Discussion Paper Series

The KENYA INSTITUTE for PUBLIC POLICY RESEARCH and ANALYSIS

Robotic Medical Services and the Future of Healthcare in Kenya

Joab Odhiambo and Jepkogei Barsoget

DP/324/2024

THE KENYA INSTITUTE FOR PUBLIC POLICY RESEARCH AND ANALYSIS (KIPPRA)

YOUNG PROFESSIONALS (YPs) TRAINING PROGRAMME

Robotic Medical Services and the Future of Healthcare in Kenya

Joab Odhiambo and Jepkogei Barsoget

Kenya Institute for Public Policy Research and Analysis

KIPPRA Discussion Paper No. 324
2024

KIPPRA in Brief

The Kenya Institute for Public Policy Research and Analysis (KIPPRA) is an autonomous institute whose primary mission is to conduct public policy research leading to policy advice. KIPPRA's mission is to produce consistently high-quality analysis of key issues of public policy and to contribute to the achievement of national long-term development objectives by positively influencing the decision-making process. These goals are met through effective dissemination of recommendations resulting from analysis and by training policy analysts in the public sector. KIPPRA therefore produces a body of well-researched and documented information on public policy, and in the process assists in formulating long-term strategic perspectives. KIPPRA serves as a centralized source from which the Government and the private sector may obtain information and advice on public policy issues.

Published 2024

Bishops Garden Towers, Bishops Road
PO Box 56445-00200 Nairobi, Kenya
tel: +254 20 2719933/4; fax: +254 20 2719951
email: admin@kippra.or.ke
website: http://www.kippra.org

ISBN 978 9914 738 63 6

The Discussion Paper Series disseminates results and reflections from ongoing research activities of the Institute's programmes. The papers are internally refereed and are disseminated to inform and invoke debate on policy issues. Opinions expressed in the papers are entirely those of the authors and do not necessarily reflect the views of the Institute.

This paper is produced under the KIPPRA Young Professionals (YPs) programme. The programme targets young scholars from the public and private sector, who undertake an intensive one-year course on public policy research and analysis, and during which they write a research paper on a selected public policy issue, with supervision from senior researchers at the Institute.

KIPPRA acknowledges generous training on futures foresight methodology by EDHEC Business School, France; and the UNESCO Futures Literacy Laboratory Chair at Dedan Kimathi University of Technology (DeKUT), Kenya. The course on "Building Strategic Foresight Capabilities" by EDHEC Business School was beneficial for building capacity of Young Professionals on futures foresight.

Abstract

With the Kenyan healthcare affected by challenges of availability, accessibility and affordability, there is a pressing need to examine how to adopt robotic medicine as a permanent solution. This study aimed to assess the adoption of robotic medical services (4IR technology) and the future of Kenyan healthcare. The specific objectives were to identify drivers of change in accelerating robotic medicine adoption and provide policy recommendations. The study employed a scenario planning approach methodology, focusing on four steps: defining the scenario question and time horizon, identifying drivers of change, and developing and applying scenarios, guided by diffusion innovation theory. The twelve key drivers of change are societal and expert acceptance of robotic medicine, compatibility with existing infrastructure, robustness of data and internet for AI, investment costs, national healthcare budget, recyclability and environmental impact of medical waste, legislative frameworks, global political collaboration, and AI-related intellectual property, liability, and ethical issues such as patient data privacy, transparency, and bias. The robustness of data and internet for AI and the level of societal acceptance were identified as driving forces. The plausible future scenarios, i.e. Successful Adoption, Low Adoption, Chaotic Change and Rejection of the Adoption were identified. The main opportunities were identified as rapid AI technological developments, medical tourism, and robotic medical innovations. Finally, the critical challenges in the plausible future were found to be regulatory uncertainty, ethical concerns, data privacy and public misconceptions from social acceptance levels. The study recommended the government to invest in AI infrastructure, develop an AI usage framework, create an enabling environment that encourages robotic medicine adoption, establish stringent data usage regulations, foster societal acceptance through targeted community engagement and education initiatives to robotic medicine adoption

Abbreviations and Acronyms

AI	Artificial Intelligence
4IR	Fourth Industrial Revolution
RSK	Robotics Society of Kenya
EHR	Electronic Health Records
MoH	Ministry of Health
MDI	Matrix of Direct Influences
MII	Matrix of Indirect Influences
MICMAC	Matrix of Cross-Impact Multiplications Applied to a Classification
MTP IV	Medium Term Plan IV
SWOT	Strength Weakness Opportunities and Threats
KNBS	Kenya National Bureau of Statistics
KNQA	Kenya National Qualifications Authority
UN	United Nations
STEEPV	Social Technical Economical Environmental Political and Value
TAM	Technology Acceptance Model
WHO	World Health Organization

Table of Contents

List of Tables

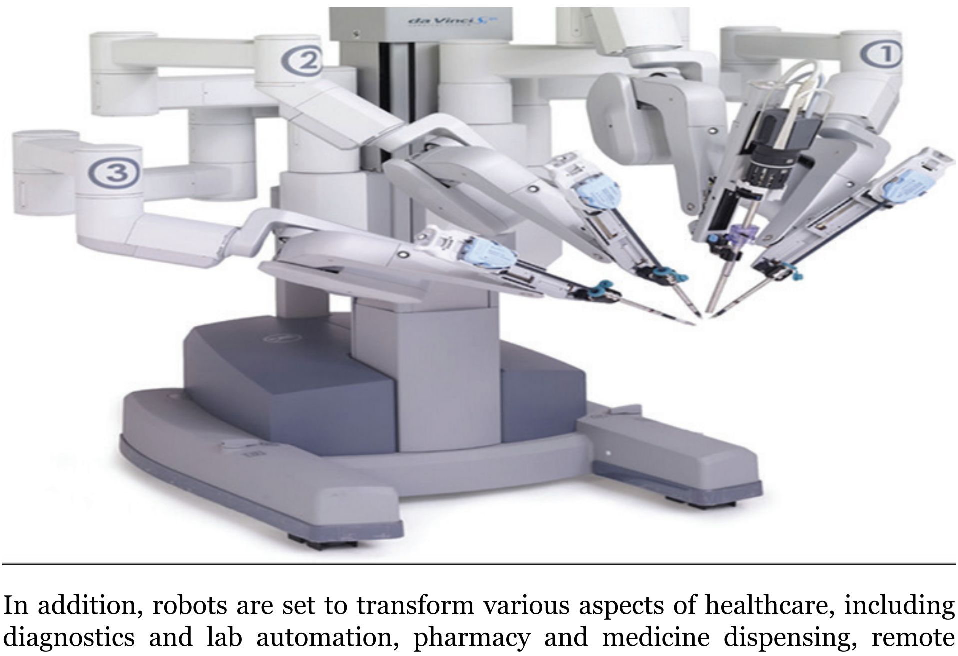
List of Figures

1. Introduction

Robots is one of the pillars of the Fourth Industrial Revolution (4IR), where industries and sectors across the globe are being transformed using a variety of increasingly interconnected applications. Robots have extended from science fiction, and they have progressively encroached into operating rooms, rehabilitation centres to even people's homes (Alip et al., 2022). Robots are machines programmed to do a specified task that requires high speed with precision and accuracy either with human or without human assistance. This is shaped by the current and developing environment composing of disruptive technologies and trends such as Artificial Intelligence (AI) and robotics (Sehume and Markus, 2020).

