responds to ongoing healthcare system challenges such as staff shortages, accessibility gaps, and the slow adoption of digital solutions amid rapid economic and technological transformation. Using a mixed-methods approach, the research combines policy and literature reviews with a bilingual survey of 100 healthcare stakeholders across both countries.

The findings highlight widespread support for modular healthcare systems, with 74% of respondents agreeing that modularity could improve healthcare delivery, despite only 32% reporting familiarity with such systems. Stakeholders identified emergency care (34%), telemedicine (28%), and workflow automation (24%) as the top priority areas for modular deployment. In terms of design, 67% emphasized the importance of technological adaptability, while 59% highlighted patient-centered approaches as critical features. Key barriers included lack of training (71%), resistance to change (42%), and regulatory uncertainty (38%).

The study proposes a conceptual framework for implementing scalable modular systems that integrate AI, automation, and business model innovation. This framework aims to support national healthcare visions by enhancing flexibility, efficiency, and patient outcomes.

Keywords: Modular Healthcare; Digital Transformation; Middle East; Qatar; Saudi Arabia; AI in Healthcare; Healthcare Innovation; Health Systems Design

Resumo

Esta dissertação explora o desenvolvimento de uma arquitetura modular escalável para cuidados de saúde, adaptada às necessidades do Médio Oriente, com foco específico no Catar e na Arábia Saudita. O estudo responde aos desafios contínuos do sistema de saúde, tais como escassez de pessoal, lacunas na acessibilidade e a lenta adoção de soluções digitais no meio de uma rápida transformação económica e tecnológica. Utilizando uma abordagem de métodos mistos, a pesquisa combina análises de políticas e literatura com um inquérito bilingue a 100 partes interessadas na área da saúde em ambos os países.

Os resultados destacam um amplo apoio aos sistemas modulares de saúde, com 74% dos inquiridos concordando que a modularidade poderia melhorar a prestação de cuidados de saúde, apesar de apenas 32% afirmarem estar familiarizados com tais sistemas. As partes interessadas identificaram os cuidados de emergência (34%), a telemedicina (28%) e a automatização do fluxo de trabalho (24%) como as áreas de maior prioridade para a implementação modular. Em termos de design, 67% enfatizaram a importância da adaptabilidade tecnológica, enquanto 59% destacaram as abordagens centradas no paciente como características críticas. As principais barreiras incluíram a falta de formação (71%), a resistência à mudança (42%) e a incerteza regulatória (38%).

O estudo propõe uma estrutura conceitual para a implementação de sistemas modulares escaláveis que integram IA, automação e inovação do modelo de negócios. Esta estrutura visa apoiar as visões nacionais de saúde, aumentando a flexibilidade, a eficiência e os resultados para os pacientes.

Palavras-chave: Cuidados de saúde modulares; Transformação digital; Médio Oriente; Catar; Arábia Saudita; IA nos cuidados de saúde; Inovação nos cuidados de saúde; Conceção de sistemas de saúde



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List of Abbreviations

AI – Artificial Intelligence

BizMo – Business Models

MNG-HA – Ministry of National Guard Health Affairs

NHS – National Health Strategy

QSTP – Qatar Science and Technology Park

QRDI – Development and Innovation Council

QGP – Qatar Genome Programme

NBS – Qatar Newborn Screening Program

QBRI – Qatar Biomedical Research Institute

MOH – Ministry of Health

NCDs – Non-communicable Diseases

SDAIA – Saudi Data and AI Authority

H.E – Her Excellency

H.H – His Highness

MCIT – Ministry of Communications and Information Technology

KACST – King Abdulaziz City for Science and Technology

NDU – National Digitization Unit

HISA – Health Informatics Service Architecture

SOAs – Service-oriented Architectures

MAHD – Modular Adaptable Healthcare Design

ITT – Innovation Think Tank

RBAC – Role-based Access Control

PDPL – Personal Data Protection Law

CBAHI – Central Board for Accreditation of Healthcare Institutions

TAM – Technology Acceptance Model

WHO – World Health Organization

OECD – Organization for Economic Co-operation and Development

GCC – Gulf Cooperation Council

1. Introduction

1.1. Background and Relevance

The healthcare systems of the Middle East, particularly in Qatar and Saudi Arabia, are undergoing rapid transformation driven by demographic shifts, economic diversification, and ambitious national development agendas such as Saudi Vision 2030 and Qatar National Vision 2030. Both countries have invested heavily in healthcare infrastructure, shifting from predominantly public-sector provision to mixed public-private models aimed at enhancing access, quality, and efficiency [1,2].

Despite these advancements, regional health systems continue to face structural and operational challenges. These include rising costs of care, limited accessibility in underserved areas, shortages of skilled healthcare professionals, and fragmented service delivery models. Regulatory complexity and limited digital infrastructure further constrain the adoption of integrated, patient-centered care [3,4]. These persistent inefficiencies undermine progress toward more equitable, efficient, and sustainable healthcare ecosystems.

In parallel, the global rise of artificial intelligence (AI), automation, and modular business models (BizMo) offer new opportunities for healthcare transformation. These technologies have demonstrated potential to improve clinical outcomes, streamline operations, and enable scalable service delivery tailored to diverse population needs [5,6]. Modular healthcare architectures characterized by their scalability, interoperability, and patient-centric design are increasingly recognized as strategic enablers of resilient and adaptive healthcare systems [7,8].

Within the context of the Middle East, where healthcare priorities vary across geographic, economic, and demographic lines, the development of a flexible and future-proof system design is both timely and necessary. This study seeks to explore these challenges and contribute to the design of a scalable modular healthcare architecture, informed by regional dynamics and aligned with emerging technology and policy trajectories.

1.2. Objectives and Hypothesis

This research is guided by the following objectives:

1. To identify and analyze the most critical unmet healthcare needs in Qatar and Saudi Arabia, particularly those affecting equity and patient-centric service delivery.
2. To assess the current readiness, enablers, and barriers for digital transformation among healthcare professionals in the region.
3. To develop a conceptual framework for scalable modular healthcare architecture tailored to regional needs, integrating AI, automation, and business model innovation.



Based on these aims, two core hypotheses were explored:

- **H1:** A scalable modular healthcare architecture is perceived as a valuable solution to improving patient care and operational efficiency across diverse healthcare settings in the Middle East.
- **H2:** The integration of AI and automation, when adapted to local system needs, is perceived to have the potential to enhance care quality and cost-effectiveness.

1.3. Structure of Master Thesis

The structure of this master thesis is organized into five main chapters:

- **Chapter 1 – Introduction:** Presents the background, objectives, hypotheses, and relevance of the study.
- **Chapter 2 – Literature Review:** Reviews the current state of healthcare systems in Qatar and Saudi Arabia, policy initiatives, and best practices in modular, AI-enabled healthcare.
- **Chapter 3 – Methodology:** Outlines the mixed-methods research design, including survey development, data collection, and analysis techniques.
- **Chapter 4 – Results:** Summarizes the findings from the survey, highlighting key statistical relationships and thematic insights into digital readiness and modular design perceptions.
- **Chapter 5 – Discussion:** Interprets results in the context of regional policy and system transformation
- **Chapter 6 – Proposed Healthcare System Architecture:** presents a high-level modular framework adapted for Gulf countries.
- **Chapter 7 – Conclusion**

1.4. Impact of the Results

This study is expected to generate both academic and applied value. From an academic perspective, it contributes new empirical evidence on healthcare system needs and innovation readiness in Qatar and Saudi Arabia regions often underrepresented in health systems design literature. Practically, it offers a data-informed modular framework that can guide digital transformation efforts and policy development across the Gulf.

The framework developed from this study will serve as a roadmap for implementing patient-centric, modular healthcare solutions that are scalable and resilient. It will also support national efforts to localize AI and automation within healthcare infrastructures, while enhancing workforce capacity and reducing health disparities. By doing so, this research supports the long-term strategic goals of both Qatar and Saudi Arabia to lead in health innovation and service excellence.



2. Literature Review

Rapid economic expansion, demographic shifts, and proactive government initiatives have all significantly contributed to the considerable evolution of the healthcare systems in Saudi Arabia and Qatar. With the founding of the Hamad Medical Corporation in 1979 and the establishment of the Primary Health Care Corporation in 2012 to address the country's expanding primary care needs, Qatar's healthcare system underwent revolutionary developments reflecting its rapid economic growth. According to Goodman (2015), Qatar's healthcare advancements have been driven by an emphasis on sustainability, quality enhancement, and patient-centric care, significantly influenced by the strategic direction provided by the Qatar National Vision 2030. This includes implementing a mandatory health insurance scheme and extensive infrastructural developments to enhance healthcare accessibility and quality [9].

In parallel, Saudi Arabia's Vision 2030 strategically prioritizes increasing the proportion of national healthcare professionals and enhancing service delivery across various healthcare tiers, driven by the necessity to manage the significant expatriate workforce and ensure sustainable development of the healthcare sector. Research by Almutairi (2017) highlighted the effectiveness of cultural competency training programs for expatriate nurses, significantly enhancing their abilities to deliver culturally sensitive and competent healthcare, thus improving healthcare outcomes [10]. Additionally, a WHO report by Al-Yousuf et al. (2012) underscored the necessity for more robust primary care services and public health initiatives as fundamental to the overall enhancement of the Saudi healthcare system [11]. Furthermore, Alhazmi and Alshammari (2023) emphasize the prioritization of health promotion activities as critical to addressing chronic diseases and public health challenges prevalent in Saudi Arabia, reinforcing the commitment to proactive health management strategies [12]. These collective efforts underline both nations' commitment to adapting and enhancing healthcare systems to effectively serve diverse populations. Additionally, generational gaps among healthcare workers complicate the delivery of care, necessitating targeted training and development programs to bridge these differences and foster effective collaboration. As highlighted in a recent editorial by Alfayez (2024), younger healthcare professionals often enter the workforce with advanced technological proficiency but may lack the interpersonal communication styles preferred by older generations, leading to misalignments in teamwork and care [13]. Similarly, in the Qatari context, cultural attitudes and generational values around mental health and authority influence how healthcare workers interact with one another and with patients, underscoring the need for culturally informed, age-sensitive approaches to workforce development [14].

Altamimi et al. (2016) found that primary healthcare workers at the Ministry of National Guard Health Affairs (MNG-HA) in Saudi Arabia had varying perspectives on health promotion activities. While most of the respondents (58.1%) were aware of existing health promotion programs in their facilities, a sizable minority (64.6%) believed these systems needed significant improvement. Language barriers (65%) and cultural views (64.6%) were regarded as major barriers to effective health promotion initiatives. Despite these obstacles, approximately 79.9% of respondents expressed confidence in their ability to promote health effectively. The study further highlighted a discrepancy between commonly utilized health promotion methods and those perceived as most effective; although printed educational materials were most frequently employed (80.6%), counseling was considered the more effective strategy by 55.8% of respondents. These results highlight the need for specific training programs to improve healthcare practitioners' competency as well as culturally and linguistically sensitive health promotion techniques [15]. Furthermore, medical experts recommended that using interactive strategies, including tailored counseling sessions, might greatly enhance patient involvement and result in health promotion programs.

Similarly, in Qatar, the healthcare system heavily relies on expatriate professionals, whose successful adaptation to the local environment is crucial for their job satisfaction and the quality of care they provide. A study by Bashir (2024) identified key factors influencing the adjustment of healthcare expatriates in Qatar, including language proficiency, social support networks, and cultural challenges. The study emphasized the need for comprehensive support mechanisms, such as language training and cultural orientation programs, to facilitate successful expatriate experiences in the Middle Eastern healthcare context [16].

Recent efforts have shifted towards a needs-based approach that prioritizes the specific healthcare requirements of populations, particularly those with mental, neurological, and substance use disorders. By utilizing epidemiological data to identify target groups and estimate resource utilization, stakeholders in both countries aim to create more responsive and efficient healthcare systems. This shift is pivotal in moving beyond traditional equity benchmarks to ensure that healthcare services are aligned with actual community needs and are accessible without financial or logistical barriers. In Qatar, this approach is increasingly supported by culturally tailored nursing practices that enhance therapeutic relationships and patient engagement. As outlined in a study by Abujaber et al. (2024), the implementation of needs-based, culturally competent care models improves both trust and clinical outcomes in patients with psychosocial and mental health conditions [17].

Moreover, healthcare infrastructure is being designed with cultural sensitivity in mind, emphasizing privacy, gender-segregated spaces, and visual cues that respect local customs, elements that contribute significantly to patient comfort and care continuity [18]. Nurses are also playing a critical role in this transformation; as frontline caregivers, they are receiving targeted training to address linguistic, cultural, and religious nuances in Qatar's diverse patient population [19]. These multi-layered strategies reflect a broader commitment to embedding equity, accessibility, and contextual relevance at the heart of healthcare service delivery.

2.1. Healthcare System in Qatar

Qatar's healthcare system has undergone significant changes in recent years, aimed at enhancing service delivery and expanding coverage. A notable initiative was the introduction of a mandatory social health insurance scheme in 2014, designed to replace existing public and employer-based schemes. However, the scheme was suspended in 2015 following feedback from stakeholders and emerging implementation challenges. More recent policy directions in 2023 and 2024 have emphasized the need to reintroduce a revised model that better aligns with Qatar's Vision 2030 goals, ensuring a stronger regulatory foundation and greater private sector involvement. The original plan targeted 100% coverage of Qatari citizens, with a phased approach to include private healthcare providers and maintain fee stability during early implementation. Law No. 22 of 2021 mandated health insurance for all non-Qatari residents and visitors, coming into effect in May 2022 [20].

In addition to resident coverage, Qatar implemented mandatory health insurance requirements for visitors starting February 1, 2023. Foreign visitors must obtain insurance valid for the duration of their stay, with the basic policy covering emergency and accident services up to QAR 150,000 annually [21].

Adapting to the Qatari healthcare context requires more than clinical expertise; it involves navigating complex social and cultural landscapes. Almutairi (2018) highlights that expatriate healthcare providers face challenges integrating into a system that demands both professional and cultural adjustment, necessitating structured institutional support [22]. In mental healthcare specifically, mismatches between cultural perceptions and available services can result in low utilization and fragmented care. In Qatar, cultural stigma surrounding mental illness, religious beliefs, and limited public discourse on psychological health have been shown to delay care-seeking behavior. A 2024 review by Alsanabel highlights culturally sensitive communication strategies, such as involving families in treatment decisions and offering gender-matched care providers, helping bridge these gaps and improve continuity of care [14]. Consequently, healthcare institutions in Qatar are adopting multi-faceted strategies such as

expanding interpreter services, diversifying workforce recruitment, and institutionalizing cultural competence training to address these disparities and enhance patient-centered communication and care delivery [23].

Infrastructure development remains a cornerstone of reform. Under the National Health Strategy (2018–2022), major investments were directed toward constructing and upgrading healthcare facilities. The newly launched NHS 2024–2030 continues this trajectory, prioritizing non-communicable disease prevention, mental health, and integrated health-social care services [24].

