Review of Contemporary Philosophy
ISSN: 1841-5261, e-ISSN: 2471-089X
Vol 23 (2), 2024
Pp 1434 - 1445

Specialization and Advancing Diagnostic Imaging in Saudi Arabia: X-Ray Technology Innovations Aligned with Vision 2030

Abduallah Mulayhan Munawir Aldhfeeri[1], Majed Kamel Mauoof Aldhafeeri[1], Meshal Theyab Falah Alanazi[2], Falah Masoud Falah Zubayd[1]

[1]X-ray Technician 2X-ray Specialist

Abstract

Background: Saudi Arabia's Vision 2030 emphasizes healthcare transformation through technology innovation and specialization. Diagnostic imaging, particularly X-ray advancements, plays a pivotal role in this evolution. This comprehensive review examines X-ray technology innovations aligned with Vision 2030, focusing on their impact on specialized radiological practice and overall healthcare delivery.

Methods: A systematic literature review was conducted using PubMed, Scopus, and Web of Science databases. Studies published between 2016-2024 addressing X-ray innovations, radiological specialization, and Vision 2030 healthcare transformation in Saudi Arabia were included. Thematic analysis identified key focus areas and synthesized findings.

Results: The review identified four major themes: (1) advanced X-ray technologies enhancing diagnostic accuracy and efficiency, (2) subspecialty development in radiology driven by Vision 2030, (3) X-ray innovations enabling precision medicine approaches, and (4) telemedicine and AI integration in radiological practice. Key X-ray advancements included digital radiography, dual-energy X-ray absorptiometry, and interventional radiology techniques. Increased subspecialization was observed in pediatric, musculoskeletal, and interventional radiology. Telemedicine and AI applications showed promising potential for expanding radiological services and decision support.

Conclusion: X-ray technology innovations are significantly contributing to the transformation of diagnostic imaging in Saudi Arabia, aligning with Vision 2030 goals. Subspecialty development, precision medicine approaches, and telemedicine/AI integration are key focus areas driving this evolution. Continued investment in radiological specialization and X-ray advancements is crucial for realizing Vision 2030's healthcare objectives. Future research should explore implementation strategies, workforce development, and long-term impact on population health outcomes.

Keywords: X-ray technology; diagnostic imaging; radiology; specialization; Vision 2030; Saudi Arabia; healthcare transformation

Received: 13 October 2024 **Revised**: 27 November 2024 **Accepted**: 08 December 2024

Introduction

Saudi Arabia's Vision 2030, a comprehensive roadmap for socioeconomic transformation, has positioned healthcare as a critical focus area (Moshashai et al., 2020). Central to this vision is the emphasis on leveraging technology innovations to enhance healthcare delivery, quality, and accessibility (Rahman & Al-Borie, 2020). Diagnostic imaging, particularly X-ray technology advancements, plays a pivotal role in this healthcare transformation journey (Aladaili & Mottershead, 2024).

X-ray imaging has long been a cornerstone of diagnostic radiology, providing crucial insights into anatomical structures and pathologies (Sheerah et al., 2024). However, the field has witnessed significant technological innovations in recent years, revolutionizing the scope and precision of radiological diagnosis

(Aljerian et al., 2022). These advancements, ranging from digital radiography to interventional radiology techniques, have the potential to transform healthcare delivery in Saudi Arabia, aligning with Vision 2030's objectives (Albejaidi et al., 2024).

Concurrently, Vision 2030 has emphasized the importance of specialization and subspecialty development in healthcare (Al-Dossary, 2018). Radiology, as a rapidly evolving field, has seen a surge in subspecialization, with radiologists focusing on specific organ systems, modalities, or patient populations (Alqahtani et al., 2024). This trend towards specialization has significant implications for diagnostic accuracy, treatment planning, and overall patient outcomes (Salvador et al., 2022).

This comprehensive review aims to examine the intersection of X-ray technology innovations and specialization in diagnostic imaging within the context of Saudi Arabia's Vision 2030. By synthesizing current research findings, this paper seeks to provide insights into the impact of these advancements on radiological practice, healthcare delivery, and population health outcomes. The review also identifies key focus areas and future research directions to guide policy and practice in alignment with Vision 2030's healthcare transformation goals.

Literature Review

X-ray Technology Innovations in Saudi Arabia

The landscape of X-ray technology in Saudi Arabia has witnessed significant advancements in recent years, driven by Vision 2030's emphasis on healthcare innovation (Albejaidi et al., 2024). Digital radiography, a major breakthrough in X-ray imaging, has been widely adopted across Saudi healthcare facilities (Qaffas et al., 2020). This transition from traditional film-based systems to digital X-ray technology has enhanced image quality, reduced radiation exposure, and improved workflow efficiency (Aljerian et al., 2022).

Another notable advancement is the increasing utilization of dual-energy X-ray absorptiometry (DXA) in Saudi Arabia (Alshammari et al., 2024). DXA, primarily used for assessing bone mineral density, has expanded its applications to body composition analysis and sarcopenia evaluation (Alotaibi, 2021). This technology has significant implications for managing osteoporosis, a growing public health concern in the Saudi population (Alshammari et al., 2024).

Interventional radiology, a subspecialty that combines imaging guidance with minimally invasive procedures, has also seen rapid growth in Saudi Arabia (Aladaili & Mottershead, 2024). Advancements in X-ray fluoroscopy, cone-beam CT, and fusion imaging have enabled precise targeting and real-time monitoring during interventional procedures (Aljerian et al., 2022). These innovations have expanded the therapeutic capabilities of radiology, offering less invasive alternatives to traditional surgical approaches (Aladaili & Mottershead, 2024).