The use of robotics in healthcare, such as blood analysis, medical procedures including surgical operations, and cell sorting has become commonplace in the modern world (Siciliano and Khatib, 2016). Presently, robotic technology is being employed in different sections of health care services from minimally invasive surgical assistants, for example Da Vinci (shown in Figure 1.1) to rehabilitation robots aiding in physical therapy. Although robotic surgery takes the attention, the application of robotic technology goes beyond operation room.

Figure 1.1: Da Vinci robots



In addition, robots are set to transform various aspects of healthcare, including diagnostics and lab automation, pharmacy and medicine dispensing, remote patient care, and hospital sanitation and disinfection(Wolbring et al., 2013). This advancement promises greater efficiency, accuracy, and accessibility in healthcare delivery. Integrating robotics into healthcare has gained popularity in many developed countries such as America, Europe, Asia with India being among the leading countries using robotics in healthcare, thus leading to better healthcare provision (Deo and Anjankar, 2023).

Despite approximately 75 per cent Kenyans living in rural areas, healthcare facilities are disproportionately located in urban areas. This makes it difficult for rural people to access medical attention. According to WHO, telemedicine can bridge geographical gaps and allow remote medical consultations for 45 per cent of Africa's population(World Health Organization, 2010). In addition, the doctor shortage has a negative impact on both patients and medical professionals.

As of 2022, Kenya had 9,638 registered medical doctors, resulting in a ratio of 19 physicians per 100,000 population, which can be translated to 1:5263. This ratio is far below the WHO recommendation of 1:1000 (Nasr et al., 2021). This doctor shortage strains the healthcare system, leading to longer wait times in emergency rooms, overcrowded hospitals, and a potential increase in healthcare costs (Mutiso et al., 2020).

Robotic medicine has the potential to be a valuable tool in mitigating the effects of Kenya's doctor shortage. Robots can be programmed to handle routine tasks such as taking vital signs, administering medications, and collecting samples. This frees up doctors' time to focus on more complex patient interactions and diagnoses. Telepresence robots can allow doctors to remotely consult with patients in underserved areas or those with limited mobility. Robots can also be programmed to perform certain procedures with consistent accuracy, reducing human error and improving the overall quality of care. By taking over some of the workload, robots can help to alleviate burnout among doctors and create a more efficient and streamlined workflow.

Adopting robotic medical services in Kenya is substantiated by its potential to revolutionize healthcare through unparalleled precision, reducing invasiveness and enhancing patient outcomes and telepresence solutions. Service robots optimize resource use, while robotic limbs and cognitive therapy robots offer personalized rehabilitation (McMillan and Varga, 2022).

The aim of this study was to provide a foresight of robotic medical services and future of healthcare services in Kenya. Specifically, the study identified the drivers of change in accelerating robotic medicine adoption by 2063 and provided policy recommendations. The rest of the paper is organized as follows: Section 2 gives an overview of robotic medical services; The literature review and methodology are provided in sections 3 and 4, respectively. The results are discussed in section 5 while section 6 concludes and provides policy recommendations.

2. Overview of Robotic Medical Services

2.1 Global Adoption

Most developed countries such as the United States, European countries (Germany, France, UK, Sweden and others) and Asian (South Korea, China and Japan) have adopted robotic medicine showing excellent results in terms of robotic surgery, with specialties such as neurosurgery and urology embracing its benefits of improved patient care, enhanced efficiency, and greater access to specialized services (Camarillo et al., 2004).

Advanced robotic systems, for instance Da Vinci (shown in Figure 1.1) are widely used, offering surgeons unparalleled dexterity and visualization during minimally invasive procedures. This translates to faster recovery times, reduced scarring, and potentially fewer complications for patients. In addition, medical robots are making their mark in labs, performing intricate tasks with precision and speed, leading to faster diagnoses and potentially earlier interventions(King, 2023).

2.2 Regional Consumption

Most developing countries in Sub-Saharan African countries face healthcare challenges, which includes insufficient medical professionals, inadequate medical specialist and advanced medical technology. However, a major problem is inadequate healthcare providers where no country has met the WHO standards ratio of 1: 1000 (doctor to patients' ratio). Sub-Saharan Africa has shortage of 2.4 million medical professionals across Africa, hence the need to increase their health workers by around 140 per cent to meet global standards (Wagner et al., 2016). In addition, quality healthcare is mostly concentrated in towns with access to medical experts, advanced treatment, and general medical services as compared to rural areas (Mbunge et al., 2022).

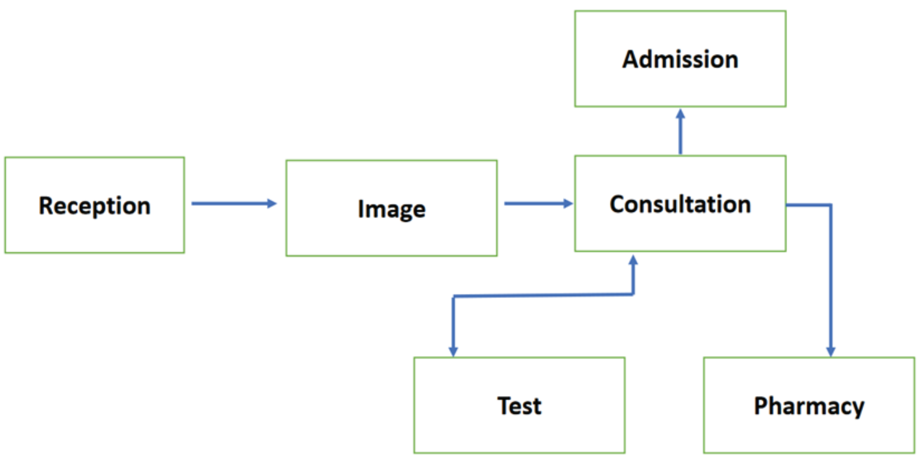
Few countries in Sub-Saharan Africa have adopted technology in medicine. For example, South Africa has adopted electronic health records, and telemedicine which have improved access to insufficient specialist care, delivery of care services to rural areas and reduce movement of patients from rural to urban in search of medication (Aragon et al., 2017). On the other hand, Rwanda launched the Rwanda Health Information Exchange (RHIE) and implemented telemedicine programmes. Ghana has integrated technology into its healthcare system with telemedicine services and electronic medical records. Uganda has incorporated technology in healthcare through telemedicine services, mobile health apps, and the use of drones for medical supply delivery. Egypt has also implemented telemedicine services, electronic medical records systems, and mobile health apps (Bhatnagar, 2020).