Qatar's healthcare innovation ecosystem is supported by a network of entrepreneurs, startups, research institutes, and government bodies. Entities such as the Qatar Business Incubation Center, Bedaya Center, Qatar Science and Technology Park (QSTP), and Digital Incubation Center are nurturing healthcare startups and digital solutions. Innovation platforms like Alchemist Doha, Tasimu Smart Qatar, Innovation Streams, and Falak.qa provide acceleration, mentorship, and funding opportunities.

Qatar also promotes translational research and commercialization through institutions like the Qatar Research, Development and Innovation Council (QRDI), Qatar Computing Research Institute, University of Doha for Science and Technology, and Ibtechar. These centers actively collaborate with hospitals and health authorities to bring AI, biotech, and genomics research into real-world applications.

Government-backed enablers such as Qatar Development Bank, Qatar Financial Centre Authority, and Qatar Free Zones Authority support investment inflows and partnerships to grow the health innovation sector. AI and genomics have become central to Qatar's future health strategy. Under the Ministry of Communications and Information Technology, the Artificial Intelligence Committee leads national AI initiatives. Qatar's National AI Strategy is built on six pillars AI for Qatar, business, government, research, education, and international cooperation. These pillars focus on embedding AI across services such as healthcare, traffic, education, and governance, with strong emphasis on ethics, transparency, and global collaboration.

Notable initiatives include:

- **Qatar Genome Programme (QGP):** Having sequenced over 25,000 Qatari genomes, now progressing to 100,000 by 2025 to support personalized care and early disease prevention [25].
- **Qatar Newborn Screening Program (NBS):** Launched in 2003, this program screens all newborns in Qatari hospitals for over 80 disorders [26].
- **Qatar Biobank:** Collects biological samples and lifestyle data to inform chronic disease research [27].



- **Qatar Biomedical Research Institute (QBRI):** Houses leading labs in stem cells, gene therapy, oncology, and systems biology to support precision medicine [28].

In 2024, Qatar hosted its first AI Week at QSTP, drawing over 3,000 global participants. H.E. Reem Al Mansouri emphasized that under HH Sheikh Tamim bin Hamad Al Thani's leadership, AI is a cornerstone of the national digital agenda [29][30]. As Qatar positions itself as a global AI leader, healthcare remains one of the most promising domains for AI deployment, investment, and innovation.

Mentioning that, the private sector is being increasingly engaged to expand medical education infrastructure including nursing, dental, and allied health institutions, aligning with Qatar's Vision 2030 to create a sustainable, high-quality, and patient-centered healthcare system [31]. This collaboration is also vital in addressing the shortage of skilled healthcare workers and ensuring a continuous pipeline of locally trained professionals equipped with both clinical and culturally competent skills. Recent partnerships between public agencies and private academic institutions have led to the launch of new health education programs, with emphasis on simulation-based learning, interdisciplinary curricula, and expanded training capacity. These efforts aim to reduce dependency on expatriate staff, increase national workforce participation in health sectors, and enhance long-term system resilience.

Moreover, the adoption of the new strategic plan, Vision 2030, presents both challenges and opportunities for the health sector, pushing it to realign its strategic priorities and long-term goals. Cultural competence in medical education is emerging as a national priority, with academic institutions like Weill Cornell Medicine–Qatar integrating it into faculty training and curriculum design. Initiatives such as the "Cultural Competence in Healthcare" lecture series and professional development modules are equipping future healthcare workers with the skills needed to navigate Qatar's multicultural environment [32].

2.2. Healthcare System in Saudi Arabia

Saudi Arabia's healthcare system has witnessed remarkable growth in infrastructure, innovation, and policy reform under the guidance of Vision 2030 [33]. The Ministry of Health (MOH), established in 1950, remains the primary public healthcare provider, operating approximately 60% of health services, while the private sector delivers around 30–40%, and other government sectors, including the Ministry of National Guard Health Affairs, the Ministry of Defense, and Saudi Aramco, contribute the remaining share [34].

Saudi nationals are entitled to free healthcare at public hospitals, while the government continues to expand private insurance coverage to expatriates and private-sector employees. According to the

Ministry of Finance's 2024 Q1 report, the healthcare sector remains a key focus, with over SAR 51.6 billion (approximately \$13.8 billion) allocated to health and social development expenditures in the first quarter alone, representing 17% of total government spending. This highlights the government's sustained commitment to universal access and quality healthcare [35].

A central pillar of reform is the Health Sector Transformation Program under Vision 2030, which focuses on enhancing healthcare quality through digital health, prevention, and privatization. The program aims to increase life expectancy to 80 years, reduce the burden of non-communicable diseases (NCDs) which currently account for 73.2% of all deaths in the Kingdom and create an efficient, patient-centered system [36].

Digital health plays a crucial role. The Seha Virtual Hospital, the largest in the region, provides remote consultations and AI-powered diagnostics. Additionally, the Nafis platform centralizes patient records, enhancing data-driven service delivery [37,38]. National innovation is supported by organizations like the Saudi Data and AI Authority (SDAIA), which oversees over 400 digital services and integrates 370+ government systems via a national data catalog [39]. SDAIA's efforts align with 66 of the 96 Vision 2030 goals, reinforcing Saudi Arabia's ambition to become a global AI leader.

Key enablers of the transformation include:

- **Ministry of Communications and Information Technology (MCIT):** Responsible for ICT regulation and the Digital Transformation Program, including AI integration and data infrastructure [40].
- **King Abdulaziz City for Science and Technology (KACST):** Drives innovation in digital health, advanced diagnostics, bioengineering, and biotechnology, while supporting startups through innovation parks and The Garage accelerator [41].
- **National Digitization Unit (NDU):** Coordinates e-government and digital services adoption, including AI-powered solutions and digital literacy training for public employees [42].
- **Ministry of Education:** Leads the integration of AI into education curricula and provides grants to support healthcare-related AI research and degree programs [43].

The private sector is actively investing in healthcare innovation and infrastructure. Recent strategic partnerships include:

- IBM's planned \$200M software lab in Riyadh aligned with Vision 2030 [44].
- AWS's \$5.3B data center investment [45].
- Microsoft and Google Cloud's training and AI infrastructure initiatives.
- Seha Virtual Hospital's AI collaboration with information technology company Alphaiota to develop work in artificial intelligence and data analysis [46].

- Aramco Digital and Intel's private 5G network development for healthcare environments [47].
- Tech firm Nybl and data automation company Basserah's merge to deliver an end-to-end AI data pipeline [48].
- The Rezolve AI-MISA collaboration to launch an AI Center of Excellence in Saudi Arabia [49].

These public-private collaborations underline Saudi Arabia's focus on healthcare innovation, data integration, and AI-driven transformation going beyond infrastructure to emphasize long-term digital resilience and workforce development.

Historically, Saudi Arabia's healthcare transformation has evolved over a century, beginning with the 1925 establishment of the first public health department in Mecca. Today, the Kingdom has over 480 hospitals with approximately 73,000 beds, forming a robust national care network [50].

According to the Saudi Ministry of Finance's Budget Statement for Fiscal Year 2024, the government has allocated approximately SAR 51.6 billion (about \$13.8 billion) to the health and social development sector in the first quarter of 2024. This expenditure represents 17% of the total government spending for that period, underscoring the Kingdom's commitment to enhancing healthcare services and social development initiatives [51]. Vision 2030 marked a major turning point by prioritizing privatization, digital transformation, and workforce nationalization. A key objective is to increase the share of Saudi nationals in the healthcare workforce from one-third to two-thirds by 2030.

This transition requires scaling training programs, modernizing curricula, and retaining talent across public and private sectors. Persistent challenges remain, including regional disparities, staff shortages, and barriers to care especially for women in rural areas. Mental health concerns are rising, particularly among women and adolescents, exacerbated by stigma and provider shortages.

To address these challenges, the Kingdom has expanded private sector engagement and public-private partnerships. to support new educational institutions for nursing, medicine, and allied health. These efforts reduce dependency on expatriate workers and promote a culturally competent, self-reliant workforce. The Health Sector Transformation Program supports this trajectory with initiatives in digitized care delivery, hospital efficiency, and preventive care.

As Saudi Arabia continues to implement Vision 2030, healthcare system reforms are expected to accelerate, demanding coordinated efforts from all stakeholders. Ensuring equity in access, maintaining service quality, and cultivating a resilient, skilled health workforce remain central pillars of this transformative agenda.

2.3. Scalable Modular Healthcare Architectures

Scalable and modular healthcare frameworks have become central to transforming modern health systems into more adaptive, patient-centered and resilient structures. These frameworks separate healthcare service delivery into flexible, interchangeable units ranging from primary care and diagnostics to specialized services such as mental health or chronic disease management. Each unit or module can be independently scaled and adapted to meet regional demand, available resources and health system capacity making modular models especially suited for fast-developing healthcare environments like Qatar and Saudi Arabia.

The foundation of modular healthcare architecture lies in system flexibility, responsiveness, and digital interoperability. The Health Informatics Service Architecture (HISA), standardized under ISO/EN 12967, is a widely recognized model supporting modularity. HISA provides a reference architecture for vendor-independent, service-oriented healthcare information systems through its middleware and common services layers [52]. It enables modular service components to interoperate through a unified communication infrastructure, regardless of vendor or platform, and is particularly beneficial for large-scale systems requiring flexibility and adaptability. This architecture ensures that healthcare providers can modify or scale individual modules such as patient records, laboratory systems, or appointment scheduling without disrupting the entire ecosystem [53].

This concept is further complemented by service-oriented architectures (SOAs) and microservices, which allow health IT systems to become loosely coupled. Each service operates independently and communicates through standard interfaces, making it easier to replace or upgrade specific functionalities. For instance, a hospital can update its AI diagnostic tool without affecting the patient admission module. This level of granularity improves maintainability, promotes system resilience, and supports cloud-native deployments, which are particularly relevant in modern smart hospital environments. In the context of national eHealth systems like those being developed in Qatar and Saudi Arabia, this modularity enables health ministries to incrementally roll out services across diverse regions while ensuring interoperability and consistent data governance.

A 2025 review by Bathelt et al. emphasizes the emergence of modular IT infrastructure in healthcare, highlighting the potential of microservice architectures to promote agility, scalability, and service-oriented delivery. These systems break down complex applications into small, loosely coupled components that can be independently deployed, maintained, and scaled, making them ideal for dynamic healthcare environments where demands shift rapidly. However, the review also identifies challenges

such as latency, high communication overhead, service orchestration complexities, and the need for effective governance structures [54].

To mitigate these issues, health systems are increasingly turning to edge computing, which brings processing power closer to data sources like diagnostic devices or wearable health monitors. This reduces latency and improves real-time responsiveness. Additionally, cloud-based organization platforms are being used to manage microservice deployment and ensure continuity of operations. These tools support modular scalability, enabling health systems to deliver virtual consultations, remote diagnostics, and data analytics at both central and peripheral care points, including in underserved or rural regions. Such innovations are particularly relevant in the Gulf region, where geographic disparities and urban–rural divides present ongoing healthcare delivery challenges.

In Qatar, modular healthcare delivery is being driven by the goals of the National Health Strategy 2024–2030 and Vision 2030. The country is decentralizing care through health clusters based on geographic and population health data. AI-powered diagnostic kiosks, mobile health units, and virtual outpatient clinics (e.g., Tasimu and Seha platforms) serve as scalable modules that can be deployed and expanded based on service demand. These modules are further integrated into national health IT systems for continuity of care and longitudinal patient data access.

Saudi Arabia has embraced modularity under its Health Sector Transformation Program through the rollout of 21 regional health clusters, each tasked with operational autonomy, while supported by digital layers such as the Seha Virtual Hospital and Nafis patient platform. These modules ensure equitable access across diverse geographies, reduce pressure on tertiary hospitals, and enhance continuity of care at the community level.

Architectural strategies such as Modular Adaptable Healthcare Design (MAHD) draw from the Open Building Concept (OBC) to create flexible clinical environments that can accommodate rapid changes in service lines or population health needs. These strategies enable modular hospitals, mobile health clinics, and outpatient pods that can be assembled, disassembled, or relocated as needed. This is especially critical for managing pandemics, mass casualty events, and refugee healthcare needs. Studies also underscore how cloud-enabled modular architectures enhance operational sustainability and scalability. By hosting modular health applications and data environments in cloud ecosystems, nations like Qatar and Saudi Arabia can optimize cost, scalability, and access to AI analytics [55].

Leading healthcare technology companies such as Siemens Healthineers are playing a pivotal role in shaping modular and scalable healthcare models. Siemens Healthineers has contributed to the development of disease-specific pathway models and reference architecture through its Innovation

Think Tank (ITT), a global network of multidisciplinary innovation hubs established to support system transformation through user-centered healthcare redesign. ITT develops white papers, modular reference architectures, and localized service models in collaboration with hospitals and health ministries, including those in the Middle East. Since February 2025, ITT has been integrated into the SHIFT innovation ecosystem and Innovation Strategy & Ecosystem organization of Siemens Healthineers. These outputs include end-to-end disease pathway models, such as stroke, oncology, cardiology, and respiratory care that integrate diagnostics, therapy, and digital monitoring across scalable modules, shown below in figure 1. These include comprehensive care frameworks for cardiovascular diseases, oncology, respiratory disorders, and neurodegenerative conditions. These models align clinical diagnostics, therapy planning, and monitoring across modular care units, facilitating seamless transitions between stages of care and promoting efficiency, standardization, and adaptability within healthcare systems.