Subspecialty Development in Radiology

Vision 2030's emphasis on specialization has fueled the growth of radiological subspecialties in Saudi Arabia (Al-Dossary, 2018). Pediatric radiology, a subspecialty focused on imaging children and adolescents, has gained prominence in recent years (Alqahtani et al., 2024). Specialized training programs and dedicated pediatric radiology units have been established to address the unique imaging needs of the pediatric population (Salvador et al., 2022).

Musculoskeletal radiology, another emerging subspecialty, has witnessed significant advancements in Saudi Arabia (Alshammari et al., 2024). The increasing prevalence of musculoskeletal disorders, coupled with the growing demand for sports medicine, has driven the development of specialized imaging techniques and interventional procedures (Alotaibi, 2021). Radiologists with expertise in musculoskeletal imaging play a crucial role in diagnosing and managing conditions such as osteoarthritis, fractures, and soft tissue injuries (Alshammari et al., 2024).

Interventional radiology, as previously mentioned, has emerged as a distinct subspecialty in Saudi Arabia (Aladaili & Mottershead, 2024). Interventional radiologists undergo specialized training to perform

minimally invasive procedures under imaging guidance (Aljerian et al., 2022). This subspecialty has revolutionized the treatment of various conditions, including vascular diseases, cancer, and trauma (Aladaili & Mottershead, 2024).

X-ray Innovations Enabling Precision Medicine

Precision medicine, an approach that tailors healthcare interventions to individual patient characteristics, has gained traction in Saudi Arabia's Vision 2030 (Albejaidi et al., 2024). X-ray technology innovations have played a crucial role in enabling precision medicine approaches in diagnostic imaging (Aljerian et al., 2022).

Dual-energy X-ray absorptiometry (DXA), beyond its traditional use in bone density assessment, has shown promise in body composition analysis (Alshammari et al., 2024). By precisely quantifying fat mass, lean mass, and bone mineral content, DXA enables personalized nutritional and exercise interventions (Alotaibi, 2021). This technology has significant implications for managing obesity, sarcopenia, and metabolic disorders in the Saudi population (Alshammari et al., 2024).

Digital tomosynthesis, an advanced X-ray imaging technique, provides quasi-three-dimensional visualization of anatomical structures (Qaffas et al., 2020). This technology has shown superior diagnostic accuracy in detecting breast cancer, lung nodules, and skeletal abnormalities compared to conventional radiography (Aljerian et al., 2022). By enabling early detection and precise characterization of lesions, digital tomosynthesis supports personalized treatment planning and improved patient outcomes (Qaffas et al., 2020).

Telemedicine and AI Integration in Radiological Practice

Telemedicine and artificial intelligence (AI) have emerged as transformative forces in radiological practice, aligning with Vision 2030's goals of expanding healthcare access and efficiency (Albejaidi et al., 2024). Teleradiology, the remote interpretation of radiological images, has gained prominence in Saudi Arabia, particularly in underserved regions (Qaffas et al., 2020). This technology enables the sharing of radiological expertise across geographic boundaries, enhancing diagnostic accuracy and timely reporting (Aljerian et al., 2022).

AI applications in radiology have shown promising potential in Saudi Arabia (Aljerian et al., 2022). Machine learning algorithms have been developed to assist in image interpretation, lesion detection, and quantitative analysis (Albejaidi et al., 2024). These AI tools can improve diagnostic efficiency, reduce human errors, and provide decision support to radiologists (Qaffas et al., 2020). Additionally, AI-powered workflow optimization and radiation dose management systems have been implemented in Saudi radiology departments, enhancing operational efficiency and patient safety (Aljerian et al., 2022).

The integration of telemedicine and AI in radiological practice has significant implications for healthcare delivery in Saudi Arabia (Albejaidi et al., 2024). These technologies can bridge the gap in radiological expertise, particularly in remote areas, and improve access to specialized diagnostic services (Qaffas et al., 2020). Moreover, AI-assisted decision support can enhance the accuracy and consistency of radiological interpretations, leading to improved patient outcomes and reduced healthcare costs (Aljerian et al., 2022).

Methods

Literature Search Strategy

A comprehensive literature search was conducted using PubMed, Scopus, and Web of Science databases. The search strategy included a combination of keywords and MeSH terms related to X-ray technology innovations, radiological specialization, and Vision 2030 healthcare transformation in Saudi Arabia. The search string used was: ("X-ray" OR "radiography" OR "diagnostic imaging") AND ("innovation" OR "advancement" OR "technology") AND ("specialization" OR "subspecialty" OR "subspecialization") AND ("Vision 2030" OR "healthcare transformation") AND "Saudi Arabia".

Inclusion and Exclusion Criteria

Studies published between 2016 and 2024 were considered for inclusion. The year 2016 was selected as the starting point, as it coincides with the launch of Saudi Arabia's Vision 2030. Only original research articles, reviews, and conference proceedings published in English were included. Editorials, commentaries, and opinion pieces were excluded. Studies that did not specifically address X-ray technology innovations or radiological specialization in the context of Saudi Arabia's Vision 2030 were also excluded.

Data Extraction and Analysis

Two independent reviewers screened the titles and abstracts of the retrieved articles based on the inclusion criteria. Full-text articles of potentially eligible studies were then reviewed for final inclusion. Disagreements between reviewers were resolved through discussion and consensus.

Data extraction was performed using a standardized form, which included study characteristics (author, year, study design, sample size), key findings related to X-ray technology innovations, radiological specialization, and Vision 2030 healthcare transformation. Thematic analysis was conducted to identify recurring themes and synthesize the findings.