2.3 Kenyan Healthcare Challenges: A Contextual Overview

More than 10,000 Kenyans seek medical services outside the country every year (Ministry of Health), thus resulting to crowdfund through WhatsApp groups to help finance medical health services outside the country (Okoroafor et al., 2022). In addition, inadequate medics in hospitals have led to long queues when seeking these medical services. One ought to book for more than three months to seek these medical services from these highly specialized medics (Wachira and Mwai, 2021).

Robotic medicine and telemedicine have potential of improving access to care even in remote areas (Francis and Mugabo, 2022). In the Kenyan healthcare system context, the deployment of companion robots for emotional support, cognitive therapy robots for rehabilitation, and robotic limbs for mobility solutions is an area that lacks comprehensive implementation (Aragon et al., 2017). The necessity of assessment underscores the importance of robotic adoption in healthcare within the Kenyan hospital patient flow system(Figure 2.1) to overcome logistical challenges, improve surgical precision, and offer diverse solutions for patient care in the evolving landscape of medical practices, thus giving it a competitive advantage not only in the East Africa but also in Africa as a whole (Ayentimi and Burgess, 2019).

Figure 2.1: Hospital patient flow



During the COVID-19 pandemic, Kenya bought three robots namely Jasiri, Tumaini and Shujaa (shown in Figure 2.3) that were successfully used in managing COVID-19 spread by screening people, and today they have since been configured for other functions after being deployed in the level VI hospitals to carry out other functions.

Figure 2.2: Examples of robots in Kenya

Kenya has made steps in the use of drones or autonomous airship technology have been utilized in Kisumu, Nyamira and Siaya counties. This has shown promise as a means of bridging healthcare access gaps while addressing last-mile delivery challenges and infrastructural inadequacies in resource-constrained settings (Wiljer and Hakim, 2019).

2.4 Policy Review

Kenya has started embracing the potential adoption of robotic medical services that will revolutionize healthcare delivery. To facilitate this adoption, the government has enacted various legislations and policies, aligning with existing legal frameworks and prioritizing patient safety, data protection, and technological innovation. For full adoption of robotic medicine, the status of policy has been summarized in Table 1.

Table 2.1: Policy review in robotic medicine adoption

Policy and Legal Framework	Gaps	Recommendations
Health Act of 2017 and Data Protection Act of 2019	Lack provisions for open medical datasets and robust regulatory frameworks for data anonymization	Amend the Health Act of 2017 and the Data Protection Act of 2019 to include specific provisions related to robotic medicine

Cybercrimes Act of 2018	Lacks clear regulatory frameworks on data usage for medical robots	Establish requirements for healthcare providers and manufacturers to implement robust cybersecurity measures, such as encryption, access controls, and regular security audits, to protect against cyber threats
Pharmacy and Poisons Act (Cap 244)	Lacks specific provisions addressing the registration importation, manufacturing, and distribution of robotic medical devices	Enhance the regulatory framework for robotic medicine
Kenya National Qualifications Framework (KNQF) Act of 2014	Lack of clear and standardized guidelines for the training and certification of healthcare professionals who operate robotic surgical systems or use robotic-assisted procedures	Develop and implement standardized training and certification guidelines for robotic medicine
Electronic Health Records (EHR) Standards	Lack of standardized formats or protocols for capturing and storing robotic data within EHR systems	Reviewing Kenya's Electronic Health Records (EHR) Standards
Science, Technology, and Innovation Act of 2013	Incorporate new robotics innovations	Amend the Science, Technology, and Innovation Act of 2013 to incorporate provisions that promote research, development, and adoption of robotic medicine within Kenya's innovation ecosystem
Standards Act 2016	Weak Robotics Standards	Amend the Standards Act of 2016 to develop and enforce comprehensive standards specifically tailored to robotic medicine
Occupational Safety and Health Act of 2007	Lack specific regulations of robotic medicine.	Develop specific guidelines for robotic medicine.

Kenya Robotic Society of Kenya Bill of 2024	A clear plan on how RSK will assist in adoption of robotic medical services	Review the establishment of open medical datasets and comprehensive regulatory frameworks for data anonymization, ensuring compliance with privacy regulations
Social Health Insurance Act of 2023	Liabilities issues on robots conducting surgery and general lack of public awareness and acceptance of robotic medical services.	Review the Social Health Insurance Act and other relevant laws to explicitly cover robotic medical services
Primary Healthcare Act of 2023	Procurement and maintenance of robotic medical systems	Review the Primary Healthcare Act of 2023 and other relevant laws to explicitly cover robotic medical services
Digital Healthcare Act of 2023	Lack of clauses on use of digital technologies in healthcare, including telemedicine and electronic health records (EHRs)	Review the Digital Healthcare Act of 2023 and other relevant laws to explicitly cover robotic medical services

By addressing these policy gaps in Table 2.1, it will be easier to enhance the full adoption of robotic medicine to achieve universal healthcare vision in Kenya.

3. Literature Review

3.1 Theoretical Literature

This theory's main objective is to offer explanations on how, why and the rate at which ideas and technology diffuse. Although adoption of robotic medicine relies on many factors, among them user acceptance, it has a potential of improving health service outcome and efficiency. The unified theory of acceptance and use of technology model (UTAUT) gives an elaborate framework explaining this theory, especially in the adoption of new technologies.

UTAUT in healthcare robots highlight the importance of its determinants, for example performance expectancy (PE), which explains the robot's ability to enhance healthcare delivery and effort expectancy (EE), which expounds on perceived ease of use (Vatandoost and Litkouhi, 2019).

Social influence considers the impact of people's perception and cultural norms affecting adoption decisions. Lastly, facilitation conditions comprise of technical support necessary for adoption of robotic in health care in Kenya (Kyrarini et al., 2021). In addition, cultural beliefs towards adoption of robots influences acceptance rates, highlighting the need for peer education.

3.1.1 Diffusion innovation theory

Innovation Diffusion Theory improved by Quinlan (2008) seeks to explain how and why new ideas, innovations, or technologies spread through societies over time. This economic theory provides insights into the adoption process, identifying the key factors that influence the rate of adoption and the characteristics of adopters. In addition, it offers a comprehensive framework for understanding the dynamics of how innovations spread within societies, considering the roles of communication, social systems, and individual adopter characteristics (Pradhan et al., 2021).

3.1.2 Technology acceptance model

Technology Acceptance Model (TAM) (Davis, 1989) was a key model in understanding the predictors of human behaviour towards potential acceptance or rejection of the technology. Additionally, TAM suggests that users' attitudes towards using a particular technology are influenced by perceived ease of use and perceived usefulness (effortless of using technology and efficiency brought by using technology) respectively.