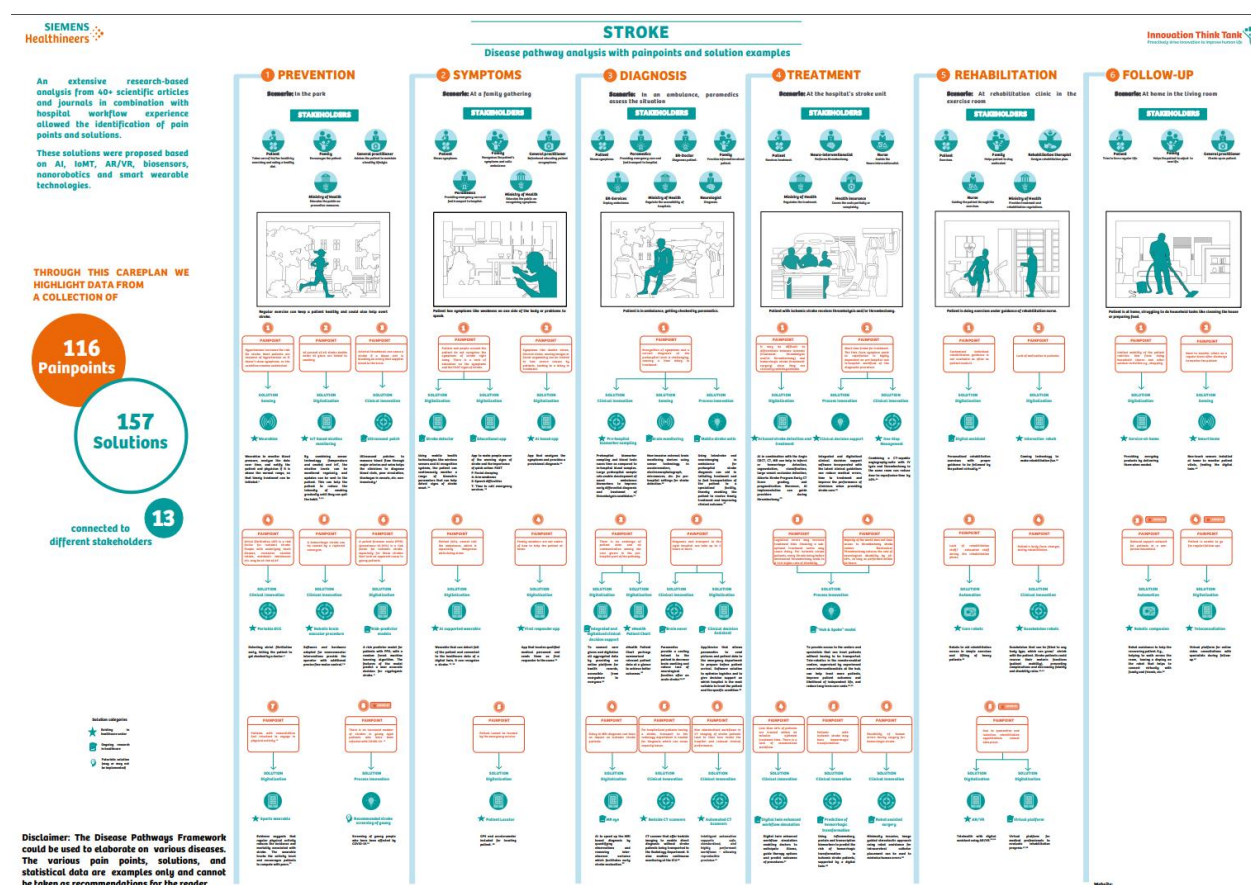


Figure 1: Stroke disease pathway analysis with painpoints and solution examples by Innovation Think Tank Siemens Healthineers [56].

The company's Innovation Think Tank, operates across more than 100 locations globally including in the Middle East focuses on co-creating solutions with healthcare providers to localize these pathway models [57]. For example, Siemens Healthineers has implemented disease-specific management service architectures for stroke, breast cancer, and chronic obstructive pulmonary disease (COPD) that align AI-supported imaging, point-of-care diagnostics, and digital follow-up tools into single interoperable workflows, as depicted in figure 1. In their stroke pathway model, for instance, AI-based CT interpretation accelerates triage decisions, while remote neurologist consultations ensure timely intervention, even in low-resource settings. White papers from the ITT emphasize a multi-layered approach to capacity building: including mobile training labs, co-designed simulation spaces for clinical skill development, and innovation challenges to promote system ownership and local adaptation. These programs have been piloted in Gulf countries, where ministries of health and private providers collaborate with ITT to build innovation capacity and embed modular clinical workflows into hospital design. Emphasis is placed on aligning health innovation with national strategies, promoting faster patient throughput, earlier diagnostics, and system-wide resilience, particularly in rapidly urbanizing environments or areas with strained workforces.

A core pillar of their modular approach is capacity building. Siemens Healthineers, through ITT programs, has launched multidisciplinary capacity-building frameworks combining clinical training, design thinking, and innovation management. These programs are tailored to healthcare professionals, system planners, and administrators in regions undergoing transformation, such as the Gulf. For example, ITT has delivered structured programs in Saudi Arabia and UAE that train local talent in modular hospital design, digital workflow innovation, and AI integration thus enabling sustainable health system modernization. Furthermore, Siemens Healthineers promotes modular hospital infrastructure design strategies through its Atellica Diagnostics platforms, AI Rad Companion, and teamplay digital health platform. These technologies enable dynamic configuration of diagnostic and treatment environments around disease service lines, adaptable patient volumes, and regional epidemiological trends. The flexibility offered by such modular ecosystems makes them well-suited for pandemic preparedness, mobile health deployment, and resource-strained urban or rural centers.

This comprehensive approach demonstrates how technology companies can drive modularity not just through infrastructure, but by embedding innovation into the workforce, care pathways, and governance frameworks of emerging health systems. Notably, the ITT white paper titled "Addressing Healthcare Needs with Innovation Think Tank Global Infrastructure and Methodology" details the importance of co-creation environments for modular healthcare development. The white paper outlines how Siemens

Healthineers' ITT Labs incorporate real-world simulation spaces, prototyping zones, and health service innovation models to facilitate hands-on co-creation between stakeholders and healthcare professionals [58].

In addition, the Innovation Think Tank Certification Programs support capacity-building through interdisciplinary training on innovation methodologies, service design, and leadership in healthcare transformation. These programs empower participants to prototype patient-centric care models and pathway-driven interventions that directly respond to regional unmet needs [59].

As population health needs evolve and global health shocks become more frequent, modular frameworks are not just desirable, they are essential. Their relevance is heightened in regions aiming to localize services while maintaining national quality standards and technological integration. Qatar's investments in genomics, precision medicine, and mobile health directly reflect modular principles, allowing the country to scale services from research labs to primary care units. Saudi Arabia's public-private partnerships in digital health and hospital infrastructure echo this commitment.

Going forward, success will depend on strong governance, interoperability standards, modular financing strategies, and workforce readiness. Both countries are investing in digital and regulatory infrastructure to support these efforts, reinforcing modularity as a cornerstone of future-proof healthcare systems.

3. Methodology

3.1. Research Design

This study employs a mixed-methods research design, utilizing an exploratory sequential approach. This method begins with a qualitative exploration of the healthcare context in Qatar and Saudi Arabia through a literature review and policy analysis, which subsequently informed the development of a bilingual (Arabic-English) survey. This design allows the researcher to first uncover region-specific nuances and challenges qualitatively, then validate these findings quantitatively, ensuring both contextual depth and empirical generalizability.

The qualitative phase synthesized academic studies, government strategies (e.g., Vision 2030), and institutional white papers related to digital transformation and modular healthcare design. Building upon these insights, a comprehensive survey instrument was developed to assess stakeholder perceptions of healthcare challenges, digital readiness, and modular healthcare system feasibility.

3.2. Data Collection

The primary data collection tool was a structured survey that served both quantitative and qualitative purposes. Developed using Microsoft Forms (2025 version), the survey ensured secure digital deployment and facilitated real-time data aggregation. The instrument consisted of 23 questions organized into five thematic sections: healthcare system challenges, underserved populations, AI and digital health readiness, modular healthcare design awareness and perceptions, and investment preferences. It incorporated a blend of question types, including multiple-choice, open-ended prompts, and 5-point Likert scales tailored to fit the context of each theme.

Three types of Likert scales were employed:

- Agreement scales (1 = Strongly Disagree to 5 = Strongly Agree), used to assess perceptions and attitudinal alignment.
- Likelihood scales (1 = Very Unlikely to 5 = Very Likely), used to estimate future intentions or investment behavior.
- Quality rating scales (1 = Poor to 5 = Excellent), used to evaluate system performance or awareness levels.

The survey was distributed digitally between March and June 2025 to healthcare professionals across Qatar and Saudi Arabia via targeted institutional and professional networks. A total of 100 valid responses were collected, covering a broad demographic spectrum of clinical practitioners, professors,

hospital administrators, policymakers, and support staff. This approach ensured a comprehensive and representative view of the region's healthcare ecosystem.

The inclusion of both qualitative and quantitative components in a single instrument was essential for this research. The qualitative responses enabled the identification of contextual barriers, opportunities, and stakeholder expectations, while the quantitative data supported pattern recognition and inferential analysis. This mixed-method approach contributed to a more nuanced, evidence-based understanding of the feasibility and potential of modular, patient-centric healthcare solutions in the Middle East.

3.3. Validity and Reliability

To ensure validity and reliability, the survey underwent a pre-distribution review and pilot testing for clarity and consistency. Quantitative validity was maintained by aligning survey constructs with existing literature and prior validated instruments where applicable. Internal consistency was monitored for reliability.

For the qualitative components, strategies such as triangulation and peer debriefing were used to confirm thematic consistency and enhance analytical rigor. While member checking was not employed due to the anonymous format of the survey, the convergence of themes across diverse respondents enhanced the credibility of the insights.

3.4. Data Analysis

Quantitative data analysis was conducted using IBM SPSS Statistics (version 27.0.1). Descriptive statistics were used to summarize the characteristics of the study sample. For categorical variables, frequencies and percentages were reported, while continuous variables were described using means and standard deviations. These measures provided a foundational understanding of the participant demographics and general response patterns.

Inferential statistical analyses were employed to explore relationships and predictive factors associated with both the perceived importance and recommendation of modular healthcare systems. Specifically, the Fisher's Exact Test was applied for 2x2 categorical comparisons, and the Fisher-Freeman-Halton Exact Test was used for larger contingency tables to assess associations between variables such as language, profession, years of experience, and digital tool usage.

To enhance analytical clarity, the original four-point Likert scale measuring the perceived importance of modular healthcare was dichotomized into two categories: "Not or Moderately Important" and "Very or

Extremely Important." This binary classification facilitated clearer group comparisons and optimized statistical power.

A multiple linear regression analysis was also performed to identify independent predictors of the likelihood to recommend modular healthcare. Independent variables included language preference, professional background, country of residence, years of experience, and reported use of AI or automation. The regression model reported both unstandardized (B) and standardized (Beta) coefficients, with 95% confidence intervals and p-values, to examine the strength and direction of associations. Due to the overwhelmingly high support for modular healthcare (99% of participants), statistical testing was not conducted on the binary support variable due to insufficient variance.

Qualitative data, primarily derived from open-ended survey responses, was subjected to thematic analysis. Responses were coded manually to identify recurring themes such as perceived system inefficiencies, barriers to digital adoption, and value drivers of modular architecture. These qualitative insights were later triangulated with quantitative findings to inform the conceptual framework for scalable modular healthcare systems in the region. A significance level of $p < 0.05$ was used for all inferential analyses to determine statistical significance.

For the qualitative component, open-ended survey responses were analyzed using thematic analysis following Braun and Clarke's six-phase framework (2006). An inductive approach was employed to allow insights to emerge organically from participant input. Responses were first transcribed and translated (where needed), then manually coded. Codes were grouped into categories and refined into five key themes that reflected recurrent patterns across the dataset.

This process included:

- Familiarization with responses across both English and Arabic languages
- Manual generation of descriptive and interpretive codes
- Iterative clustering of codes into candidate themes
- Review and refinement of themes for internal coherence and alignment with research objectives
- Selection of representative quotes to support each theme

Themes were triangulated with quantitative findings to enrich interpretation and highlight the socio-cultural, operational, and regulatory dimensions influencing healthcare innovation readiness in Qatar and Saudi Arabia. This dual analysis approach ensured methodological rigor, contextual depth, and alignment with the study's hypotheses.

3.5. Ethical Considerations

Ethical compliance was maintained throughout the research process. Informed consent was obtained from all participants prior to survey completion. Responses were collected anonymously, with no personal identifiers recorded. Data was stored securely and analyzed in aggregate form to ensure confidentiality and privacy. The research was conducted in full compliance with institutional and GDPR standards.

4. Results

4.1. Quantitative Results

4.1.1. Demographic Characteristics of Respondents

The survey captured responses from a diverse group of 100 healthcare stakeholders, primarily residing in Qatar (88%) and, to a lesser extent, Saudi Arabia (9%), with a small group operating across both countries (3%). The professional background of respondents was predominantly clinical, with doctors representing the majority at 64%, followed by professors (12%), hospital administrators and nurses (each at 5%), policymakers (1%), and other roles including technical or support staff (13%). The linguistic profile indicated a strong preference for English (93%), with only 7% identifying Arabic as their primary language of communication. In terms of professional experience, the majority had substantial tenure in the field, with 38% having 11–20 years of experience and 27% possessing more than 20 years. A quarter of respondents (25%) were relatively early in their careers with 0–5 years of experience, while 10% had 6–10 years. This demographic snapshot, shown in table 1, reflects a highly experienced and clinically driven participant pool, with a strong presence in Qatar's healthcare landscape and a predominant use of English in professional settings.

Table 1: Demographic Characteristics of Respondents

		N	%
Language	Arabic	7	7.0%
	English (United States)	93	93.0%
Profession	Doctor	64	64.0%
	Professor	12	12.0%
	Hospital Admin	5	5.0%
	Nurse	5	5.0%
	Policy Maker	1	1.0%
	Other	13	13.0%
Country of Residence	Both	3	3.0%
	Qatar	88	88.0%
	Saudi Arabia	9	9.0%
Years of Experience	0 – 5 years	25	25.0%
	6 – 10 years	10	10.0%
	11 – 20 years	38	38.0%
	20 + years	27	27.0%

4.1.2 Current Healthcare Challenges, System Efficiency, and Digital Health Adoption Barriers

These findings, shown in table 2, highlight several pressing challenges and trends within the healthcare systems of the region, as perceived by 99 respondents. The most critical issues identified were high healthcare costs (38.4%) and staff shortages (35.4%), followed closely by limited accessibility (31.3%) and restrictive policies and regulations (28.3%). Non-communicable diseases (18.2%) and technological limitations (7.1%) were also noted as areas of concern. Despite these challenges, the perceived efficiency of the healthcare system was generally positive, with 45.5% rating it as “very good” and 24.2% as “excellent,” while only a small fraction (4%) rated it as “poor.” When asked about underserved populations, a significant majority (62.2%) pointed to low-income groups, while other vulnerable groups such as the disabled (12.2%), rural communities (9.2%), chronic disease patients (7.1%), and the elderly (4.1%) were also recognized. Adoption of AI and automation remains relatively limited, with 62% reporting no current use, although 38% indicated some level of implementation. Barriers to digital health and AI adoption are substantial, with lack of training being the most frequently cited obstacle (71.4%), followed by cost concerns (37.8%), trust issues (31.6%), regulatory challenges (26.5%), low community acceptance (25.5%), and infrastructure limitations (21.4%). These findings underscore a clear need for targeted investment in workforce development, digital literacy, and regulatory modernization to support more inclusive and tech-enabled healthcare systems.