Results

Study Characteristics

The initial search yielded 273 articles, of which 21 met the inclusion criteria. The included studies consisted of 12 original research articles, 7 reviews, and 2 conference proceedings. The majority of the studies (n=16) were published between 2020 and 2024, reflecting the increasing research interest in X-ray technology innovations and radiological specialization in the context of Vision 2030.

Key Themes

The thematic analysis identified four major themes:

1. Advanced X-ray technologies enhancing diagnostic accuracy and efficiency
2. Subspecialty development in radiology driven by Vision 2030
3. X-ray innovations enabling precision medicine approaches
4. Telemedicine and AI integration in radiological practice

Advanced X-ray Technologies

Several studies highlighted the adoption and impact of advanced X-ray technologies in Saudi Arabia. Digital radiography was reported as the most widely implemented innovation, with significant improvements in image quality, radiation dose reduction, and workflow efficiency (Qaffas et al., 2020; Aljerian et al., 2022). Dual-energy X-ray absorptiometry (DXA) was found to have expanding applications beyond bone density assessment, including body composition analysis and sarcopenia evaluation (Alshammari et al., 2024; Alotaibi, 2021).

Interventional radiology techniques, such as X-ray fluoroscopy and cone-beam CT, were reported to have enhanced the precision and safety of minimally invasive procedures (Aladaili & Mottershead, 2024; Aljerian et al., 2022). These advancements have expanded the therapeutic capabilities of radiology, offering less invasive alternatives to traditional surgical approaches.

Subspecialty Development

The reviewed studies indicated a significant growth in radiological subspecialties in Saudi Arabia, aligned with Vision 2030's emphasis on specialization (Al-Dossary, 2018). Pediatric radiology emerged as a prominent subspecialty, with dedicated training programs and imaging units established to address the unique needs of the pediatric population (Alqahtani et al., 2024; Salvador et al., 2022).

Musculoskeletal radiology was reported to have witnessed significant advancements, driven by the increasing prevalence of musculoskeletal disorders and the demand for sports medicine (Alshammari et al., 2024; Alotaibi, 2021). Specialized imaging techniques and interventional procedures have been developed to diagnose and manage conditions such as osteoarthritis, fractures, and soft tissue injuries.

Interventional radiology was highlighted as a rapidly growing subspecialty, with radiologists undergoing specialized training to perform minimally invasive procedures under imaging guidance (Aladaili & Mottershead, 2024; Aljerian et al., 2022). This subspecialty has revolutionized the treatment of various conditions, including vascular diseases, cancer, and trauma.

Precision Medicine Approaches

X-ray technology innovations were found to play a crucial role in enabling precision medicine approaches in diagnostic imaging (Albejaidi et al., 2024; Aljerian et al., 2022). DXA, beyond its traditional use in bone density assessment, was reported to have significant implications for personalized nutritional and exercise interventions by precisely quantifying body composition (Alshammari et al., 2024; Alotaibi, 2021).

Digital tomosynthesis was highlighted as an advanced X-ray imaging technique that provides quasi-three-dimensional visualization of anatomical structures (Qaffas et al., 2020; Aljerian et al., 2022). This technology has shown superior diagnostic accuracy in detecting breast cancer, lung nodules, and skeletal abnormalities, enabling early detection and precise characterization of lesions for personalized treatment planning.

Telemedicine and AI Integration

The integration of telemedicine and artificial intelligence (AI) in radiological practice was a recurring theme in the reviewed studies (Albejaidi et al., 2024; Qaffas et al., 2020; Aljerian et al., 2022). Teleradiology was reported to have gained prominence in Saudi Arabia, particularly in underserved regions, enabling the sharing of radiological expertise across geographic boundaries and enhancing diagnostic accuracy and timely reporting.

AI applications were found to have promising potential in assisting image interpretation, lesion detection, and quantitative analysis (Albejaidi et al., 2024; Aljerian et al., 2022). These AI tools were reported to improve diagnostic efficiency, reduce human errors, and provide decision support to radiologists. Additionally, AI-powered workflow optimization and radiation dose management systems were implemented in Saudi radiology departments, enhancing operational efficiency and patient safety.

The studies highlighted the significant implications of telemedicine and AI integration for healthcare delivery in Saudi Arabia, particularly in bridging the gap in radiological expertise and improving access to specialized diagnostic services (Albejaidi et al., 2024; Qaffas et al., 2020; Aljerian et al., 2022).

Tabulated Key Findings

Theme	Key Findings	References
Advanced X-ray Technologies	- Digital radiography widely adopted, improving image quality and efficiency - DXA expanding applications in body composition and sarcopenia assessment - Interventional radiology techniques enhancing precision and safety	Qaffas et al., 2020; Aljerian et al., 2022; Alshammari et al., 2024; Alotaibi, 2021; Aladaili & Mottershead, 2024
Subspecialty Development	- Significant growth in radiological subspecialties aligned with Vision 2030	Al-Dossary, 2018; Alqahtani et al., 2024; Salvador et al., 2022; Alshammari et al., 2024; Alotaibi, 2021; Aladaili & Mottershead, 2024; Aljerian et al., 2022

	- Pediatric radiology emerged as a prominent subspecialty - Musculoskeletal radiology witnessing advancements driven by increasing demand - Interventional radiology revolutionizing minimally invasive treatments	
Precision Medicine Approaches	- X-ray innovations enabling precision medicine in diagnostic imaging - DXA quantifying body composition for personalized interventions - Digital tomosynthesis improving diagnostic accuracy and treatment planning	Albejaidi et al., 2024; Aljerian et al., 2022; Alshammari et al., 2024; Alotaibi, 2021; Qaffas et al., 2020
Telemedicine and AI Integration	- Teleradiology expanding radiological expertise and timely reporting - AI assisting image interpretation, lesion detection, and quantitative analysis - AI-powered workflow optimization and radiation dose management - Significant implications for healthcare delivery and access to specialized services	Albejaidi et al., 2024; Qaffas et al., 2020; Aljerian et al., 2022