The model contends that by knowing what makes one's determination, it will allow the organization to manipulate those factors, hence increase adoption of Information Technology (IT) as in the case of robotic medicine (Bianchi et al., 2023) and offers a theoretical tool for Health IT to help try understanding why employees were not using ITs made available to them, thus increasing the adoption of information technology (IT) to first make people accept it.

3.2 Empirical Literature

As technology advances, the integration of robots continues to reshape industries, offering innovative solutions to complex problems and enhancing the overall efficiency and safety of various processes and thus reducing robotic surgery costs by 20 per cent (Pramod, 2021).

Deo and Anjankar (2023), Sehume and Markus (2020), and Stasevych and Zvarych (2023) identified several key drivers for adoption of robotic medicine, for instance to enhance healthcare services such surgeries, diagnostics, rehabilitation, and medication dispensing, although use of robots in surgery is rising. However, robotic medicine could help alleviate this shortage of medical experts, make medical services affordable and increase the number of patients accessing the services. In India, urologic robot named Da Vinci S was first introduced in the year 2006 and since then there has been extensive increase of robotic surgery. By the year 2019, 66 medical centres with more than 500 skilled robotic surgeons had aided more than 12,800 surgeries (Deo and Anjankar, 2023).

For instance, shortage of urologists (in the USA, with a ratio of one urologist serving approximately 17,600 people, Brazil where there is 1 urologist for about 50,000 people and even in China with a ratio of 1 urologist for roughly 108,300 people, respectively), has led to adoption of robotic medicine globally. The strain on healthcare providers is noticeable and the demand for urological services poses a challenge (Vidya, 2010).

While robots will contribute significantly to delivering the UN Sustainable Development Goals, they can also lead to emergence of new challenges that might lead to social disparities, change in environment, the redirection of resources away from established solutions and reduce freedom and privacy due to insufficient governance. These diverse threats are interconnected, posing risks to societal balance and global stability (Guntur et al., 2019).

The success of robotics in healthcare has relied on many innovative technologies, and the effective integration of this technology into the intricate interactions between humans and machines within the healthcare environment. Now, here is the consideration of human factors more critical for the success of technology applications than in the use of robotics in clinical settings (Kyrarini et al., 2021). The use of robotics is more prevalent in surgery than in any other healthcare specialty.

There is emerging policy interest in seeing a similar transition in health care; this is being fueled by the drive to improve the quality and safety of care while simultaneously controlling expenditure in many developing countries such as Kenya (Yang et al., 2020).

Deployments of robots in healthcare settings are likely to rise because of increasing technological capabilities, reduced costs, and increasing pressure to curb costs. However, robots are potentially highly disruptive innovations, and it is essential to understand the socio-technical challenges likely to be encountered as robots are deployed to find mitigating strategies. The socio-technical approaches to studying technology implementation view social and technical factors as shaping each other over time (Shuaib et al., 2020). It is assumed that technologies are shaped by their social environments, such as through designs being modified) but also that social environments are shaped by technological features, like when users' work practices change because of the introduction of technology.

Telepresence robots, equipped with screens on wheels, have emerged as valuable tools for remote healthcare consultations and monitoring. These robots enable healthcare professionals to interact with patients virtually, expanding access to medical expertise and enhancing the delivery of care (Patrício et al., 2020).

3.3 Analytical Framework

In this study, we highlighted the importance of exploring the emerging trend and key drivers' adoption of robotic medical services basing on scenarios India, China, Japan, and Germany. In academic literature, scenarios were classified into three categories referred to as predictive, explorative, and normative. Whereby, predictive tries what was going to happen in the future, while explorative was to explore the situation and normative scenarios focus on achieving specific goal in future(Sood and Leichtle, 2013).

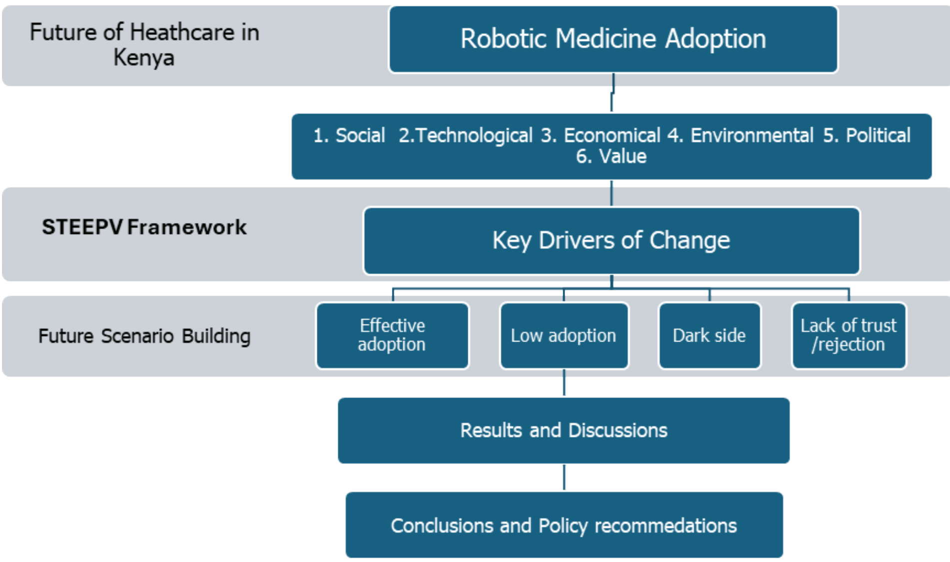
4. Methodology

4.1 Introduction

The research study primarily employed futures foresight methodologies entailing systematic approaches utilized to anticipate and plan for potential future scenarios. Through this method, the study aimed to develop plausible and preferred scenarios, examining the implications of attaining an ideal state in adoption of robotic medicine (Gatune and Cloette, 2022).

As a foresight research tool, Social, Technological, Economic, Environmental, Political, and value factors (STEEPV) analysis was employed to examine the uncertainties and develop scenarios (Thakur, 2021). The study used STEEPV analysis to identify the key drivers of change on the adoption of robotic medicine in Kenya's future healthcare industry. Figure 4.1 shows the STEEPV dimensions of Sustainable Robotic Medicine in Kenyan Healthcare.

Figure 4.1: Proposed foresight design under STEEPV dimensions



STEEPV analysis, part of the Systemic Foresight Methodology, offered a structured approach to predicting future trends and scenarios by examining key influencing drivers of change. A comprehensive scan of the environment was conducted to identify trends, drivers of change, and potential disruptors. The identified trends were analyzed to understand their potential impact, leading to the development of multiple future scenarios based on these trends and drivers.

4.2 Data Sample and Collection Methods

The study used secondary data from a systematic literature review using STEEPV to identify the twelve drivers of change. Purposive sampling was used among the stakeholders when collecting their opinions. Data (experts' opinions) was collected through Google forms for the two future foresight methodologies.