Table 2: Current Healthcare Challenges, System Efficiency, and Digital Health Adoption Barriers

		N	%
Biggest Healthcare Challenges in Our Country (N=99)	Cost	38	38.4%
	Accessibility	31	31.3%
	Policies & Regulations	28	28.3%
	Staff Shortage	35	35.4%
	Non-Communicable Diseases	18	18.2%
	Tech limitations	7	7.1%
	Other	2	2.0%
Healthcare System Efficiency Rate (N=99)	Poor	4	4.0%
	Good	26	26.3%
	Very Good	45	45.5%
	Excellent	24	24.2%
Underserved Populations (N=98)	Low-income groups	61	62.2%
	Disabled	12	12.2%
	Rural communities	9	9.2%
	Chronic disease patients	7	7.1%
	Elderly patients	4	4.1%
	Other	5	5.1%
Use of AI/Automation	No	62	62.0%
	Yes	38	38.0%
Barriers to AI/Digital Health Adoption (N=98)	Lack of training	70	71.4%
	Cost	37	37.8%
	Trust issues	31	31.6%
	Regulations	26	26.5%
	Community acceptance	25	25.5%
	Infrastructure	21	21.4%
	Other factors	4	4.1%

4.1.3 Awareness, Percieved Importance, and Support for Modular Healthcare Systems

These findings, shown in table 3, reveal that while familiarity with modular healthcare architecture remains limited 64% of respondents reported no knowledge of the concept and only 3% have hands-on experience there is overwhelming support for its adoption, with 99% expressing favor for its

implementation. Regarding its perceived importance, most of the participants viewed modular healthcare as significant, with 45% rating it as “very important” and 21% as “extremely important,” while only 1% dismissed its importance altogether. Investment preferences indicate a strong inclination toward government involvement, with 50% favoring government-led initiatives and 48% supporting public-private partnerships, whereas support for purely private sector leadership was negligible.

Additionally, the likelihood of recommending modular healthcare was high, with 53% stating they are “highly likely” and 16% “very highly likely” to recommend it, underscoring a strong endorsement despite the current gap in practical familiarity. These insights reflect a clear enthusiasm for modular healthcare solutions and a readiness for systemic change, provided there is adequate awareness-building and policy support.

Table 3: Awareness, Perceived Importance, and Support for Modular Healthcare Systems

		N	%
Familiarity with Modular Healthcare Architecture	No, I am not familiar with it	64	64.0%
	Yes, I have heard of it but have not used it	33	33.0%
	Yes, I have implemented or worked with it	3	3.0%
Support for Modular Healthcare	No	1	1.0%
	Yes	99	99.0%
Perceived Importance of Modular Healthcare	Not Important	1	1.0%
	Moderately Important	33	33.0%
	Very Important	45	45.0%
	Extremely Important	21	21.0%
Investment Preference for Modular Healthcare	No, I don't think it's necessary	1	1.0%
	Yes, a public-private partnership is ideal	48	48.0%
	Yes, government should lead	50	50.0%
	Yes, private sector should lead	1	1.0%
Likelihood to Recommend Modular Healthcare	Very Unlikely	2	2.0%
	Unlikely	2	2.0%
	Moderately Likely	27	27.0%
	Highly Likely	53	53.0%
	Very Highly Likely	16	16.0%

4.1.4 Percieved Benefits, Value Drivers, and Implementation Barriers of AI and Modular Healthcare

These results, depicted in table 4, highlight several perceived advantages of integrating AI and modular architecture into healthcare systems. Among the recognized benefits of AI, the most cited was reduced workload (67.7%), followed by improved patient outcomes (38.4%) and better diagnostics (37.4%), while cost savings were identified by a smaller segment (19.2%). Regarding modular healthcare, respondents found cost-effectiveness and improved patient care to be the most valuable aspects (each noted by 58%), followed closely by scalability (47%) and interoperability (46%). However, despite these perceived benefits, multiple barriers to implementation remain prominent. The leading challenges include resistance to change among healthcare professionals (51%), high initial costs (47%), and both a lack of clear government policies and technical integration difficulties (42% each). Additionally, concerns over data security and privacy (40%) and limited digital literacy among healthcare workers (32%) further hinder progress. These findings underscore a strong recognition of the potential of AI and modular systems to transform healthcare delivery, coupled with a clear need for structural, educational, and policy-level interventions to facilitate their effective adoption.

Table 4: Perceived Benefits, Value Drivers, and Implementation Barriers of AI and Modular Healthcare

		N	%
Perceived Benefits of AI in Healthcare (N=99)	Reduced workload	67	67.7%
	Better diagnostics	37	37.4%
	Improved patient outcomes	38	38.4%
	Cost savings	19	19.2%
Most Valuable Aspects of Modular Healthcare	Interoperability	46	46.0%
	Cost-effectiveness	58	58.0%
	Improved patient care	58	58.0%
	Scalability	47	47.0%
	AI-driven decision support	26	26.0%
	I don't know	4	4.0%
Barriers to Implementing Modular Healthcare	Lack of clear government policies/regulations	42	42.0%
	Resistance to change from healthcare professionals	51	51.0%
	Technical integration challenges	42	42.0%
	High initial costs	47	47.0%
	Limited digital literacy among healthcare workers	32	32.0%
	Data security and privacy concerns	40	40.0%

4.1.5 Priority and Design Considerations for Modular Healthcare Systems

This cohort reveals insightful trends regarding both functional and design priorities in the implementation of modular healthcare systems, depicted in table 5a and 5b. In terms of functional priority areas, emergency and critical care emerged as the top choice, ranked first by 34% of respondents, though it also showed a notable drop-off with 28% placing it last (fifth). Hospital administration and workflow automation was ranked first by 21%, and opinions were evenly distributed across other ranks. Telemedicine and remote patient monitoring was most frequently ranked third (28%) and second (24%), suggesting moderate prioritization, while chronic disease management was commonly ranked third (26%) and fourth (24%), with only 10% placing it first. AI-driven diagnostics saw a split view, with 17% ranking it first and another 29% ranking it fourth, indicating some ambiguity regarding its priority.

On the design side, flexibility to integrate new technologies was the most favored feature, with 37% placing it first and 29% second. Standardized communication protocols followed, ranked first by 22% and second by 23%, though 30% rated it fourth, suggesting a slightly more divisive view. The patient-centric

approach was also significant, with 27% ranking it first and a balanced spread across other ranks, pointing to consistent appreciation of its importance. Conversely, cost reduction through efficient resource use was the least prioritized, with only 14% selecting it as the top choice and the majority (35%) ranking it fourth, suggesting that economic efficiency is viewed as secondary to adaptability and patient-centered design. These findings collectively emphasize the importance of responsive, technology-ready, and clinically focused modular healthcare systems.

Table 5a: Priority and Design Considerations for Modular Healthcare Systems

		Rank				
		1	2	3	4	5
		%	%	%	%	%
Priority Areas for Modular Healthcare (Rank in order of priority)	Hospital administration & workflow automation	21	24	16	14	25
	Telemedicine & remote patient monitoring	18	24	28	24	6
	Chronic disease management	10	21	26	24	19
	AI-driven diagnostics	17	15	17	29	22
	Emergency & critical care	34	16	13	9	28
Design Priorities for Modular Healthcare Systems (Rank in order of priority)	Flexibility to integrate new technologies	37	29	25	9	
	Standardized communication protocols	22	23	25	30	
	Cost reduction	14	27	24	35	
	Patient-centric approach	27	21	26	26	

Priority Areas for Modular Healthcare & Design Priorities for Modular Healthcare Systems
(Rank in order of priority)

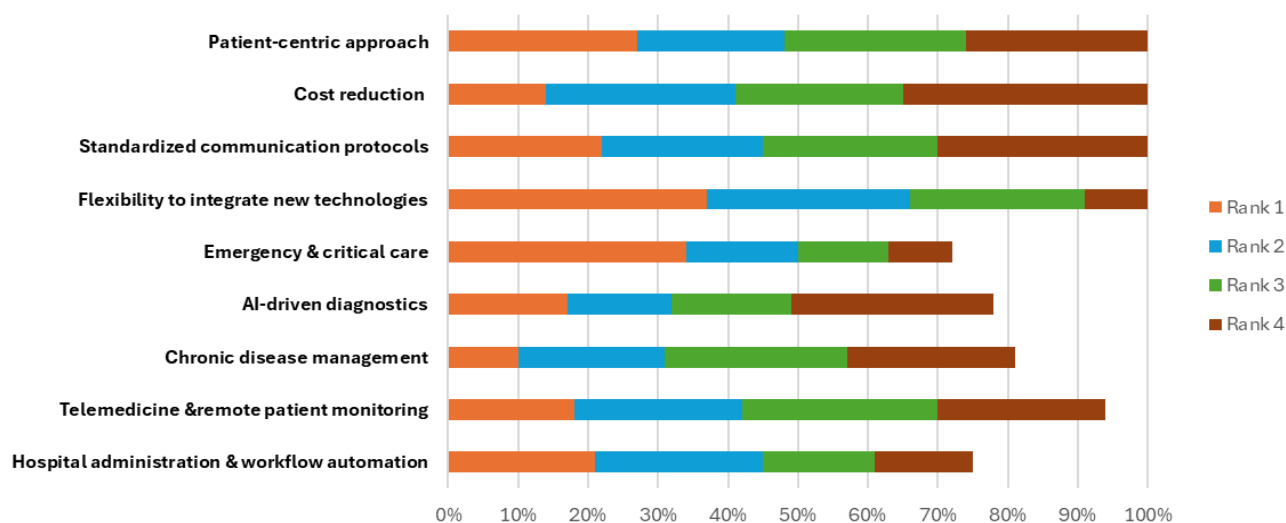


Figure 2: Priority and Design Considerations for Modular Healthcare Systems (Ranked in order of priority)

4.1.6 Mean Rankings of Priority Areas and Design Considerations for Modular Healthcare Systems

This cohort highlights the key functional and design priorities for implementing modular healthcare systems. Emergency and critical care emerged as the highest priority, followed by hospital administration and workflow automation, telemedicine and remote patient monitoring, AI-driven diagnostics, and chronic disease management. However, based on overall mean rankings, telemedicine and remote patient monitoring received the most favorable score (mean = 2.76, SD = 1.18), reflecting its perceived urgency and practical relevance. This was closely followed by emergency and critical care (mean = 2.81, SD = 1.65), hospital administration and workflow automation (mean = 2.98, SD = 1.50), chronic disease management (mean = 3.21, SD = 1.26), and AI-driven diagnostics (mean = 3.24, SD = 1.40). These results indicate a strong preference for technology-driven care models and systemic improvements as focal points for modular healthcare integration.

In terms of system design, standardized communication protocols emerged as the highest-ranked priority, with the lowest mean score (mean = 2.03, SD = 1.13), followed closely by flexibility to integrate new technologies (mean = 2.06, SD = 0.99). Patient-centric approaches were also considered important, with a moderate mean score (mean = 2.51, SD = 1.15), suggesting steady support across participants. In contrast, cost reduction through efficient resource use was relatively deprioritized, receiving the highest

mean score among design factors (mean = 2.80, SD = 1.07), indicating it was more often ranked lower. Overall, the findings underscore a clear inclination toward adaptable, interoperable, and patient-focused modular systems, with less emphasis on cost-saving as a primary driver (Figure 2).

Table 5b: Mean Rankings of Priority Areas and Design Considerations for Modular Healthcare Systems

		Mean	SD
Priority Areas for Modular Healthcare (Rank in order of priority)	AI-driven diagnostics	3.24	1.40
	Chronic disease management	3.21	1.26
	Hospital administration & workflow automation	2.98	1.50
	Emergency & critical care	2.81	1.65
	Telemedicine & remote patient monitoring	2.76	1.18
Design Priorities for Modular Healthcare Systems (Rank in order of priority)	Cost reduction	2.80	1.07
	Patient-centric approach	2.51	1.15
	Flexibility to integrate new technologies	2.06	0.99
	Standardized communication protocols	2.03	1.13

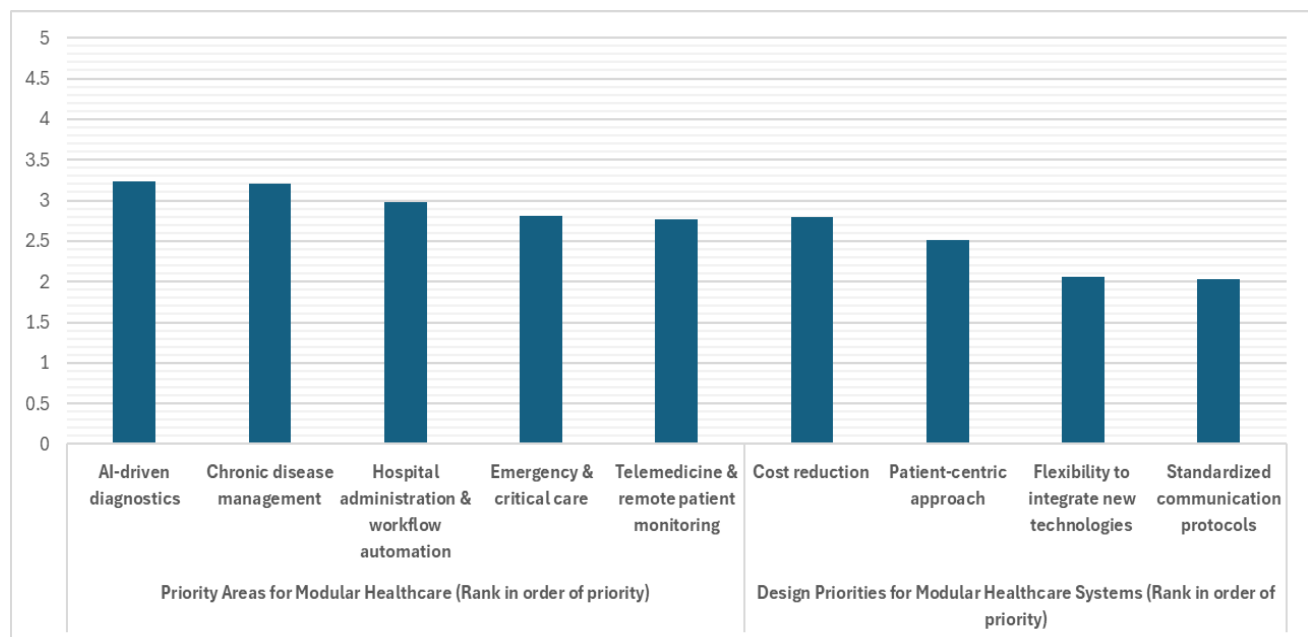


Figure 3: Mean Rankings of Priority Areas and Design Considerations for Modular Healthcare Systems

4.1.7 Association Between Demographic Characteristics and Perceived Importance of Modular Healthcare Systems

Analysis of the perceived importance of modular healthcare across demographic and professional groups revealed notable variations, depicted in table 6. Language appeared significantly associated with perceived importance ($p = 0.006$), with 85.7% of Arabic-speaking respondents ($N = 6$) considering modular healthcare not or moderately important, compared to only 30.1% ($N = 28$) of English-speaking respondents in that category; conversely, 69.9% ($N = 65$) of English speakers viewed it as very or extremely important. While differences among professions were not statistically significant ($p = 0.131$), trends showed that 84.6% ($N = 11$) of participants identifying as "Other," 80.0% ($N = 4$) of nurses, and 100.0% ($N = 1$) of policy makers rated modular healthcare as very or extremely important, in contrast to only 20.0% ($N = 1$) of hospital administrators. Professors and doctors also showed a favorable view, with 75.0% ($N = 9$) and 62.5% ($N = 40$), respectively, rating it highly. No statistically significant differences were observed by country of residence ($p = 0.397$), though higher support was seen in Saudi Arabia (77.8%, $N = 7$) and Qatar (65.9%, $N = 58$) compared to dual residents (33.3%, $N = 1$). Years of experience also showed no significant association ($p = 0.242$), though support for modular healthcare increased with experience: 52.0% ($N = 13$) in the 0–5 years group versus 77.8% ($N = 21$) in the 20+ years group. These findings suggest that language and cultural context may influence attitudes toward modular healthcare more strongly than profession or experience alone, highlighting the need for tailored communication and engagement strategies in promoting such systems.