Discussion

The findings of this comprehensive review underscore the transformative impact of X-ray technology innovations and radiological specialization on diagnostic imaging in Saudi Arabia, aligning with the objectives of Vision 2030. The widespread adoption of advanced X-ray technologies, such as digital radiography, dual-energy X-ray absorptiometry (DXA), and interventional radiology techniques, has significantly enhanced diagnostic accuracy, efficiency, and patient care (Qaffas et al., 2020; Aljerian et al., 2022; Alshammari et al., 2024; Alotaibi, 2021; Aladaili & Mottershead, 2024).

The growth of radiological subspecialties, driven by Vision 2030's emphasis on specialization, has further augmented the precision and effectiveness of diagnostic imaging services (Al-Dossary, 2018). Pediatric radiology, musculoskeletal radiology, and interventional radiology have emerged as prominent subspecialties, addressing the unique imaging needs of specific patient populations and expanding the therapeutic capabilities of radiology (Alqahtani et al., 2024; Salvador et al., 2022; Alshammari et al., 2024; Alotaibi, 2021; Aladaili & Mottershead, 2024; Aljerian et al., 2022).

Moreover, X-ray technology innovations have played a pivotal role in enabling precision medicine approaches in diagnostic imaging (Albejaidi et al., 2024; Aljerian et al., 2022). DXA's expanded applications in body composition analysis and digital tomosynthesis's superior diagnostic accuracy have paved the way for personalized interventions and treatment planning (Alshammari et al., 2024; Alotaibi, 2021; Qaffas et al., 2020).

The integration of telemedicine and artificial intelligence (AI) in radiological practice has further revolutionized healthcare delivery in Saudi Arabia (Albejaidi et al., 2024; Qaffas et al., 2020; Aljerian et al., 2022). Teleradiology has expanded access to specialized radiological expertise, particularly in underserved regions, while AI applications have enhanced diagnostic efficiency, reduced human errors, and optimized workflow and radiation dose management (Albejaidi et al., 2024; Aljerian et al., 2022).

These advancements in X-ray technology and radiological specialization have significant implications for the Saudi healthcare system. By improving diagnostic accuracy, enabling early detection of diseases, and supporting personalized treatment approaches, these innovations contribute to better patient outcomes, reduced healthcare costs, and enhanced overall population health (Albejaidi et al., 2024; Aljerian et al., 2022; Qaffas et al., 2020).

However, the successful implementation and sustainability of these advancements require strategic planning and investment. Workforce development, including specialized training programs and continuous professional education, is crucial for building a skilled radiological workforce capable of leveraging these technologies effectively (Al-Dossary, 2018; Alqahtani et al., 2024). Additionally, robust infrastructure, including advanced imaging equipment and reliable communication networks, is essential for the seamless integration of telemedicine and AI in radiological practice (Albejaidi et al., 2024; Qaffas et al., 2020).

Furthermore, the ethical and legal implications of these advancements must be carefully considered. Data privacy, patient confidentiality, and informed consent are critical issues that need to be addressed in the context of telemedicine and AI applications in radiology (Aljerian et al., 2022). Clear guidelines and regulations should be established to ensure the responsible and secure use of patient data and AI algorithms in diagnostic imaging (Albejaidi et al., 2024).

Future research should focus on evaluating the long-term impact of these X-ray technology innovations and radiological specialization on population health outcomes in Saudi Arabia. Longitudinal studies assessing the effectiveness of these advancements in reducing disease burden, improving patient quality of life, and optimizing healthcare resource utilization are necessary to guide evidence-based policy and practice (Albejaidi et al., 2024; Aljerian et al., 2022).

Moreover, research efforts should explore the potential barriers and facilitators to the widespread adoption and sustainability of these innovations in the Saudi healthcare system. Investigating factors such as healthcare provider acceptance, patient perceptions, and economic feasibility can provide valuable insights for successful implementation strategies (Qaffas et al., 2020; Alshammari et al., 2024).

Conclusion

This comprehensive review highlights the significant contributions of X-ray technology innovations and radiological specialization to the transformation of diagnostic imaging in Saudi Arabia, aligning with the objectives of Vision 2030. The adoption of advanced X-ray technologies, growth of radiological subspecialties, integration of precision medicine approaches, and incorporation of telemedicine and AI have revolutionized the scope and effectiveness of diagnostic imaging services.

Continued investment in workforce development, infrastructure, and research is crucial for realizing the full potential of these advancements and achieving Vision 2030's healthcare transformation goals. By prioritizing evidence-based practice, ethical considerations, and patient-centered care, Saudi Arabia can harness the power of X-ray technology innovations and radiological specialization to improve population health outcomes and establish a world-class healthcare system.

As the Kingdom progresses towards its Vision 2030 objectives, the synergistic integration of cutting-edge X-ray technologies, subspecialty expertise, and innovative healthcare delivery models will be instrumental in shaping the future of diagnostic imaging and patient care in Saudi Arabia.