For Cross Impact Analysis, a total of 44 professional experts, which includes medics, robotic experts, and health insurance experts. For Impact Uncertainty Analysis, the expert opinion was sought from 200 professional experts including medics, robotic experts, and health insurance experts. The distribution of expert's opinions is given in Appendix A1 and A2, respectively. The sample questionnaires are given in Appendix A3 and A4, respectively.

4.3 Impact Uncertainty Analysis

Impact Uncertainty Analysis is a futures foresight method of evaluating strategies by considering their impact (I) and associated uncertainty (U). In this study, each strategy's impact and uncertainty were assigned values, typically on a scale from 1 to 5. We calculated the mean impact (μI) and mean of uncertainty (μU) of the drivers of change. Each strategy was represented as a point (I, U).

We selected those drivers of change with the highest impact (μI) and mean of uncertainty (μU) and used it to develop future scenarios. We plotted the results on a 2D graph with impact on the x-axis and uncertainty on the y-axis. This visualization helped identify strategies with high impact and low uncertainty, aiding in effective decision-making in building future scenarios.

4.4 Cross Impact Analysis

Cross Impact Analysis is a strategic planning method particularly useful in scenarios marked by complex interdependencies and evaluation on how various drivers of change under STEEPV might interact within different scenarios (Enzer, 1971). The drivers of change were analyzed and quantified, typically using a matrix where rows and columns represented the variables, and each cell described the impact of one driver on another to facilitate scenario building analysis.

Table 4.1: : Cross impact matrix

	D_1	D_2	D_3	…	$D_{(n-1)}$	D_n	K
D_1							X_1
D_2							X_2
D_3							X_3
…							…
$D_{(n-1)}$							$X_{(n-1)}$
D_n							X_n
W	Y_1	Y_2	Y_3	…	$Y_{(n-1)}$	Yn	

where

$D_1, D_2, D_3,\ldots,D_{(n-1)}, D_n$ are drivers of change

$X_1, X_2, X_3,\ldots,X_{(n-1)}, X_n$ are active sum values

$Y_1, Y_2, Y_3,\ldots,Y_{(n-1)}, , Y_n$ are passive sum values

Passive sum $=W=\sum^{n}_{(i=1)}Y_i$

Active sum$=K=\sum^{n}_{(j=1)}X_i$

The Cross-Impact matrix in Table 4.1 was used in building scenarios for the key drivers with the highest Active and passive sums.

4.5 Future Scenarios Building

Future scenario building is a strategic planning tool that helps stakeholders envision and prepare for potential future developments. In the context of robotic medicine adoption, building scenarios could illuminate pathways, challenges, and transformative impacts of integrating robotic technologies in healthcare systems(Winkler and Moser, 2016).

Figure 4.2: Frames for future scenarios

Figure 4.2 shows how the study employed a scenario-based approach to understand the key drivers of change for successful adoption of robotic medicine. It involved analyzing the current state (reference), forecasting future impacts, and developing detailed plans (elaborate storylines). The study included predictive analysis (forecasting), exploring innovative approaches, and implementing targeted interventions to ensure effective integration as shown in Table 4.2.

5. Adoption of Robotics Health

This section examines the outcomes for each driver of change, plausible scenarios, opportunities and challenges by focusing on two distinct facets: impact, and uncertainty and cross-impact analysis vital for building future scenarios for robotic medicine adoption in Kenya.

5.1 Identification of Drivers of change

The STEEPV analysis approach identified the drivers of change with the greatest impact and highest uncertainty in this study. It focused on the two most pivotal areas of impact and uncertainty for scenario analysis. According to (Rha, 2008), scenarios were built on two key elements: impact and uncertainty. 'Impact' and 'Uncertainty' measured how significantly each driver and challenge and probability of various scenarios occurring may influence the future adoption of robotic medicine.

Table 5.1: Drivers of change for robotic medical services under STEEPV

Foresight Framework	Indicators/driver of change	Short Labels of Drivers of change	Source
Social (SO)	Level of societal acceptance of robotic medicine	SO1	Raje et al. (2021a); Bera et al., (2019); Bianchi et al., (2023); Vatandoost and Litkouhi (2019)
	Medical health experts' awareness and acceptance level	SO2	De Togni et al. (2021); Shevtsova et al. (2024); Gray et al. (2007)
Technological (TO)	Compatibility levels of robotic medicine with existing healthcare infrastructure	TO1	King (2023); Kumar et al. (2021); Owolabi et al. (2022); Deo and Anjankar (2023); Guntur et al. (2019)
	Level of data and internet infrastructure for AI algorithms for robotic medicine	TO2	Haidegger et al., (2011); Ng and Tam (2014); Appio et al., (2023); George et al. (2018)
Economical (EO)	Cost of Investments in robotic medicine technologies.	EO1	Jiang et al. (2023); Gunderman et al. (2023); Pandey (2024)

	National budget for Kenyan healthcare	EO2	Sequeira(2019),(Yang et al., 2020),(Kasimoglu et al., 2020)
Environmental (EN)	Level of recyclability of robotic medical technologies waste	EN1	Deo and Anjankar (2023); Sharma et al. (2023); Cao et al. (2020), Guo and Li (2018)
	The amount of robotics medical waste into the environment	EN2	Abdi et al. (2018); Alip et al. (2022; Altyar et al. (2023); Maibaum et al. (2022)
Political (PO)	Government legislation, policies, and regulations on robotic medicine in Kenyan healthcare	PO1	Cui et al. (2013); Kalan et al. (2010); George et al. (2018); Mbunge et al. (2022); Bhatnagar (2020)
	Political global collaboration for standardized, safe robotic medicine development and use	PO2	Davenport and Kalakota (2019); Archibald and Barnard (2018); Sehume and Markus (2020; Rahimi et al. (2023)
Value (VE)	Level of AI Intellectual property rights, liability issues, and compliance standards	V01	Wynsberghe, 2016); De Togni et al. (2021); Archibald and Barnard (2018) and Stasevych and Zvarych (2023)
	The AI ethical issues like patient data privacy, algorithm transparency, and bias	V02	Ebnali et al. (2024); Rahimi et al. (2023); Raje et al. (2021b); Baines et al. (2020)

Table 5.1 shows the drivers of change that were derived from the systematic literature review and experts' opinion (both medics and robotics experts) as per the Delphi technique.

5.2 SWOT Analysis

SWOT analysis was crucial in studying the adoption of robotic medicine in Kenya as it provides a structured approach to evaluating the strengths, weaknesses, opportunities, and threats related to this technological advancement from Table 5.1 (Albanese et al., 2024).