Table 6: Association Between Demographic Characteristics and Perceived Importance of Modular Healthcare

		Perceived Importance of Modular Healthcare				
		Not or Moderately		Very or Extremely		P value
		Important		Important		
		N	Row %	N	Row %	
Language	Arabic	6	85.7%	1	14.3%	0.006*
	English (US)	28	30.1%	65	69.9%	
Profession	Doctor	24	37.5%	40	62.5%	0.131
	Professor	3	25.0%	9	75.0%	
	Hospital	4	80.0%	1	20.0%	
	Admin					
	Nurse	1	20.0%	4	80.0%	
	Policy Maker	0	0.0%	1	100.0%	
	Other	2	15.4%	11	84.6%	
Country of	Both	2	66.7%	1	33.3%	0.397
Residence	Qatar	30	34.1%	58	65.9%	
	Saudi Arabia	2	22.2%	7	77.8%	
Years of Experience	0 – 5 years	12	48.0%	13	52.0%	0.242
	6 – 10 years	4	40.0%	6	60.0%	
	11 – 20 years	12	31.6%	26	68.4%	
	20 + years	6	22.2%	21	77.8%	
Fisher’s Exact test						
Fisher–Freeman–Halton Exact test						
*p<0.05, Significant						

4.1.8 Association Between Perceived Importance of Modular Healthcare and Key System Characteristics

An analysis of factors influencing the perceived importance of modular healthcare revealed no statistically significant associations with most healthcare challenges identified in respondents' countries. For example, among those who did not identify cost as a major challenge, 69.4% (N = 43) viewed modular healthcare as very or extremely important compared to 60.5% (N = 23) of those who did, though this difference was not significant (p = 0.391). Similar trends were observed for accessibility (p = 0.504),

policies and regulations ($p = 0.639$), staff shortages ($p = 1.000$), non-communicable diseases ($p = 0.784$), technology limitations ($p = 1.000$), and other challenges ($p = 0.547$). Perceptions of healthcare system efficiency showed an upward trend in support for modular healthcare with higher perceived system quality, ranging from 50.0% ($N = 2$) in “poor” systems to 83.3% ($N = 20$) in “excellent” systems, though this was not statistically significant ($p = 0.113$).

Regarding underserved populations, support was highest among those identifying elderly patients (100.0%, $N = 4$) and “other” groups (100.0%, $N = 5$), but differences were again not significant ($p = 0.308$). Interestingly, respondents who did not use AI or automation were more likely to rate modular healthcare as very or extremely important (72.6%, $N = 45$) compared to users (55.3%, $N = 21$), though this trend approached but did not reach statistical significance ($p = 0.086$). Two barriers to digital health adoption showed significant associations: respondents who believed community acceptance was not a barrier were less likely (60.0%, $N = 45$) to support modular healthcare than those who identified it as a barrier (84.0%, $N = 21$; $p = 0.031$).

Additionally, trust issues had a strong inverse relationship: 75.4% ($N = 52$) of those who did not see trust as a barrier supported modular healthcare compared to only 45.2% ($N = 14$) among those who did ($p = 0.006$). These findings suggest that while general healthcare challenges and demographic factors had limited predictive value, attitudes toward modular healthcare are more strongly influenced by trust and perceived community openness to technological change.

Table 7: Association Between Perceived Importance of Modular Healthcare and Key System Characteristics

			Perceived Importance of Modular Healthcare				P value
			Not/Moderately Important		Very/Extremely Important		
			N	%	N	%	
Biggest Healthcare Challenges in Our Country (N=99)	Cost	No	19	30.6	43	69.4%	0.391
		Yes	15	39.5	23	60.5%	
	Accessibility	No	22	31.9	47	68.1%	0.504
		Yes	12	38.7	19	61.3%	
	Policies & Regulations	No	26	36.1	46	63.9%	0.639
		Yes	8	28.6	20	71.4%	
	Staff Shortage	No	22	33.8	43	66.2%	1.000
		Yes	12	34.3	23	65.7%	
	Non-Communicable Diseases	No	27	32.9	55	67.1%	0.784
		Yes	7	38.9	11	61.1%	
	Tech limitations	No	32	34.4	61	65.6%	1.000
		Yes	2	28.6	5	71.4%	
	Other	No	34	34.7	64	65.3%	0.547
		Yes	0	0.0	2	100.0%	
Healthcare System Efficiency Rate (N=99)	Poor	2	50	2	50.0%	0.113	
	Good	12	46.2	14	53.8%		
	Very Good	15	33.3	30	66.7%		
	Excellent	4	16.7	20	83.3%		
Underserved Populations (N=98)	Chronic disease patients	1	14.3	6	85.7%	0.308	
	Disabled	4	33.3	8	66.7%		
	Elderly patients	0	0.0	4	100.0%		
	Low-income groups	23	37.7	38	62.3%		
	Rural communities	4	44.4	5	55.6%		
	Other	0	0.0	5	100.0%		

Fisher's Exact test

Fisher-Freeman-Halton Exact test

*p<0.05, Significant

Table 7 (continued): Association Between Perceived Importance of Modular Healthcare and Key System Characteristics

			Perceived Importance of Modular Healthcare				
			Not/Moderately Important		Very/ Extremely Important		P value
			N	%	N	%	
Use of AI/Automation		No	17	27.4	45	72.6%	0.086
		Yes	17	44.7	21	55.3%	
Barriers to AI/Digital Health Adoption (N=98)	Cost	No	21	33.3	42	66.7%	1.000
		Yes	13	35.1	24	64.9%	
	Lack of training	No	12	40.0	18	60.0%	0.491
		Yes	22	31.4	48	68.6%	
	Community acceptance	No	30	40.0	45	60.0%	0.031
		Yes	4	16.0	21	84.0%	
	Trust issues	No	17	24.6	52	75.4%	0.006
		Yes	17	54.8	14	45.2%	
	Infrastructure	No	25	31.6	54	68.4%	0.437
		Yes	9	42.9	12	57.1%	
	Regulations	No	24	32.4	50	67.6%	0.634
		Yes	10	38.5	16	61.5%	
	Other factors	No	34	35.4	62	64.6%	0.269
		Yes	0	0.0	4	100.0%	

Fisher's Exact test

Fisher-Freeman-Halton Exact test

*p<0.05, Significant

4.1.9 Association Between Perceived Importance of Modular Healthcare and Key System Characteristics

A multiple linear regression analysis was conducted to examine predictors of the likelihood to recommend modular healthcare. Compared to Arabic speakers, those who preferred English had a slightly higher likelihood of recommending modular healthcare, but this was not statistically significant ($B = 0.220$, $p = 0.536$, 95% CI = -0.483 to 0.922). None of the professional categories showed statistically significant associations when compared to the reference group (Other); for example, doctors had a lower likelihood ($B = -0.249$, $p = 0.318$, 95% CI = -0.741 to 0.244), while policy makers showed a higher, though non-significant, tendency to recommend modular healthcare ($B = 1.425$, $p = 0.176$, 95% CI = -0.652 to 3.501). Regarding country of residence, individuals residing in both countries were less likely to recommend it ($B = -0.763$, $p = 0.282$, 95% CI = -2.164 to 0.637) compared to those living only in Saudi Arabia. Years of experience did not significantly predict recommendation likelihood, with values ranging from $B = -0.236$ (11–20 years, $p = 0.262$, 95% CI = -0.652 to 0.179) to $B = 0.189$ (20+ years, $p = 0.404$, 95% CI = -0.259 to 0.636). Similarly, use of AI/automation was not a significant predictor ($B = 0.188$, $p = 0.298$, 95% CI = -0.169 to 0.545). Overall, none of the examined demographic or professional factors were statistically significant predictors of the likelihood to recommend modular healthcare, suggesting that endorsement of modular care may be influenced by other factors beyond those included in this model.

Table 8: Linear Regression Analysis Predicting Likelihood to Recommend Modular Healthcare

Coefficients							
Model		Unstandardized Coefficients		Standardized Coefficients	95.0% Confidence Interval for B		P value
		B	Std. Error	Beta	Lower Bound	Upper Bound	
Language	Arabic	Ref	Ref	Ref	Ref	Ref	Ref
	English (US)	.220	.353	.070	-.483	.922	0.536
Profession	Doctor	-.249	.248	-.149	-.741	.244	0.318
	Hospital Admin	-.060	.455	-.016	-.963	.844	0.896
	Nurse	.425	.434	.115	-.437	1.288	0.330
	Policy Maker	1.425	1.045	.176	-.652	3.501	0.176
	Professor	.231	.346	.094	-.457	.919	0.506
	Other	Ref	Ref	Ref	Ref	Ref	Ref
Country of Residence	Both	-.763	.705	-.162	-2.164	.637	0.282
	Qatar	-.284	.309	-.115	-.898	.330	0.360
	Saudi Arabia	Ref	Ref	Ref	Ref	Ref	Ref
Years of Experience	0 – 5 years	Ref	Ref	Ref	Ref	Ref	Ref
	6 – 10 years	-.055	.315	-.020	-.681	.571	0.862
	11 – 20 years	-.236	.209	-.143	-.652	.179	0.262
	20 + years	.189	.225	.104	-.259	.636	0.404
Use of AI/Automation	No	Ref	Ref	Ref	Ref	Ref	Ref
	Yes	.188	.180	.114	-.169	.545	0.298

a. Dependent Variable: Likelihood to Recommend Modular Healthcare

4.2. Qualitative Results

4.2.1. Thematic Analysis of Open-Ended Responses

To deepen the understanding of stakeholder perspectives, a qualitative analysis was conducted on the open-ended responses from the bilingual survey (Arabic-English) distributed across Qatar and Saudi Arabia. Of the 100 total respondents, 76 provided substantive qualitative input, offering insights into contextual, cultural, and systemic factors shaping their views on modular healthcare, digital transformation, and innovation readiness.

Following Braun and Clarke's six-phase thematic analysis approach, qualitative data were manually coded and analyzed through an inductive process [60]. Codes were clustered into categories, which were then abstracted into higher-order themes. Five major themes were identified, each linked to core research objectives and hypotheses.

Theme 1: Systemic Fragmentation and the Demand for Integration

A dominant theme across both countries was the perceived fragmentation of healthcare services and the lack of integrated, interoperable systems. Respondents emphasized siloed workflows, inefficient patient handovers, and absence of centralized health records as contributors to medical errors, duplicated services, and administrative delays.

"We often repeat diagnostics because prior results are inaccessible. Interoperability is the biggest missing link." – Radiologist, Qatar

This theme reinforces the need for a modular architecture that supports interoperability and continuity of care, directly linked to hypothesis 1 (H1): modular systems can enhance operational efficiency.

Moreover, several participants alluded to poor communication between departments and providers, which erodes patient experience and increases operational cost:

"The journey from primary to tertiary care is chaotic. There's no shared patient roadmap." – Hospital Admin, KSA

Theme 2: Workforce Digital Readiness and Perceived Competency Gaps

Despite high support for modular innovation, many participants expressed concerns regarding digital literacy and workforce preparedness. The lack of training in AI, digital systems, and workflow automation was cited as a major inhibitor to adoption. This theme underscores the importance of capacity-building, which is a precondition for successful implementation.

“Nurses are still documenting manually. Without proper onboarding to digital tools, any AI module will fail.” — Nurse, Qatar

This aligns with both H1 and H2, suggesting that even if modular or AI systems are technically feasible, their value is constrained by human system limitations. It also ties to national strategies around workforce localization and upskilling.

Interestingly, early-career professionals were more optimistic:

“Younger clinicians are ready for AI, but the transition needs to be institutionalized through structured programs.” — Junior Doctor, KSA

Theme 3: Governance and Regulatory Uncertainty

Participants expressed significant unease regarding the lack of clear regulatory frameworks, particularly surrounding AI in diagnostics, patient data protection, and modular procurement models. This regulatory ambiguity inhibits experimentation and delays institutional investment in modular solutions.

“We don’t have clarity on data ownership with AI systems. Hospitals are afraid of lawsuits.” — Doctor, Qatar

Concerns were also raised about misalignment between policy ambitions and actual infrastructure:

“Vision 2030 is visionary, but on-ground rules are outdated. The legal system isn’t ready for autonomous systems.” — Manager, KSA

This finding stresses the importance of policy innovation as an enabler of technical innovation. It also suggests a top-down strategic roadmap is required to align modular deployment with existing legal systems and public trust.

Theme 4: Conceptual Support for Modularity Coupled with Cognitive Dissonance

While 99% of respondents supported the idea of modular healthcare, only 3% had direct experience with it. This discrepancy created a noticeable cognitive dissonance: while the perceived benefits were strong (flexibility, scalability, patient-centricity), actual understanding was often limited or inconsistent.

“The term is new to me, but the idea of building care around patient needs using smaller components makes perfect sense.” — General Practitioner, Qatar

This indicates an opportunity for conceptual education and localized demonstration projects. Respondents expressed a desire for case studies, simulations, and pilot programs to help translate theory into practical frameworks.

“If we can see real-world examples of how modularity works, it’ll be easier to adapt it to our systems.” — Doctor, KSA

This theme supports the need for co-created frameworks and reinforces the role of stakeholder education in system transformation.

Theme 5: Trust, Cultural Perception, and Ethical Acceptance of AI

Perhaps the most culturally rooted theme was that of trust in AI-driven care and the cultural dynamics surrounding patient acceptance. Respondents cited varying levels of skepticism toward AI in clinical decision-making often linked to generational, linguistic, or religious considerations.

“Patients still expect decisions from doctors, not machines, especially in mental health and women’s health.” — Doctor, Qatar

Concerns about automation bias, depersonalization of care, and algorithmic transparency were also raised. This theme aligns with Hypothesis 2 (H2) by illustrating that the success of AI depends not only on its performance but also on its social and ethical embedding.

“Trust isn’t just technical, it’s cultural. If people don’t understand how AI works, they won’t allow it to decide for them.” — Public Health Researcher, KSA

4.2.2. Synthesis and Implications

These five themes highlighted in table 9 are the interconnected nature of technical, cultural, institutional, and human factors in the Middle East healthcare context. They serve to triangulate the quantitative findings, particularly the barriers and support levels captured in survey Tables 2–4.