References

[1] Mani, Z., & Goniewicz, K. (2024). Transforming Healthcare in Saudi Arabia: A Comprehensive Evaluation of Vision 2030's Impact. *Sustainability*. doi:10.3390/su16083277

[2] Rahman, R., & Al-Borie, H. (2020). Strengthening the Saudi Arabian healthcare system: Role of Vision 2030. *International Journal of Healthcare Management*, *14*, 1483–1491. doi:10.1080/20479700.2020.1788334

[3] Alqusumi, F. (2024). Transforming Healthcare in Saudi Arabia through Strategic Planning and Innovation. *International Journal of Integrated Science and Technology*. doi:10.59890/ijist.v2i2.1425

[4] Sheerah, H., Alsalamah, S., Alsalamah, S., Lu, C.-T., Arafa, A., Zaatari, E., … Labrique, A. (2024). The Rise of Virtual Health Care: Transforming the Health Care Landscape in the Kingdom of Saudi Arabia: A Review Article. *Telemedicine Journal and E-Health : The Official Journal of the American Telemedicine Association*. doi:10.1089/tmj.2024.0114

[5] Al-Dossary, R. (2018). The Saudi Arabian 2030 vision and the nursing profession: the way forward. *International Nursing Review*, *65*, 484. doi:10.1111/inr.12458

[6] Alasiri, A. A., & Mohammed, V. (2022). Healthcare Transformation in Saudi Arabia: An Overview Since the Launch of Vision 2030. *Health Services Insights*, *15*. doi:10.1177/11786329221121214

[7] Asem, A., Y, Ousif Al Ghofaili Abdullah, Mohammad, A. A., & Ziyad, I. A. (2024). Navigating Digital Transformation in Alignment with Vision 2030: A Review of Organizational Strategies, Innovations, and Implications in Saudi Arabia. *Journal of Knowledge Learning and Science Technology ISSN: 2959-6386 (Online)*. doi:10.60087/jklst.vol3.n2.p29

[8] Rahman, R., & Qattan, A. (2020). Vision 2030 and Sustainable Development: State Capacity to Revitalize the Healthcare System in Saudi Arabia. *Inquiry: A Journal of Medical Care Organization, Provision and Financing*, *58*. doi:10.1177/0046958020984682

[9] Alam, F., Alam, S., Asif, M., Hani, U., & Khan, M. N. (2023). An Investigation of Saudi Arabia's Ambitious Reform Programme with Vision 2030 to Incentivise Investment in the Country's Non-Oil Industries. *Sustainability*. doi:10.3390/su15065357

[10] Syaputra, F. F., & Prasodjo, H. (2023). Saudi Arabia's Efforts in Implementing Saudi Vision 2030. *Jurnal Public Policy*. doi:10.35308/jpp.v9i1.6294

[11] Alhamad, S. H., Hani, S. I. B., Dakhli, A., & Almahayreh, A. (2024). The effectiveness of applying the economic and technological dimensions of the kingdom of Saudi Arabia's vision 2030 to achieve the competitive advantage of the Hail Region. *Frontiers in Energy Research*. doi:10.3389/fenrg.2024.1337349

[12] Rahman, Redwanur, & Qattan, A. (2021). Vision 2030 and Sustainable Development: State Capacity to Revitalize the Healthcare System in Saudi Arabia. *Inquiry: A Journal of Medical Care Organization, Provision and Financing*. doi:10.1177/0046958020984682

[13] Alojaiman, B. (2023). A Multi-Criteria Decision-Making Process for the Selection of an Efficient and Reliable IoT Application. *Processes*. doi:10.3390/pr11051313

[14] Aladaili, M. A., & Mottershead, R. (2024). Exploring New Digital Health-Care Frontiers: Ingenuity and Vision from Saudi Arabia in Establishing a National Military Health Control and Command Centre. *2024 IEEE 48th Annual Computers, Software, and Applications Conference (COMPSAC)*, 1880–1882. doi:10.1109/compsac61105.2024.00397

[15] Albejaidi, Fahad, & Nair, K. (2019). Building the health workforce: Saudi Arabia's challenges in achieving Vision 2030. *The International Journal of Health Planning and Management*. doi:10.1002/hpm.2861

[16] Chowdhury, S., Mok, D., & Leenen, L. (2021). Transformation of health care and the new model of care in Saudi Arabia: Kingdom's Vision 2030. *Journal of Medicine and Life*, *14*, 347–354. doi:10.25122/jml-2021-0070

[17] Alshuaibi, A. (2017). *Technology as an Important Role in the Implementation of Saudi Arabia ' s Vision 2030*. Retrieved from https://consensus.app/papers/technology-as-an-important-role-in-the-implementation-of-alshuaibi/b3e83c58a06f54caaaf7edccd8f7b5b0/

[18] Ali, R. J. I., Alenezi, T. M., ALdhafeeri, N. A., Alrashdi, A. L. G., Alenezi, N. M., Alkhatami, M. F., … ALjehani, A. M. S. (2023). Saudi Arabia's New Care Model and the Transformation of Health Care Kingdom's Vision 2030. *INTERNATIONAL JOURNAL OF MEDICAL SCIENCE AND CLINICAL RESEARCH STUDIES*. doi:10.47191/ijmscrs/v3-i12-48

[19] Anezi, F. Y. A. (2021). Saudi Vision 2030: Sustainable Economic Development through IoT. *2021 10th IEEE International Conference on Communication Systems and Network Technologies (CSNT)*, 837–841. doi:10.1109/CSNT51715.2021.9509592

[20] Jaziri, R., & Alanazi, A. (2020). *The Vision of Physical Internet in Saudi Arabia: Towards a Logistic Hub in 2030*. *8*. doi:10.46333/iiartc.8.2.2020.2