Strengths lie in the presence of established research institutions that will foster the adoption of robotic medicine. However, weaknesses included a need for more human capacity and adequate regulatory and policy frameworks for full adoption. Opportunities arose from government partnerships and donor funding aimed at promoting robotic medicine. Conversely, threats encompass technological disruptions, misinformation, and public resistance to robotic medical solutions due to unfamiliarity or mistrust as per the STEEPV framework in Figure 4.1.

Figure 5.1: SWOT analysis for the drivers of change

SWOT analysis in Figure 5.1 and identification of potential challenges and advantages were done to enable better strategic scenario planning, thus helping in aligning Kenya's healthcare objectives towards robotic medicine adoption from the drivers of change in Table 5.1.

5.3 Impact Uncertainty Approach

The Impact Uncertainty Analysis enabled a comprehensive understanding of the risks and uncertainties associated with adoption of robotic medicine in the healthcare (Thakur, 2021).

Figure 5.2: Impact-uncertainty analysis for the robotic medicine adoption

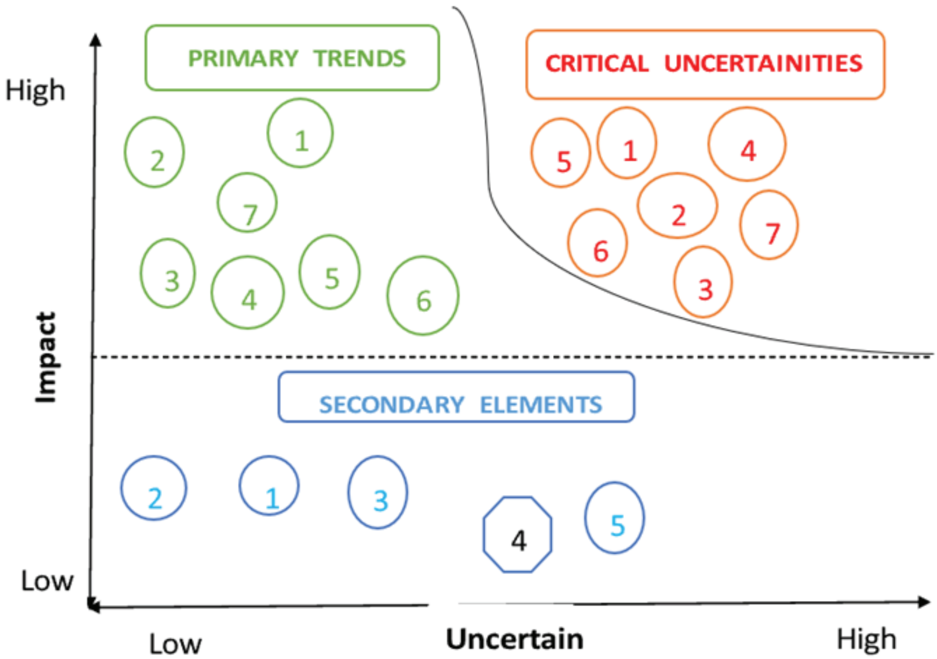


Figure 5.2 shows the systematic approach of the impact-uncertainty analysis used to scan the horizon for the drivers of the adoption of robotic medicine in terms of the primary trends, critical uncertainties and secondary elements that related to the key drivers in Table 5.1.

Table 5.2: Horizon scanning output for the drivers of robotic medicine adoption

Primary Trends	Critical Uncertainties	Secondary elements
1. Government funding allocation for healthcare 2. Regulatory framework for medical robotics 3. Skilled workforce availability 4. Technological advancements in robotic medicine 5. Public acceptance of robotic medical solutions 6. Robotic-enabled healthcare infrastructure development	Evolution of robotic technology and knowledge transfer Global health threats and pandemics Intellectual property regulations on robotic medical devices Political stability and alignment with technological advancements Public perception and acceptance of robotic medical solutions Collaboration between public and private sectors Advancements in regulatory standards for robotic medicine	1. Demographics dynamics 2. Technological literacy 3. Interconnectivity 4. Supply chain resilience for robotic medical equipment. 5. Population growth and increase in healthcare demand

Table 5.2 shows the horizon scanning output for the drivers of robotic medicine adoption identified in Table 5.1. They provided the enabling environment in which the drivers of change were classified as per the STEEPV framework.

5.4 Applications and Analysis of Key Drivers of change

These analyses were designed to ascertain the significance, influence, and unpredictability of drivers of change as the STEEPV framework. The drivers of change with the highest mean scores indicated the most significant uncertainty and impact on adoption of robotic medicine adoption. Under Cross-Impact Analysis, the drivers with the highest active and passive sums were identified. The top two predominant drivers of change, characterized by their significant impact and uncertainty, were employed in subsequent sections during the construction of future scenario analysis.

5.4.1 Impact Uncertain Analysis

5.4.1.1 Mean of drivers of change corresponding with Impact

Table 5.3 delineated the mean values and the respective tendencies regarding the impact of each driver. "T02/ Level of data and internet infrastructure for AI algorithms for robotic medicine" emerged as the driver with the highest mean score of 4.1550, indicating its substantial impact. This was narrowly followed by "S01/ Level of societal acceptance of robotic medicine", which attained a mean score of 4.115. "E01/ Cost of Investments in robotic medicine technologies" and "E02/ National budget for Kenyan healthcare" both followed closely, each with a mean score of 3.770 and 3.550, respectively. Conversely, 'P01/Government legislation, policies, and regulations on robotic medicine in Kenyan healthcare ' was identified as the driver with the least impact, reflected by its lower mean score of 3.080.

Table 5.3: Mean of drivers on impact

No	Short Labels of Drivers of Change	Mean	Trend Projections
1	SO1	4.11500	High
2	SO2	3.49000	Moderate
3	TO1	3.46000	Moderate
4	TO2	4.15500	High
5	EO1	3.77000	Moderate
6	EO2	3.55000	Moderate
7	EN1	3.25000	Moderate
8	EN2	3.30500	Moderate
9	PO1	3.08000	Moderate
10	PO2	3.23500	Moderate
11	VO1	3.29500	Moderate
12	VO2	3.33000	Moderate

5.4.1.2 Mean of drivers of change corresponding with Uncertainty levels

Table 5.4 presents the mean values and tendencies pertaining to the uncertainty associated with each driver." V01/ Level of AI Intellectual property rights, liability issues, and compliance standards" was identified as having the highest level of uncertainty, with a mean score of 2.3050, followed by "V02/ The AI ethical issues like patient data privacy, algorithm transparency, and bias "at 2.2400. "E02/ National budget for Kenyan healthcare" also showed a notable level of uncertainty, scoring 2.1150.

On the other end of the spectrum, the drivers with the lowest degree of uncertainty were “T02/ Level of data and Internet infrastructure for AI algorithms for robotic medicine” and “P02/Political global collaboration for standardized, safe robotic medicine development and use”, which had a mean score of 1.8250 in both cases.