Table 9: Thematic Insights Linked to Strategic Enablers of Scalable Modular Healthcare Systems

Theme	Strategic Integration
Systematic Fragmentation	Prioritize interoperability and data integration
Workforce Digital Readiness	Embed digital health training into national upskilling programs
Regulatory Ambiguity	Develop modularity and AI-specific policy frameworks
Conceptual Gaps	Launch awareness campaigns and pilot demonstration projects
Cultural Trust in AI	Localize AI ethics and enhance patient-provider communication

5. Discussion

As healthcare systems in the Middle East undergo rapid digital transformation, the voices of clinicians, administrators, and policymakers reveal both a strong appetite for innovation and persistent structural challenges. This chapter explores how stakeholder insights captured through quantitative and qualitative data converge around key systemic barriers such as fragmentation, limited digital readiness, and regulatory uncertainty. These findings are interpreted in the context of national healthcare strategies in Qatar and Saudi Arabia, and in relation to the study's hypotheses. The discussion not only validates the demand for scalable, patient-centric healthcare systems but also establishes a clear rationale for the modular architecture proposed in Chapter 6.

The first hypothesis of the study proposed that a scalable modular healthcare architecture would be perceived as a valuable solution to improving patient care and operational efficiency across diverse healthcare settings in the Middle East. This hypothesis is strongly supported by the data. The overwhelming majority of respondents (99%) expressed support for modular healthcare, and 66% rated it as "very" or "extremely important." However, only a small minority (3%) reported prior experience with modular systems. This finding suggests a significant gap between conceptual endorsement and practical exposure, a gap that is not uncommon in emerging health systems undergoing digital transformation. This trend is also reflected in similar studies. For example, Al-Kuwaiti et al. (2021) found that while healthcare professionals in the Gulf region recognized the potential of modular digital platforms to improve care coordination, actual adoption remained low due to lack of training and organizational readiness [62]. Likewise, Alami et al. (2020) observed that although there is strong stakeholder enthusiasm for modular and interoperable systems across Middle Eastern countries, real-world implementation is hampered by institutional inertia and fragmented IT infrastructure [63]. These findings align closely with the present study, reinforcing the idea that awareness and support for modularity exist, but are not yet matched by operational capabilities or strategic execution.

Qualitative responses revealed widespread dissatisfaction with current care delivery models, which were described as fragmented, siloed, and administratively burdensome. The perceived lack of interoperability, continuity of care, and responsiveness to patient needs was consistently highlighted across both countries. This result can be partly explained by the historical development of healthcare infrastructure in the region, where rapid parallel growth—particularly across public and private sectors—has often occurred without the guidance of unified national digital health strategies [64]. As a consequence, many institutions rely on proprietary systems with low interoperability, impeding the development of patient-centric, scalable solutions [63]. These insights reinforce the notion that

modularity, when effectively implemented, can serve as a foundational design principle to overcome legacy inefficiencies and support sustainable innovation in digital health.

The second hypothesis posited that the integration of AI and automation, when adapted to local system needs, is perceived as a promising strategy for enhancing care quality and cost-effectiveness. While adoption of AI tools remains relatively limited (38% of respondents reported current use), the potential benefits were widely acknowledged. Two-thirds of respondents (67.7%) believed AI could reduce clinician workload, while others cited improvements in diagnostic accuracy and patient outcomes. Nonetheless, several barriers were clearly articulated, including lack of training (71.4%), implementation cost (37.8%), and trust in automation (31.6%). These findings are consistent with previous studies in the region and globally. A cross-country study by Hamid et al. (2021) across GCC countries similarly found that while healthcare providers expressed optimism about AI's potential to improve diagnostics and streamline workflows, major concerns included workforce readiness, infrastructure limitations, and mistrust in autonomous systems [65]. Another study by Khairat et al. (2019) in the MENA region reported that AI adoption in clinical settings often stalls due to the absence of robust training programs and clear ethical frameworks, despite strong conceptual endorsement by healthcare leaders [66]. These parallels reinforce the validity of the present study's findings and suggest that such barriers are not unique to Qatar and Saudi Arabia but are shared across emerging digital health ecosystems.

The qualitative data deepened this understanding, illustrating how resistance to AI is shaped not only by practical gaps but also by ethical, cultural, and emotional concerns. Clinicians working in sensitive areas such as mental health and women's health expressed particular hesitation, citing a preference for human interaction and concerns over algorithmic decision-making. This echoes findings from recent reviews and regional studies, which emphasize that AI tools in culturally sensitive specialties require stronger trust-building measures, clear accountability, and localized training before clinicians will adopt them [67,68,69]. These findings suggest that AI implementation must go beyond technological readiness to include workforce training, regulatory clarity, and cultural alignment.

Thematic analysis provided further insight into the institutional, behavioral, and policy level constraints facing healthcare innovation. Five core themes were identified: systemic fragmentation, workforce digital readiness, regulatory ambiguity, conceptual gaps in modularity, and trust in AI. Each theme reflects a broader structural challenge but also points toward an actionable design need. Respondents described healthcare systems as disconnected and inefficient, with minimal data sharing across providers. This lack of integration leads to duplicated diagnostics, administrative errors, and delayed treatment issues that modular systems are specifically designed to resolve.

The theme of digital readiness emphasized uneven levels of technical proficiency across staff roles, with nurses and administrative personnel frequently described as underprepared to adopt AI or automated workflows. This limitation poses a serious risk to implementation, as it suggests that even well-designed systems may fail if end-user needs are not adequately considered. This aligns with recent evidence highlighting low digital competencies among healthcare professionals, particularly nurses, as a persistent barrier to digital innovation in MENA, despite broader investments in digital health infrastructure [70,71]. These findings suggest that AI implementation must go beyond technological readiness to include workforce training, regulatory clarity, and cultural alignment.

Regulatory concerns also emerged as a recurring barrier. Participants reported uncertainty around data governance, liability in AI decision-making, and procurement standards for modular systems. This finding emphasizes the need for policy frameworks to evolve alongside technological innovation, ensuring that innovation does not outpace legal and ethical safeguards. Similar conclusions were drawn by WHO EMRO (2022), which emphasized the urgency of establishing AI governance frameworks in Middle Eastern health systems to guide procurement, ethical oversight, and data sovereignty [72].

Perhaps the most notable finding was the disconnect between high conceptual support for modularity and the lack of real-world familiarity or visibility into how modular systems function. While the term “modularity” resonated with participants, many had difficulty articulating what it meant in practical terms. This suggests that stakeholder engagement and demonstration projects will be crucial to closing the implementation gap. Comparable challenges have been described by Zhang et al. (2025), who found that modular health IT frameworks in Asia and Latin America gained traction only after successful pilot implementations demonstrated their tangible value to clinicians and managers [73].

Finally, the theme of trust in AI highlighted a complex interplay of social, generational, and cultural factors that influence acceptance of automation in care delivery. These findings collectively underscore that successful healthcare transformation requires more than new tools; it demands alignment across people, processes, policies, and platforms.

The modular healthcare architecture developed as part of this study, and presented in Chapter 6, is designed to directly respond to these challenges. It is structured around seven core layers: patient access, clinical workflow, AI analytics, interoperability, privacy and consent, modular service nodes, and a business layer. Each of these components addresses a specific barrier identified in the research. For example, interoperability challenges are met through HL7 and FHIR-based APIs, while workforce training gaps are addressed through role-based dashboards and embedded user support tools. The inclusion of blockchain-backed consent and PDPL/CBAHI compliance mechanisms reflects the regulatory concerns

expressed by stakeholders, while the use of multilingual chatbot triage and culturally adjusted screening tools responds to the issue of trust and cultural fit. The architecture is thus not a generic technical solution but a contextualized system tailored to the operational and cultural dynamics of healthcare in the Gulf.

This framework is also aligned with regional health policy strategies. In Qatar, it supports the goals of the NHS 2024–2030 by enabling digital-first service clusters, genomic linkage, and patient data centralization. In Saudi Arabia, it complements Vision 2030 objectives by enabling remote service delivery, public-private partnerships, and population-level analytics. It also adheres to international best practices, including WHO and OECD principles of interoperability, equity, and ethical innovation.

Despite these strengths, the study has several limitations. The sample was disproportionately composed of Qatar-based respondents, limiting regional generalizability. Most responses were also in English, which may have filtered perceptions through a particular linguistic and professional demographic. Furthermore, while the qualitative data provided valuable insights, it was limited to open-ended survey responses. Future studies could expand this work through in-depth interviews, focus groups, or longitudinal pilot testing. Finally, while the proposed framework is grounded in real-world tools and stakeholder input, it remains a conceptual model that requires field validation.

In summary, the study provides strong support for both hypotheses and offers a data-informed path forward for healthcare system innovation in the Middle East. The modular healthcare architecture developed in this research is more than a design; it is a strategic response to real barriers expressed by clinicians, administrators, and policymakers. It reflects the region's readiness to embrace transformation, provided that such systems are thoughtfully implemented, culturally adapted, and supported by policy and training infrastructure. The next chapter introduces this framework in full detail.

6. Proposed Modular Healthcare Framework

The proposed modular healthcare architecture emerges as a direct response to the unmet needs, operational inefficiencies, and stakeholder insights identified throughout the research. Designed to overcome the fragmentation and rigidity of current healthcare systems in the Middle East, the framework offers a scalable, patient-centric model grounded in interoperability, automation, and ethical AI integration. It reflects the realities of clinical practice in both urban and remote contexts, while remaining adaptable to national strategic goals such as Qatar's NHS 2024–2030 and Saudi Arabia's Vision 2030. Informed by both data and policy, the architecture aims to serve as a blueprint for healthcare transformation in the region.

The framework is structured around five core design principles:

1. **Modularity:** Each function of the system is decoupled into discrete, interoperable modules. These can be deployed independently or in combination, allowing for flexible scaling and customization based on facility size, location, or specialty.
2. **Interoperability:** The architecture uses HL7 FHIR, DICOM, and ISO 12967 standards to enable seamless communication between internal modules and external health information systems. This ensures continuity of care and reduces duplication across providers.
3. **Patient-Centricity:** The framework places patient needs and experience at its core. This includes culturally sensitive design, multilingual support, biometric access, and AI-driven triage that respects individual privacy and autonomy.
4. **AI-Enabled Decision Support:** AI models are integrated into diagnostic and triage processes to enhance clinical accuracy, reduce clinician workload, and optimize system efficiency. The architecture allows for ethical, transparent deployment of AI based on contextual risk.
5. **Data Privacy and Security:** Security mechanisms are embedded throughout the architecture, including blockchain-backed consent, role-based access control (RBAC), and compliance with Qatar's PDPL and Saudi Arabia's CBAHI regulations.

6.1. Modular Healthcare System Architecture Overview

The architecture, shown below, is composed of seven interoperable layers, each serving a distinct function. The design ensures that services can be introduced progressively or adapted to local context without full infrastructure overhauls.

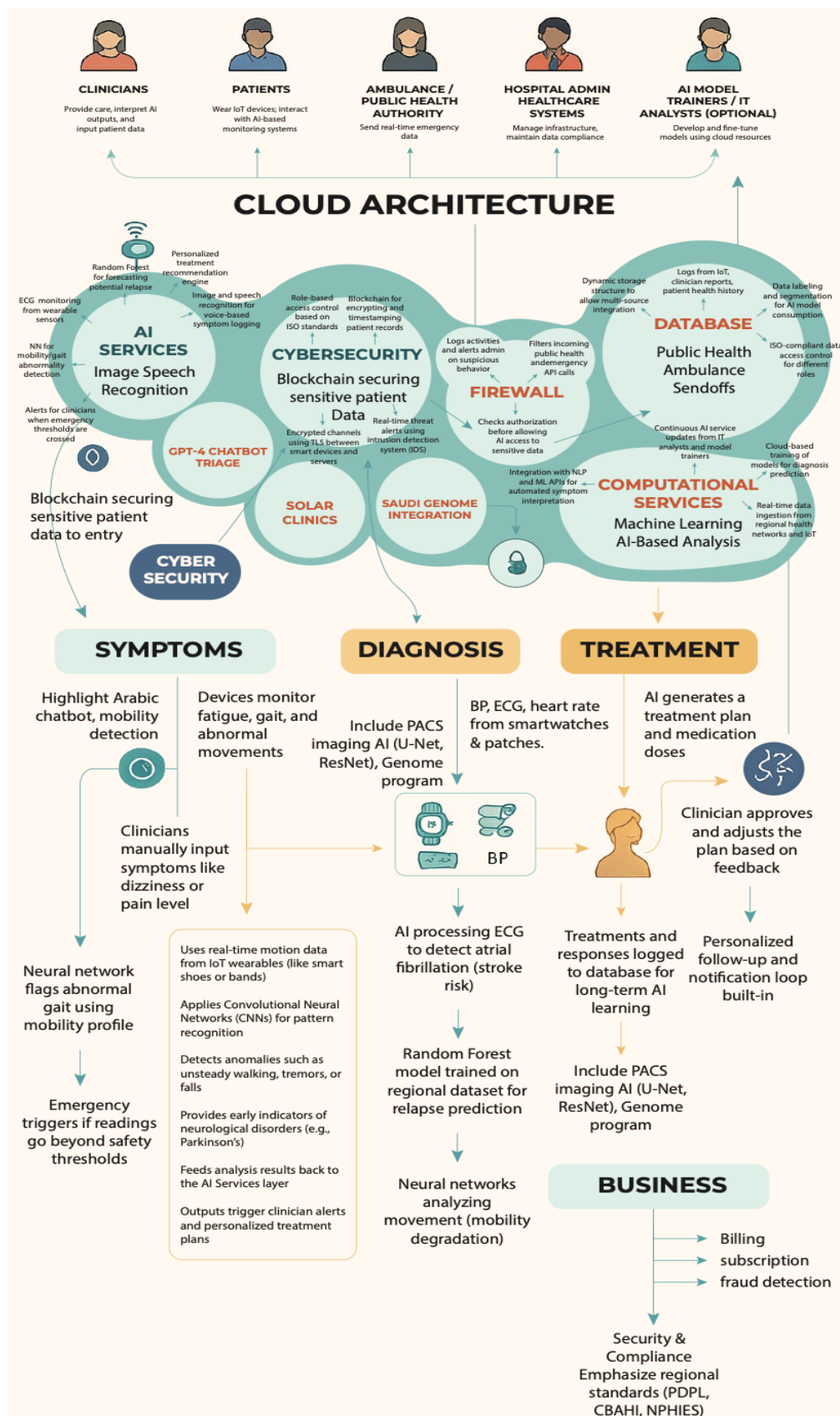


Figure 4: Modular Healthcare System Architecture

6.2. Architectural Layers

Table 10: Modular healthcare system architecture layers

Layer	Component	Function/Description
Patient Access and Identity Layer	Biometric facial recognition login	Uses national IDs (e.g., QID or Tawakkalna) for secure, patient-verified login.
	Multilingual chatbot	Facilitates symptom triage and appointment scheduling across diverse populations.
	AI-enhanced PHQ-9 and GAD-7 screeners	Structured intake tools for mental health assessment.
	Document upload system	Allows uploading of insurance cards, prescriptions, referrals.
Clinical Workflow Layer	SOAP templates	Standardized format for clinical documentation.
	Voice-to-text integration	Enables efficient clinical data entry.
	Real-time decision support	Alerts for missing vitals or clinical flags.
	Smart referral system	Maintains feedback loops for continuity of care.
AI and Analytics Layer	AI model integration	U-Net (radiology), LSTM (triage), ResNet (diagnostics).
	Predictive analytics	Detects readmission risk, patient deterioration, and fraud.
	Chatbot sentiment analysis	Flags mental health concerns based on user interaction.
	Customizable dashboards	Provides real-time insights for clinical decision-making.
Interoperability Layer	HL7 and FHIR APIs	Enables integration with external EHR systems.
	DICOM image sharing	Supports medical imaging with embedded viewers.
	Data lake infrastructure	Handles both structured and unstructured health data.
Interoperability Layer	Standards compliance	Aligns with ICD-10, SNOMED, and LOINC coding.