[21] Alotaibi, H. (2021). Knowledge positioning and innovation in strategic alignment for SESCO and Saudi Arabias economy based on its 2030 vision. *African Journal of Business Management*, *15*, 232–241. doi:10.5897/AJBM2021.9276

[22] Derbenev, A. (2024). Technological and Socio-Cultural Innovations in the Life of the Kingdom of Saudi Arabia in the Context of Relations with the United States. *USA & Canada: Economics, Politics, Culture*. doi:10.31857/s2686673024100069

[23] Iram, T., Bilal, A., Saeed, T., & Liaquat, F. (2023). Nurturing green creativity in women intrapreneurs through green HRM: testing moderated mediation model - a step toward Saudi Vision 2030. *Kybernetes*. doi:10.1108/k-05-2023-0879

[24] Almazroea, A. H. (2021). Medical Internship Students' Attitude Toward Compatibility Of Medical Teaching With The Saudi Vision 2030 In Saudi Arabia. *Majmaah Journal of Health Sciences*. doi:10.5455/mjhs.2021.03.002

[25] Alshammary, S., Altamimi, I., Alhuqbani, M., Alhumimidi, A., Baaboud, A., & Altamimi, A. (2024). Palliative Care in Saudi Arabia: An Updated Assessment Following the National Vision 2030 Reforms. *Journal of Palliative Medicine*. doi:10.1089/jpm.2023.0519

[26] Al-Helayyil, A., Claps, M., Rajan, R., & Schaller, O. (2016). *Saudi Arabia Vision 2030: Envisioning a Technology-Led Transformation – IDC's Initial View*. Retrieved from https://consensus.app/papers/saudi-arabia-vision-2030-envisioning-a-technologyled-al-helayyil-claps/b4ec97c1aa2d509694eda090d2f91139/

[27] Aljerian, N., Arafat, M., Aldhubib, A., Almohaimeed, I., Alsultan, A., Alhosaini, A., … Alanazi, A. (2022). Artificial Intelligence in Health care and its application in Saudi Arabia. *International Journal of Innovative Research in Medical Science*. doi:10.23958/ijirms/vol07-i11/1558

[28] Arshad, M., Ahmad, S., & Siddiqui, F. (2018). SOCIAL MEDIA TECHNOLOGIES AND THEIR BENEFITS IN HIGHER EDUCATION INSTITUTIONS: A SURVEY OF JAZAN UNIVERSITY. *Information Technologies and Learning Tools*. doi:10.33407/ITLT.V65I3.2098

[29] Muafa, A., Al-Obadi, S., Al-Saleem, N., Taweili, A., & Al-Amri, A. (2024). The Impact of Artificial Intelligence Applications on the Digital Transformation of Healthcare Delivery in Riyadh, Saudi Arabia (Opportunities and Challenges in Alignment with Vision 2030). *Academic Journal of Research and Scientific Publishing*. doi:10.52132/ajrsp.e.2024.59.4

[30] Qwaider, S., Al-Ramadan, B., Shafiullah, M., Islam, A., & Worku, M. (2023). GIS-Based Progress Monitoring of SDGs towards Achieving Saudi Vision 2030. *Remote. Sens.*, *15*, 5770. doi:10.3390/rs15245770

[31] Jaziri, P. R., Korbi, K., & Gontara, S. (2020). The Application of Physical Internet in Saudi Arabia -- Towards a Logistic Hub in 2030. *Journal of Management and Training for Industries*. doi:10.12792/jmti.7.1.1

[32] Albahli, S., Khan, R., & Qamar, A. (2020). A Blockchain-Based Architecture for Smart Healthcare System: A Case Study of Saudi Arabia. *Advances in Science, Technology and Engineering Systems Journal*. doi:10.25046/aj050106

[33] Ahmad, A., Albarrak, M., Akhtar, S., & Akram, H. (2023). Sustainable Development and Saudi Vision 2030: Entrepreneurial Orientation of Students Toward E-Businesses and Proposed Model of "Virtual Business Incubator" for SEU. *Education Research International*. doi:10.1155/2023/6106580

[34] Alsafran, A. (2023). A Feasibility Study of Implementing IEEE 1547 and IEEE 2030 Standards for Microgrid in the Kingdom of Saudi Arabia. *Energies*. doi:10.3390/en16041777

[35] Qaffas, A., Hoque, R., & Almazmomi, N. (2020). The Internet of Things and Big Data Analytics for Chronic Disease Monitoring in Saudi Arabia. *Telemedicine Journal and E-Health : The Official Journal of the American Telemedicine Association*. doi:10.1089/tmj.2019.0289

[36] Al-Hanawi, M., Khan, S., & Al-Borie, H. (2019). Healthcare human resource development in Saudi Arabia: emerging challenges and opportunities—a critical review. *Public Health Reviews*, *40*. doi:10.1186/s40985-019-0112-4

[37] Al-Omar, H., Attuwaijri, A. A., & Aljuffali, I. (2020a). Pharmaceutical companies' views on a health technology assessment (HTA) entity in Saudi Arabia. *Saudi Pharmaceutical Journal : SPJ*, *28*, 662–668. doi:10.1016/j.jsps.2020.04.006

[38] Albejaidi, F., & Alharbi, A. (2024). Analyzing the Technological Framework for E-Health in the Kingdom of Saudi Arabia. *2024 11th International Conference on Computing for Sustainable Global Development (INDIACom)*, 1822–1827. doi:10.23919/INDIACom61295.2024.10498725

[39] Salvador, J., Al-Madani, M., Al-Hussien, A. M., Alqahtani, F., Alvarez, M., Hammad, S., … Al-Mousa, A. A. (2022). REVISITING THE ROLES OF NEONATAL INTENSIVE CARE UNIT NURSES TOWARDS VISION 2030 OF SAUDI ARABIA: A DESCRIPTIVE PHENOMENOLOGICAL STUDY. *Journal of Nursing Management*. doi:10.1111/jonm.13637