Table 5.4: Mean drivers on uncertainty

No	Short Labels of Drivers of Change	Mean	Trend Projections
1	SO1	1.8850	Low
2	SO2	2.0100	Low
3	TO1	2.0900	Low
4	TO2	1.8250	Very Low
5	EO1	1.9650	Very Low
6	EO2	2.1150	Low
7	EN1	2.1000	Low
8	EN2	2.1750	Low
9	PO1	2.0000	Low
10	PO2	1.8250	Low
11	VO1	2.3050	Low
12	VO2	2.2400	Low

After calculating the mean values for both impact and uncertainty, Table 5.4 was constructed to provide clear data on these two distinct aspects in preparation for the impact-uncertainty analysis. Consequently, the two most critical drivers—"T02/ Level of data and internet infrastructure for AI algorithms for robotic medicine" and "S01/Level of societal acceptance of robotic medicine"—were selected for the development of scenario-building analysis.

Figure 5.3: Impact-uncertainty analysis

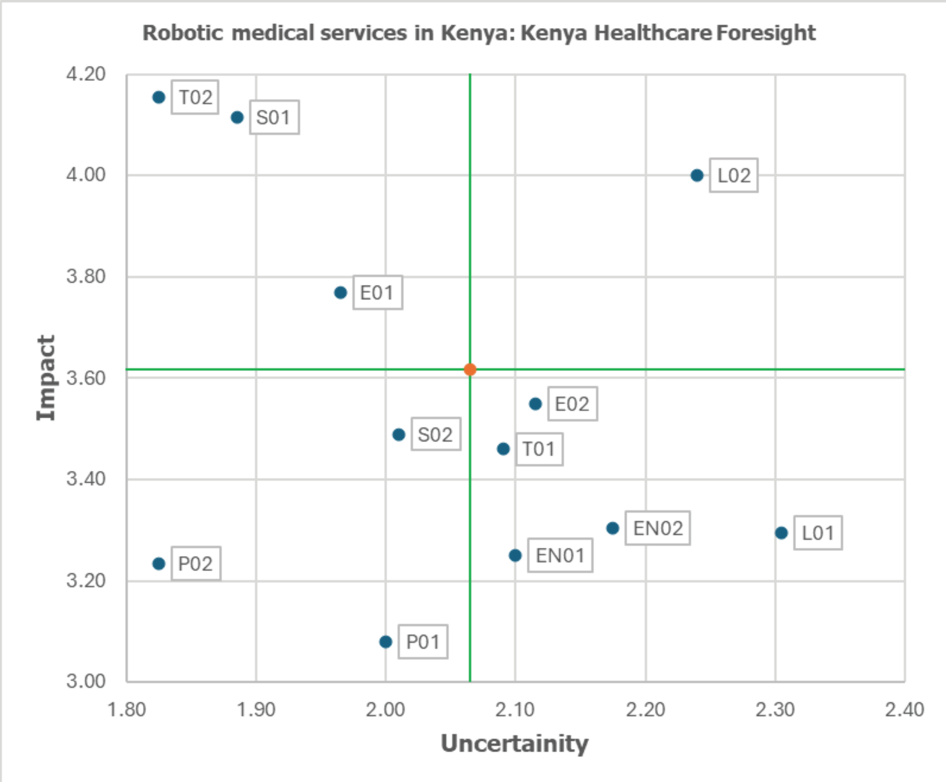


Figure 5.3 shows in the Impact-Uncertainty Analysis that the level of data and Internet infrastructure for AI algorithms for robotic medicine and societal acceptance of robotic medicine play a crucial role in realizing robotic medical services in Kenya. It means we could build a future while considering these key drivers of change.

5.4.2 Cross impact analysis

A Cross Impact Analysis Matrix is a tool used to evaluate how different events or changes influence each other within a system. It involved creating a table where rows and columns represent various factors or variables, with each cell detailing the impact one variable has on another.

This matrix helped in visualizing interactions and dependencies, aiding in scenario planning and strategic decision-making by highlighting potential effects and interactions between factors. MICMAC tool was used for analysis and ranking of the key drivers of change necessary for building future scenarios.

Table 5.5: Cross impact analysis matrix

So1	So2	To1	To2	Eo1	Eo2	ENo1	ENo2	Po1	Po2	Vo1	Vo2	K	
So1		3	3	3	2	3	3	3	3	3	3	3	32
So2	2		2	3	2	2	2	2	2	2	2	2	23
To1	3	2		3	2	2	2	2	2	2	2	1	23
To2	3	3	3		2	3	3	3	3	3	3	3	32
Eo1	3	2	2	3		2	2	2	2	2	2	2	24
Eo2	3	2	2	2	3		2	2	2	2	2	1	23
ENo1	3	2	1	3	2	2		2	2	2	1	2	22
ENo2	2	3	2	2	2	2	2		2	2	2	2	23
Po1	2	1	2	2	2	2	1	2		2	2	2	20
Po2	3	2	1	3	2	2	2	2	2		1	1	21
Vo1	3	2	2	2	2	1	2	2	2	2		2	22
Vo2	3	2	2	2	1	2	2	2	2	2	2		22
W	30	24	22	28	22	23	23	24	24	24	22	21	

From Table 5.5 in the Cross Impact Analysis Matrix, drivers of change "So1", "To2", which were Level of societal acceptance of robotic medicine and Level of data and internet infrastructure for AI algorithms for robotic medicine, respectively, recorded the highest passive and active sums denoted stronger influences, thus supporting strategic planning and the anticipation of potential future scenarios.

Figure 5.4: Direct Influence graph

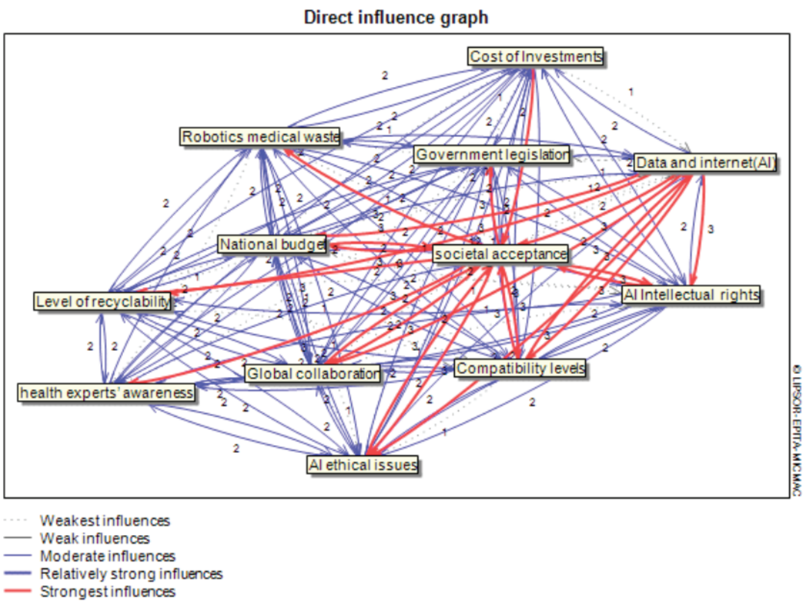


Figure 5.5 of "Direct Influence Graph," showed that "S01", "T02" which are Level of societal acceptance of robotic medicine and Level of data and internet infrastructure for AI algorithms for robotic medicine, respectively, had the strongest influence on the adoption of robotic medical services. Other drivers of change had a relatively strong influence on the key drivers of change such as "P01", "E01", "S02" as from Table 2.