Table 10 (continued): Modular healthcare system architecture layers

Layer	Component	Function/Description
Consent, Privacy, and Audit Layer	Blockchain consent registry	Offers patient-controlled access to health data.
	Smart contracts	Manages access authorization and revocation.
	Immutable audit trails	Ensures traceability for internal and external audits.
	RBAC (Role-Based Access Control)	Differentiated access for clinicians, staff, insurers, and regulators.
Consent, Privacy, and Audit Layer	Smart contracts	Manages access authorization and revocation.
	RBAC (Role-Based Access Control)	Differentiated access for clinicians, staff, insurers, and regulators.
Modular Service Nodes	Portable clinical stations	For primary care, radiology, and mental health services.
	IoT-enabled diagnostics	Telehealth-ready vital sign monitoring tools.
	Lab and pharmacy kiosks	Integrated with backend APIs.
	Mental health pods	Equipped with NLP triage and remote consultation.
Administrative and Business Layer	Real-time cost and ROI tools	Assesses modular deployment viability.
	NPHIES and insurance integration	Connects with KSA health and insurance systems.
	AI-as-a-Service and data marketplace	Business modeling for monetizing AI tools and datasets.
	Fraud detection	Uses risk models for claim and billing integrity.

6.3. Implementation Roadmap

A phased approach is recommended to support controlled rollout and stakeholder engagement:

Table 11: Implementation timeline, objectives and key activities

Phase	Timeline	Objective	Key Activities
Phase 1	Months 0–6	Co-Creation and Pilot Simulation	- Stakeholder engagement (clinicians, patients, regulators) - Build low-fidelity prototypes - Conduct workshops and usability testing - Refine architecture based on early feedback
Phase 2	Months 7–15	Urban Clinical Deployment	- Implement access, consent, and AI triage layers in urban outpatient clinics - Train staff on new tools and workflows - Monitor digital literacy and patient experience
Phase 3	Months 16–24	Remote and Rural Expansion	- Deploy portable modular nodes (e.g., diagnostic pods, mental health kiosks) - Integrate IoT-enabled vitals and wearables - Tailor UX for multilingual and offline access
Phase 4	Months 25–36	Systemwide Integration	- Connect to national health systems (NPHIES, SEHA, QID-EHR) - Enable cross-facility data sharing - Align with insurance, lab, and pharmacy networks
Phase 5	Months 37–48	Scale and Innovation	- Roll out commercial models (AI-as-a-Service, PPPs, bundled care) - Embed analytics for outcomes, equity, and ROI - Develop playbooks for replication in other regions

Each phase includes embedded monitoring, with patient, clinician, and administrative feedback loops to ensure:

- Ethical AI behavior
- Cultural and linguistic fit
- Clinical effectiveness
- Policy compliance

The proposed modular healthcare framework is closely aligned with both national priorities and international digital health standards. In Qatar, it supports the objectives of the National Vision 2030 and NHS 2024–2030 by enabling the integration of health clusters, advancing the digitization of primary care, and facilitating patient-centered pathways, particularly in genomics and mental health.

To further ground these findings, it is useful to situate them within established theoretical models. The Technology Acceptance Model (TAM), for example, underscores that perceived usefulness and ease of use are key predictors of adoption, both of which are supported in this study's findings [60]. Moreover, WHO's Digital Health Framework and OECD's policy recommendations for trustworthy AI emphasize not

only technical feasibility but also the necessity of user trust, regulatory alignment, and long-term sustainability. The modular architecture proposed in this thesis embodies these global standards while remaining tailored to local constraints and opportunities.

The framework's emphasis on interoperability and ethical AI also aligns with national efforts such as the Qatar Genome Programme and emerging mental health initiatives. In Saudi Arabia, the architecture complements the country's Vision 2030 by reinforcing SEHA Virtual Hospital strategies, integrating with the NPHIES platform, and expanding modular services to rural and underserved areas. Its design supports ongoing healthcare privatization goals and aligns with the evolution of insurance reimbursement models.

More broadly, the framework adheres to global principles established by the World Health Organization (WHO) and the Organisation for Economic Co-operation and Development (OECD), including standards for digital interoperability, system resilience, trust, and transparency.

This discussion also reveals how the core thematic findings; fragmentation, readiness, regulation, conceptual clarity, and trust were each explicitly addressed in the modular system's design. Rather than imposing a static model, the architecture enables progressive, adaptable implementation. For instance, facilities with limited digital maturity can begin with basic triage and referral nodes, while advanced systems can adopt AI-enabled diagnostics and national-scale interoperability.

Despite these strengths, the study has several limitations. The sample was disproportionately composed of Qatar-based respondents, limiting regional generalizability. Most responses were also in English, which may have filtered perceptions through a particular linguistic and professional demographic. Furthermore, while the qualitative data provided valuable insights, it was limited to open-ended survey responses. Future studies could expand this work through in-depth interviews, focus groups, or longitudinal pilot testing. Finally, while the proposed framework is grounded in real-world tools and stakeholder input, it remains a conceptual model that requires field validation.

In summary, this study provides empirical support for a modular approach to healthcare transformation in the Gulf region. More than a technical design, the framework reflects a strategy to reconcile policy goals, stakeholder needs, and operational constraints. It demonstrates that innovation must be grounded in contextual intelligence aligning human, organizational, and regulatory factors to ensure real-world impact. The next chapter presents the full architecture and phased implementation roadmap in detail.



7. Conclusion

This thesis set out to explore the unmet healthcare needs of two rapidly transforming Gulf nations, Qatar and Saudi Arabia, and to propose a modular, patient-centric healthcare architecture aligned with regional strategies such as Qatar's NHS 2024–2030 and Saudi Arabia's Vision 2030. By integrating stakeholder insights, literature benchmarking, and business–technology alignment, the study provides a contextualized model for scalable digital healthcare transformation.

The research confirmed two central hypotheses: first, that a modular digital health architecture is perceived as a valuable approach to improving healthcare system efficiency and patient-centeredness; and second, that AI and automation, when thoughtfully integrated, are seen as promising yet underutilized tools for enhancing care delivery. While support for modularity was near-universal, familiarity and practical experience with such systems were low—indicating a pressing need for awareness-building and real-world pilot implementation. Similarly, enthusiasm for AI was tempered by concerns around trust, training, and cultural fit.

To address these findings, the study proposed a layered modular framework, grounded in stakeholder feedback and designed to overcome key barriers such as system fragmentation, uneven digital readiness, and regulatory uncertainty. This architecture incorporates principles of modularity, interoperability, AI integration, patient empowerment, and data security. Crucially, it is not presented as a rigid blueprint but as an adaptable roadmap tailored to the evolving needs and capacities of diverse healthcare settings.

The implications of this research are both practical and strategic. Practically, the proposed framework offers policymakers, system designers, and healthcare administrators a structured pathway to modernize healthcare delivery in phases. Strategically, it contributes to the broader discourse on healthcare innovation in emerging markets by demonstrating that transformation efforts must be context-driven, inclusive, and ethically grounded. In regions like the Middle East—where top-down digital visions are abundant but implementation challenges persist—this work provides a bridge between aspiration and actionable design.

While the sample leaned heavily toward Qatar-based stakeholders, the findings remain broadly relevant to the Gulf region due to the shared healthcare governance structures, digital health priorities, and policy frameworks present across GCC countries. Nevertheless, the lack of in-depth interviews and absence of real-world deployment restrict the conclusions to a conceptual level. Future research should therefore focus on piloting the framework in selected facilities, testing both its clinical and economic impacts, and refining it through continuous stakeholder feedback.

In closing, the modular healthcare system proposed here is not an endpoint, but a beginning—a foundation for building more integrated, intelligent, and inclusive healthcare systems in the Middle East. As the region continues its digital transformation journey, success will depend not only on the tools adopted but also on how well they align with the people, policies, and purposes they are meant to serve.

References

1. Vision 2030 Kingdom of Saudi Arabia. Riyadh: Council of Economic and Development Affairs; 2016. Available from: <https://vision2030.gov.sa/>
2. General Secretariat for Development Planning. Qatar National Vision 2030. Doha: State of Qatar; 2008. Available from: <https://www.gco.gov.qa/en/about-qatar/national-vision2030/>
3. Almalki M, Fitzgerald G, Clark M. Health care system in Saudi Arabia: an overview. *East Mediterr Health J.* 2011;17(10):784–93. Available from: https://applications.emro.who.int/emhj/v17/10/17_10_2011_0784_0793.pdf
4. Alasiri AA, Mohammed V. Healthcare transformation in Saudi Arabia: an overview since the launch of Vision 2030. *J Med Life.* 2022;15(4):505–509. doi:10.25122/jml-2022-0070
5. Topol E. Deep medicine: how artificial intelligence can make healthcare human again. New York: Basic Books; 2019. Available from: <https://dl.acm.org/doi/10.5555/3350442>
6. World Health Organization. Ethics and governance of artificial intelligence for health: WHO guidance. Geneva: World Health Organization; 2021. Available from: <https://www.who.int/publications/i/item/9789240029200>
7. Haider S, Eitel A, Osman A, Kim J, Muehlematter UJ, Akbar Z, et al. Addressing the healthcare needs with Innovation Think Tank global infrastructure and its methodology. In: Holzinger A, Kieseberg P, Tjoa AM, Weippl E, editors. *Machine learning and principles and practice of knowledge discovery in databases*. Cham: Springer; 2022. p. 642–658. doi:10.1007/978-3-031-08191-0_45
8. Siemens Healthineers. Innovation Think Tank: healthcare system framework white paper. Erlangen: Siemens Healthineers; 2021. Available from: https://marketing.webassets.siemens-healthineers.com/7d1104582b9c32c6/853f1604ebc8/siemens-healthcare_itt_white_paper_healthcare_system_framework.pdf
9. Al-Khaldi YM. The development of the Qatar healthcare system: a review of the literature. *Health.* 2014;6(5):284–290. doi:10.4236/health.2014.65040. Available from: <https://www.scirp.org/journal/paperinformation?paperid=55024>

10. Almutairi AF. The effect of cultural competency training programs on expatriate nurses' levels of cultural competence in Saudi Arabia as measured by the Inventory for Assessing the Process of Cultural Competence (IAPCC-R) [dissertation]. Birmingham (AL): University of Alabama at Birmingham; 2015. Available from: <https://digitalcommons.library.uab.edu/cgi/viewcontent.cgi?article=3880&context=etd-collection>
11. Al-Mohaimed A. Promoting health and well-being in Saudi Arabia: priorities for action. *East Mediterr Health J*. 2012;18(12):1239–1246. Available from: https://applications.emro.who.int/emhj/v18/12/EMHJ_2012_18_12_1239_1246.pdf
12. Al-Zalabani AH. Prioritizing health promotion in Saudi Arabia. *Int J Health Sci (Qassim)*. 2011;5(2):125–129. Available from: https://manara.qnl.qa/articles/online_resource/Prioritizing_health_promotion_in_Saudi_Arabia/23954820?file=42005190
13. Alanzi T. The role of digital health in the Saudi health care system: a review. *Cureus*. 2021;13(2):e12903. doi:10.7759/cureus.12903. Available from: <https://assets.cureus.com/uploads/editorial/pdf/329000/20250129-302781-17qkxo.pdf>
14. Alsanabel Center. Cultural influences on mental health: Qatar 2024. Doha: Alsanabel; 2024 [cited 2025 June 21]. Available from: <https://alsanabel.qa/en/cultural-influences-on-mental-health-qatar-2024/>
15. Al-Mandhari A, Al-Zakwani I, Al-Kindi M, Al-Shafae M, El-Shafie O. Health promotion practices as perceived by primary healthcare professionals at the Ministry of National Guard Health Affairs, Saudi Arabia. *Qatar Med J*. 2016;2016(4):4. doi:10.5339/qmj.2016.4. Available from: <https://www.qscience.com/content/journals/10.5339/qmj.2016.4>
16. Shammari EA, Bashir M, Elhassan NM. Bridging the generational gap between nurses and nurse managers: a qualitative study from Qatar. *BMC Nurs*. 2024;23:32. doi:10.1186/s12912-024-01588-0. Available from: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC10960732/>
17. Pattison N, Alshraim M, Al-Kuwari F, Al-Kaabi A, Al-Kubaisi M, Al-Khalifa F, et al. How nurses can provide culturally competent care in Qatar: a qualitative study. *BMC*

- Nurs.* 2024;23:75. doi:10.1186/s12912-024-02296-y. Available from: <https://bmcnurs.biomedcentral.com/articles/10.1186/s12912-024-02296-y>
18. **Hospital Design Hub.** The importance of cultural sensitivity in hospital design in Qatar. 2023 [cited 2025 June 21]. Available from: <https://hospitaldesignhub.com/hospital-deisggn-hub-the-importance-of-cultural-sensitivity-in-hospital-design-in-qatar/>
 19. **Star Nursing Co.** How nurses can provide culturally competent care in Qatar. 2024 [cited 2025 June 21]. Available from: <https://starnursingco.com/blog/how-nurses-can-provide-culturally-competent-care-in-qatar>
 20. **P4H Network.** Qatar Healthcare Services Law No. 22 of 2021 effective as of 4 May 2022. 2022 [cited 2025 June 21]. Available from: <https://p4h.world/en/news/qatar-healthcare-services-law-no-22-of-2021-effective-as-of-4-may-2022/>
 21. **Library of Congress.** Qatar: health insurance now required for obtaining entry visas. *Global Legal Monitor.* 2023 Jun 12 [cited 2025 June 21]. Available from: <https://www.loc.gov/item/global-legal-monitor/2023-06-12/qatar-health-insurance-now-required-for-obtaining-entry-visas/>
 22. **Almutairi AF.** Relating Almutairi's critical cultural competence model for healthcare providers transitioning to Qatar. *J Multidiscip Healthc.* 2022;15:2161–2169. doi:10.1177/11786329221121214. Available from: <https://www.researchgate.net/publication/324500264>
 23. **Clyde & Co.** New mandatory health insurance system introduced in Qatar. 2021 Dec 1 [cited 2025 June 21]. Available from: <https://www.clydeco.com/en/insights/2021/12/new-mandatory-health-insurance-system-introduced-i>
 24. **P4H Network.** Qatar unveils National Health Strategy 2024–2030 with ambitious goals for health and well-being. 2024 [cited 2025 June 15]. Available from: <https://p4h.world/en/documents/qatar-unveils-national-health-strategy-2024-2030-with-ambitious-goals-for-health-and-well-being/>
 25. **Global Alliance for Genomics and Health (GA4GH).** Qatar Genome Program. 2024 [cited 2025 June 21]. Available from: https://www.ga4gh.org/driver_project/qatar-genome-program/