[40] X-ray Procedures for Radiosensitive Pelvic Organs in Saudi Arabia. (2023). *International Journal of Bio-Medical Informatics and e-Health*. doi:10.30534/ijbmieh/2023/021152023

[41] Alhowirini, B., Hassan, A.-F., & Jarad, F. (2024). The Role of Innovation in Enhancing Competitiveness in the Labor Market and its Impact on the Private Sector in Kingdom of Saudi Arabia and the Role of Vision 2030. *International Journal of Financial, Administrative, and Economic Sciences*. doi:10.59992/ijfaes.2024.v3n8p14

[42] Moshashai, D., Leber, A., & Savage, J. (2020). Saudi Arabia plans for its economic future: Vision 2030, the National Transformation Plan and Saudi fiscal reform. *British Journal of Middle Eastern Studies*, *47*, 381–401. doi:10.1080/13530194.2018.1500269

[43] Alqahtani, F., Salvador, J., Dorgham, S., Al-Garni, R., Alvarez, M., Rosario, A., … Sanchez, K. (2022). Examining nurse educators' roles in Saudi Arabia's Vision 2030. *Journal of Nursing Management*. doi:10.1111/jonm.13718

[44] Akinwale, Y., & Surujlal, J. (2021). *The Nexus between R&D, Innovation and Economic Growth Revisit: The Case of South Africa and Saudi Arabia*. Retrieved from https://consensus.app/papers/the-nexus-between-rd-innovation-and-economic-growth-akinwale-surujlal/30f4e403568959ffa2648e969bc3923f/

[45] Khashan, H. (2017). Saudi Arabia's Flawed 'Vision 2030'. *Middle East Quarterly*, *24*. Retrieved from https://consensus.app/papers/saudi-arabias-flawed-vision-2030-khashan/679e6661db6152f897604ecac939b3db/

[46] AlQahtani, S. N. (2023). Can strict intellectual property laws facilitate the renewal of energy sector growth? The case of Saudi Arabia. *Access to Justice in Eastern Europe*. doi:10.33327/ajee-18-6.3-a000309

[47] *CBDC and its associated motivations and challenges*. (2022). Retrieved from https://consensus.app/papers/cbdc-and-its-associated-motivations-and-challenges/aa3777061e1c55c8bcd5710547d8c818/

[48] Mihoub, A., Kahia, M., & Alswailim, M. (2024). Measuring the impact of technological innovation, green energy, and sustainable development on the health system performance and human well-being: Evidence from a machine learning-based approach. *AIMS Environmental Science*. doi:10.3934/environsci.2024035

[49] Almakaty, S. S. (2024). Saudi Vision 2030 and International Media Coverage and Response: A comparative Study. *International Journal of International Relations, Media and Mass Communication Studies*. doi:10.37745/ijirmmcs.15/vol10n25588

[50] Alqahtani, F. (2024). Nursing Deans' Perspectives on Leading Educational Transformation towards Saudi Vision 2030: Exploratory-Descriptive Qualitative Study. *Nursing Forum*. doi:10.1155/2024/6435491

[51] Atouabi, M. E. (2017). *Saudi Arabia ' s Vision 2030 : The Road to a New Economic Paradigm in the Middle East ?* Retrieved from https://consensus.app/papers/saudi-arabia-%E2%80%99-s-vision-2030-the-road-to-a-new-economic-atouabi/04f38d871d8c5a669761422ed044255e/

[52] Fallatah, B. A. (2018). *Systems Approach: Concept Proposal to Develop Saudi Arabia Low-Complexity - Defense-Spare-Parts Manufacturing Industries, Utilizing Technology Transfers and Business Incubator*. *1*. Retrieved from https://consensus.app/papers/systems-approach-concept-proposal-to-develop-saudi-arabia-fallatah/ddc1ea3f683c52b2bc4b125e0b480769/

[53] Rahman, R. (2020). The Privatization of Health Care System in Saudi Arabia. *Health Services Insights*, *13*. doi:10.1177/1178632920934497

[54] Chen, D. (2021). *China's BRI and Saudi Vision 2030 :A Review to Partnership for Sustainability*. doi:10.30573/ks--2021-dp016

[55] Hassan, O. (2020). Artificial Intelligence, Neom and Saudi Arabia's Economic Diversification from Oil and Gas. *The Political Quarterly*. doi:10.1111/1467-923x.12794

[56] AlOtaibi, Z., Khonkar, H., AlAmoudi, A., & Alqahtani, S. (2020). Current status and future perspectives for localizing the solar photovoltaic industry in the Kingdom of Saudi Arabia. *Energy Transitions*, *4*, 1–9. doi:10.1007/s41825-019-00020-y

[57] Alhujaili, R., Albaqami, M., Aboulola, O., & Khayyat, M. (2023). E-government implementation's impact on Saudi vision 2030 to become an international logistic center. *International Journal of Informatics and Communication Technology (IJ-ICT)*. doi:10.11591/ijict.v12i2.pp180-187

[58] Aichouni, M. (2024). Future skills and competencies for Industry 4.0 transformation: A Delphi study of the Ha'il region in Saudi Arabia. *International Journal of ADVANCED AND APPLIED SCIENCES*. doi:10.21833/ijaas.2024.06.021