26. **Hamad Medical Corporation.** Qatar National Screening Program – English. Doha: HMC; 2023 [cited 2025 June 21]. Available from: <https://www.hamad.qa/en/your%20health/patient%20and%20family%20education%20unit/publications/diseases-and-care/maternal-and-child/maternal%20and%20child/qatar%20national%20screening%20program%20-%20english.pdf>
27. **Qatar Biobank.** Qatar Biobank official website. Doha: Qatar Foundation; 2024 [cited 2025 June 21]. Available from: <https://www.qatarbiobank.org.qa/>
28. **Qatar Foundation.** Qatar Biomedical Research Institute. Doha: Qatar Foundation; 2024 [cited 2025 June 21]. Available from: <https://www.qf.org.qa/research/qatar-biomedical-research-institute>
29. **Qatar Science & Technology Park.** Qatar Foundation's QSTP to host AI Week marking 15th anniversary of Science Park. 2024 [cited 2025 June 21]. Available from: <https://qstp.org.qa/qatar-foundations-qstp-to-host-ai-week-marking-15th-anniversary-of-science-park/>
30. **Qatar Science & Technology Park.** 'Qatar is ready to lead' the new era of AI, says H.E. Reem Al Mansouri at QSTP AI Week 2024. 2024 [cited 2025 June 21]. Available from: <https://qstp.org.qa/qatar-is-ready-to-lead-the-new-era-of-ai-says-h-e-reem-al-mansouri-at-qstp-ai-week-2024/>
31. **Planning and Statistics Authority, State of Qatar.** Qatar Third National Development Strategy 2024–2030. Doha: PSA; 2024 [cited 2025 June 21]. Available from: <https://andp.unescwa.org/sites/default/files/2024-06/Qatar%20Third%20National%20Development%20Strategy%202024-2030.pdf>
32. **Weill Cornell Medicine–Qatar.** Cultural competence in medical education. Doha: Weill Cornell Medicine–Qatar; 2023 [cited 2025 June 21]. Available from: <https://qatar-weill.cornell.edu/continuing-professional-development/topic-of-the-month/archive/cultural-competence-in-medical-education>
33. **Kingdom of Saudi Arabia.** رؤية السعودية 2030 [Saudi Vision 2030]. Riyadh: Government of Saudi Arabia; 2016 [cited 2025 June 21]. Available from: <https://www.vision2030.gov.sa/ar/>

34. **Al-Zalabani AH, Kasim KA.** Prevalence and predictors of obesity and overweight among adults in Saudi Arabia: a cross-sectional study. *East Mediterr Health J.* 2020;26(4):468–476. doi:10.26719/2020.26.4.8. Available from: <https://applications.emro.who.int/emhj/v26/04/10203397-2020-2604-468-476.pdf>
35. **Ministry of Finance, Kingdom of Saudi Arabia.** First quarter budget performance report 2024. Riyadh: Ministry of Finance; 2024 [cited 2025 June 21]. Available from: <https://www.mof.gov.sa/en/financialreport/2024/Documents/Q1E%202024-%20F.pdf>
36. **Al-Mohaimed A.** Noncommunicable diseases in Saudi Arabia: toward effective interventions for prevention. *Prev Chronic Dis.* 2022;19:E04. doi:10.5888/pcd19.210262. Available from: <https://www.researchgate.net/publication/357807390>
37. **Saudi Ministry of Health.** Seha Virtual Hospital: transforming digital healthcare in the Kingdom. Riyadh: Ministry of Health; 2022 [cited 2025 June 21]. Available from: <https://www.moh.gov.sa/en/Ministry/Projects/Documents/Seha-Virtual-Hospital.pdf>
38. **Nafis Program.** Emirati talent competitiveness council – official website. Abu Dhabi: Nafis; 2024 [cited 2025 June 21]. Available from: <https://nafis.gov.ae/>
39. **Saudi Data and Artificial Intelligence Authority (SDAIA).** Official website. Riyadh: SDAIA; 2024 [cited 2025 June 21]. Available from: <https://sdaia.gov.sa/en/default.aspx>
40. **Ministry of Communications and Information Technology (MCIT).** Official website. Riyadh: MCIT; 2024 [cited 2025 June 21]. Available from: <https://www.mcit.gov.sa/en/>
41. **King Abdulaziz City for Science and Technology (KACST).** Official website. Riyadh: KACST; 2024 [cited 2025 June 21]. Available from: <https://kacst.gov.sa/>
42. **National Data Management Office (NDMO).** About the NDMO. Riyadh: Ministry of Communications and Information Technology; 2024 [cited 2025 June 21]. Available from: <https://ndu.mcit.gov.sa/ar/about>



43. Ministry of Education, Kingdom of Saudi Arabia. Official website. Riyadh: Ministry of Education; 2024 [cited 2025 June 21]. Available from: <https://www.moe.gov.sa/en/Pages/default.aspx>
44. Arab News. Saudi Arabia launches \$200m fund for early investment in high-tech companies. *Arab News*. 2023 Aug 21 [cited 2025 June 21]. Available from: <https://www.arabnews.com/node/2358236/business-economy>
45. CDO Magazine. AWS to set up Saudi data centers, announces \$5.3 Bn investment. *CDO Magazine*. 2024 May 23 [cited 2025 June 21]. Available from: <https://www.cdomagazine.tech/aiml/aws-to-set-up-saudi-data-centers-announces-53-bn-investment>
46. Arab News. Saudi Health Ministry, Alphaiota sign deal in data, AI. *Arab News*. 2023 Jan 3 [cited 2025 June 21]. Available from: <https://www.arabnews.com/node/2223486/saudi-arabia>
47. Intel Corporation. Intel teams with partners to enable and grow end-to-end private networks market. Intel Newsroom. 2023 Jul 17 [cited 2025 Aug 21]. Available from: <https://newsroom.intel.com/5g-wireless/intel-partners-grow-private-networks-market>
48. Nybl, Basserah merge to expand their regional reach [Internet]. Wamda; 2024 Feb 21 [cited 2025 June 21]. Available from: <https://www.wamda.com/2024/02/nybl-basserah-merge-expand-regional-reach>
49. Saudi Arabia establishes AI Centre of Excellence with Rezolve AI [Internet]. Investing.com; 2024 Mar 18 [cited 2025 June 21]. Available from: <https://www.investing.com/news/stock-market-news/saudi-arabia-establishes-ai-centre-of-excellence-with-rezolve-ai-93CH-3341717>
50. Kattan W, Alshareef N. *2022 insights on hospital bed distribution in Saudi Arabia: evaluating needs to achieve global standards* [Internet]. BMC Health Services Research. 2024 Aug 8 [cited 2025 June 21]. Available from: <https://bmchealthservres.biomedcentral.com/articles/10.1186/s12913-024-11391-4>
51. Saudi Ministry of Finance. Budget Statement Fiscal Year 2024 [Internet]. Riyadh: Ministry of Finance; 2023 [cited 2025 Aug 21]. Available from:

<https://www.mof.gov.sa/en/budget/2024/Documents/Bud-E%202024%20F4.pdf>

52. Scherrer JR, Spahni S. Healthcare information system architecture (HISA) and its middleware models [Internet]. In: *Proceedings of the AMIA Annual Symposium*; 1999 Feb; United States. p. 935–9 [cited 2025 June 21]. Available from: https://www.researchgate.net/publication/12733729_Healthcare_information_system_architecture_HISA_and_its_middleware_models
53. International Organization for Standardization. ISO 12967-1:2020 Health informatics – Service architecture – Part 1: Enterprise viewpoint [Internet]. 2nd ed. Geneva: ISO; 2020 [cited 2025 June 21]. Available from: <https://www.iso.org/obp/ui/en/#iso:std:iso:12967:-1:ed-2:v1:en>
54. Bathelt F, Lorenz S, Weidner J, Sedlmayr M, Reinecke I. Application of modular architectures in the medical domain—a scoping review [Internet]. *J Med Syst*. 2025 Feb 18;49(1):27. [cited 2025 June 21]. Available from: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC11835905/>
55. The role of modular architectures in advancing healthcare systems [Internet]. HealthManagement.org; 2025 Mar 3 [cited 2025 June 21]. Available from: <https://healthmanagement.org/c/it/News/the-role-of-modular-architectures-in-advancing-healthcare-systems>
56. Siemens Healthineers. *Disease Pathway Framework: Stroke* [Internet]: Siemens Healthineers; [cited 2025 June 21]. Available from: https://marketing.webassets.siemens-healthineers.com/e15627dd74b2e24a/05c3d65af6eb/Siemens-Healthineers_ITT-Disease-Pathway-Framework_Stroke.pdf
57. Siemens Healthineers. Innovation Think Tank [Internet]. 2025 [cited 2025 June 21]. Available from: <https://www.siemens-healthineers.com/innovation-think-tank>
58. Haider S. Addressing the Healthcare Needs with Innovation Think Tank Global Infrastructure and its Methodology. In: Friebe M, editor. *Novel Innovation Design for the Future of Health*. Cham: Springer; 2022 Nov 27 [cited June 23]. p.557–66. DOI:10.1007/978-3-031-08191-0_45

59. Siemens Healthineers. Innovation Think Tank Certification Programs [Internet]. 2025 [cited 2025 June 23]. Available from: <https://www.siemens-healthineers.com/innovation-think-tank/certification-programs>
60. Yardley E. Braun and Clarke Thematic Analysis – How to do the six-step process in your qualitative research project [Internet]. Degree Doctor®; 31 May 2024 [cited 23 June 2025]. Available from: <https://www.thedegreedoctor.com/blog/braun-and-clarke-thematic-analysis-how-to-do-the-six-step-process-in-your-qualitative-research-project>
61. Marikyan D, Papagiannidis S. Technology Acceptance Model: A review [Internet]. In: Papagiannidis S, editor. *TheoryHub Book*. 2025 [cited 2025 June 23]. Available from: <https://open.ncl.ac.uk/theory-library/technology-acceptance-model.pdf>
62. Al-Kuwaiti A, Abu El Kheir M, Al Muhanna F. Digital Health in the GCC: Opportunities and Barriers. *J Med Internet Res*. 2021 Mar 3;23(3):e22625. [cited 2025 Aug 15]. Available from: <https://doi.org/10.2196/22625>
63. Alami H, Rivard L, Lehoux P, Hoffman SJ, Cadeddu SB, Savoldelli M, et al. Health information technologies—A major challenge to public health practice: A review of the literature. *BMC Med Inform Decis Mak*. 2020;20(1):1–17. [cited 2025 Aug 15]. DOI: 10.1186/s12911-020-01228-7
64. World Health Organization Regional Office for the Eastern Mediterranean. Regional strategy for fostering digital health in the Eastern Mediterranean Region (2023–2027) [Internet]. Cairo: WHO Regional Office for the Eastern Mediterranean; 2022 [cited 2025 Aug 21]. Available from: Regional strategy for fostering digital health in the Eastern Mediterranean Region (2023–2027) (Technical paper EM/RC69/8)
65. Hamid Z, Al Yami M, Khan M. Barriers to AI adoption in GCC healthcare: A survey of stakeholders. *Int J Med Inform*. 2021;149: [Article number, if available]. [cited 2025 Aug 15].
66. Khairat S, Marc D, Crosby W, Al Sanousi A. Reasons for physicians not adopting clinical decision support systems: Critical analysis. *JMIR Med Inform*. 2018 Apr 18;6(2):e24. [cited 2025 Aug 15]. DOI: 10.2196/medinform.8912

67. Ibrahim AM, Zoromba MA, Abousoliman AD, Zaghamir DEF, Alenezi IN, Elsayed EA, et al. Ethical implications of artificial intelligence integration in nursing practice in Arab countries: literature review. *BMC Nurs.* 2025;24:159. [cited 2025 Aug 15]. Available from: <https://bmcnurs.biomedcentral.com/articles/10.1186/s12912-025-02798-3>
68. Alomair N, Alkhaldi G, Alsadhan NM, Alkasabi R, Alageel S. Public perceptions of digital mental health awareness campaign in the Arab Gulf states: a qualitative thematic analysis. *Front Public Health.* 2024 Dec 13;12:1477315. [cited 2025 Aug 15]. Available from: <https://www.frontiersin.org/articles/10.3389/fpubh.2024.1477315/full>
69. Tavory T, Chen J, Luchins DJ, Greene T, Shapiro GK, Mandl KD. Regulating AI in mental health: Ethics of care perspective. *Psychiatr Serv.* 2024;75(7):728–35. [cited 2025 Aug 15]. Available from: <https://pmc.ncbi.nlm.nih.gov/articles/PMC11450345/>
70. Alotaibi N, Brown Wilson C, Traynor M. Enhancing digital readiness and capability in healthcare: a systematic review of interventions, barriers, and facilitators. *BMC Health Serv Res.* 2025;25:500. [cited 2025 Aug 15]. Available from: <https://bmchealthservres.biomedcentral.com/articles/10.1186/s12913-025-12663-3>
71. Thapa S, Nielsen JB, Aldahmash AM, Qadri FR, Leppin A. Willingness to use digital health tools in patient care among health care professionals and students at a university hospital in Saudi Arabia: quantitative cross-sectional survey. *JMIR Med Educ.* 2021 Feb 19;7(1):e18590. [cited 2025 Aug 15]. Available from: <https://pubmed.ncbi.nlm.nih.gov/33605896/>
72. World Health Organization Regional Office for the Eastern Mediterranean. Regional strategy for fostering digital health in the Eastern Mediterranean Region (2023–2027) [Internet]. Cairo: WHO Regional Office for the Eastern Mediterranean; 2022 Sep [cited 2025 Aug 16]. Available from: <https://applications.emro.who.int/docs/Digital-Health-EMR-2023-2027-eng.pdf>



73. Zhang J, Budhdeo S, Wasswa W, Cerrato P, Shuaib H, Sood H, et al. Moving towards vertically integrated artificial intelligence development. *npj Digit Med*. 2022;5(1):143. [cited 2025 Aug 16]. Available from: <https://doi.org/10.1038/s41746-022-00690-x>

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