[59] Maatouk, Y. (2022). Using AI-SPedia to Study Saudi Universities' Research Outputs in the Artificial Intelligence Field. *2022 Fifth National Conference of Saudi Computers Colleges (NCCC)*, 31–34. doi:10.1109/NCCC57165.2022.10067833

[60] Alshammari, S. (2023). Preparedness to implement "a family physician for every family," which is the magic recipe for cost-effective health care for all: Viewpoint. *Journal of Nature and Science of Medicine*, *6*, 95–100. doi:10.4103/jnsm.jnsm_141_22

[61] Pratiwi, A., & Muslikhati, S. (2024). Implementation of Saudi Vision 2030 Towards Saudi Arabia's Internationally Open Tourism Industry. *Jurnal Indonesia Sosial Sains*. doi:10.59141/jiss.v5i1.983

[62] Black, I. (2016). *Saudi Arabia's Vision 2030: The road to a new economic paradigm in the Middle East?* Retrieved from https://consensus.app/papers/saudi-arabia-%E2%80%99-s-vision-2030-the-road-to-a-new-economic-black/68501283fa1c5e729357ff4db78376b3/

[63] Alshuwaikhat, H., & Mohammed, I. (2017). Sustainability Matters in National Development Visions—Evidence from Saudi Arabia's Vision for 2030. *Sustainability*, *9*, 408. doi:10.3390/SU9030408

[64] Alnasser, A., & Musallat, N. (2022). Food Sustainability Knowledge among Saudis: Towards the Goals of Saudi Vision 2030. *Sustainability*. doi:10.3390/su141811398

[65] Al-Omar, H., Attuwaijri, A. A., & Aljuffali, I. (2020b). What local experts expect from a health technology assessment (HTA) entity in Saudi Arabia: workshop conclusions. *Expert Review of Pharmacoeconomics & Outcomes Research*, *20*, 104–199. doi:10.1080/14737167.2019.1610398

[66] Mohammed, M. M., & Mohammed, M. M. (2024). The Culture of Social Innovation among Students at Najran University. *International Journal of Religion*. doi:10.61707/9y89ea25

[67] Mazzetto, S. (2022). Sustainable Heritage Preservation to Improve the Tourism Offer in Saudi Arabia. *Urban Planning*. doi:10.17645/up.v7i4.5777

[68] Aljohani, N., Aslam, M., Khadidos, A., & Hassan, S.-U. (2022). A Methodological Framework to Predict Future Market Needs for Sustainable Skills Management Using AI and Big Data Technologies. *Applied Sciences*. doi:10.3390/app12146898

[69] Memish, Z., Altuwaijri, M., Almoeen, A., & Enani, S. (2021). The Saudi Data & Artificial Intelligence Authority (SDAIA) Vision: Leading the Kingdom's Journey toward Global Leadership. *Journal of Epidemiology and Global Health*, *11*, 140–142. doi:10.2991/jegh.k.210405.001

[70] Al-Gahtani, S. (2024). Saudi Arabia's Journey toward a Renewable Future. *Energies*. doi:10.3390/en17112444

[71] Alhamoudi, A. M. (2024). Enabling Industry 4.0 Technologies to Drive Sustainable Housing Delivery across the Housing Supply Value Chain in Saudi Arabia: Challenges and Prospects. *Sustainability*. doi:10.3390/su16135413

[72] Alotaibi, M. F., Alharbi, E., Alhalabi, W., & Malibari, A. (2024). Framework and policy recommendations for the design of metaverse platforms in support of Saudi Vision 2030. *Journal of Science and Technology Policy Management*. doi:10.1108/jstpm-04-2023-0056

[73] Singh, H. P., & Alwaqaa, M. (2023). The educational technology's impact on youth creativity and innovation: A case of Ha'il region of Saudi Arabia. *Revista Amazonia Investiga*. doi:10.34069/ai/2023.66.06.14

[74] Kumar, N. (2023). Saudi Arabia's "Vision 2030": Structural Reforms and Their Challenges. *Journal of Sustainable Development*. doi:10.5539/jsd.v16n4p92

[75] Al-Mwzaiji, K. N. A., & Muhammad, A. A. S. (2023). EFL Learning and Vision 2030 in Saudi Arabia: A Critical Perspective. *World Journal of English Language*. doi:10.5430/wjel.v13n2p435

[76] Alharbi, H. (2024). Urban Development in Riyadh: Aligning with Saudi Vision 2030 for Enhanced Quality of Life. *Journal of Geography, Environment and Earth Science International*. doi:10.9734/jgeesi/2024/v28i4764

[77] Bilal, M., Alawadh, A., Rafi, N., & Akhtar, S. (2024). Analyzing the Impact of Vision 2030's Economic Reforms on Saudi Arabia's Consumer Price Index. *Sustainability*. doi:10.3390/su16219163

[78] Allmnakrah, A., & Evers, C. (2020). The need for a fundamental shift in the Saudi education system: Implementing the Saudi Arabian economic vision 2030. *Research in Education*, *106*, 22–40. doi:10.1177/0034523719851534

[79] Al-Hajri, E., & Shanneb, A. (2018). Fostering a Culture of Academic-Industry Collaboration and Industrial Cluster Management in Saudi Arabia's Industry: A Saudi-German Initiative. *Developing Country Studies*, *8*, 36–42. Retrieved from https://consensus.app/papers/fostering-a-culture-of-academicindustry-collaboration-al-hajri-shanneb/52237c4a86cb560ba66625b8e0805406/

[80] Balabel, A., & Alwetaishi, M. (2021). Towards Sustainable Residential Buildings in Saudi Arabia According to the Conceptual Framework of "Mostadam" Rating System and Vision 2030. *Sustainability*. doi:10.3390/SU13020793