Figure 5.5: Direct Influence/Dependence Graph

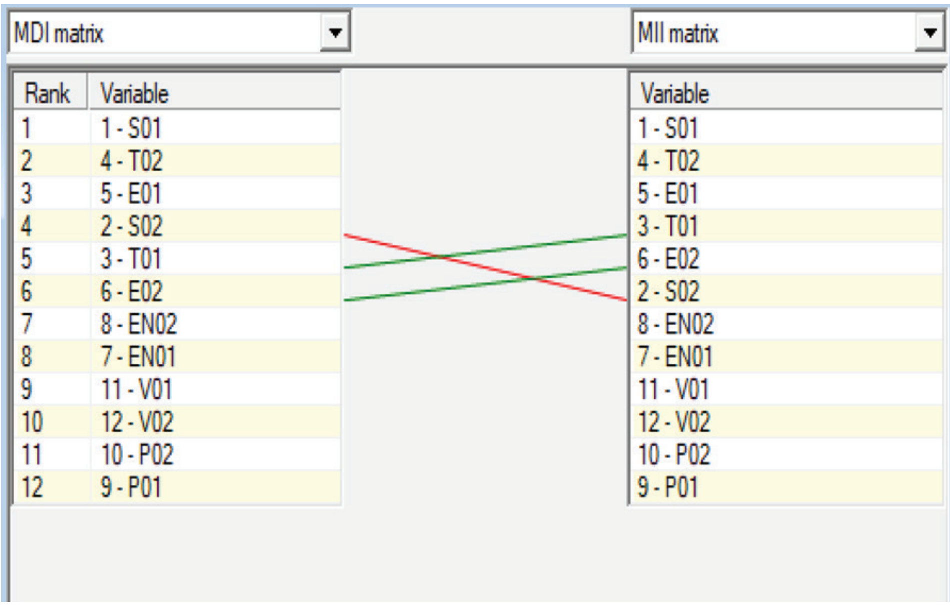


Figure 5.5 shows the direct influence and dependence graph with "S01", "T02" which are Level of societal acceptance of robotic medicine and Level of data and internet infrastructure for AI algorithms for robotic medicine, respectively, as the strongest drivers of change in terms of influence and dependence on the adoption of robotic medical services in Kenya as shown in Table 5.1 and Table 5.5. Other drivers of change had relatively low influence on the adoption thus we could build scenarios as the key drivers of change.

Figure 5.6: Rank of drivers of change by influence

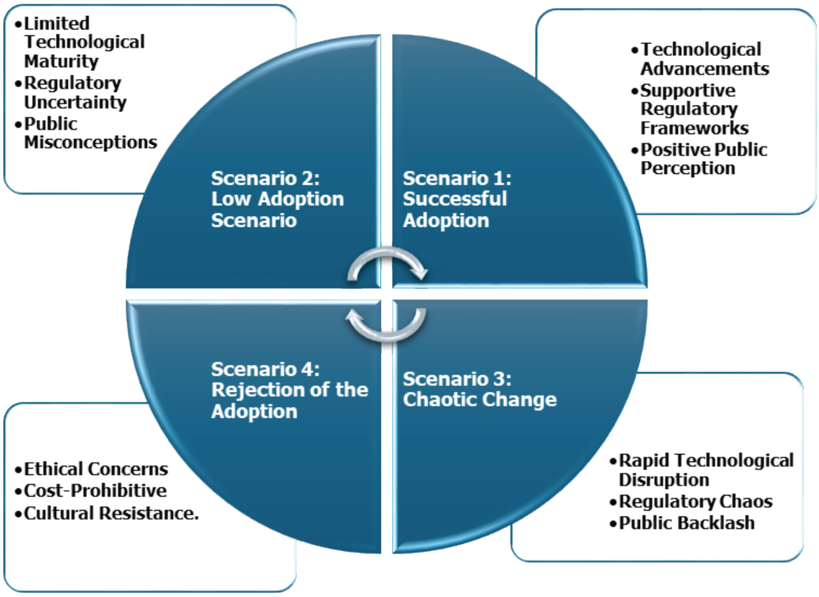
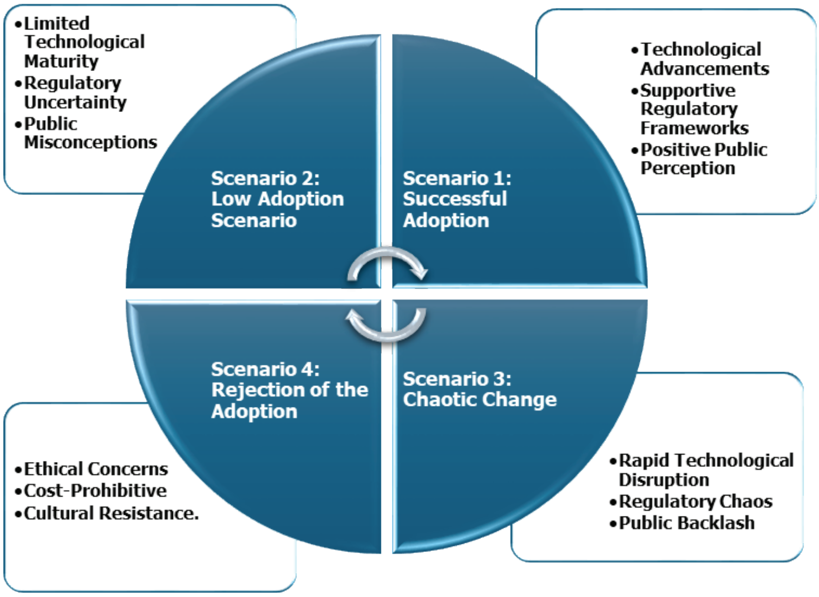


Figure 5.6 shows that "S01", "T02" which were Level of societal acceptance of robotic medicine and Level of data and internet infrastructure for AI algorithms for robotic medicine, respectively, had the highly ranked drivers of change thus important in building future scenarios as derived from Table 5.1 and Table 5.5.

5.5 Building of Future Scenarios

Based on the analysis of key drivers of change (degrees of social acceptance and protection against data manipulation concerning robotic medicine in Kenya), we developed the following potential scenarios as shown in Figure 5.7.

Figure 5.7: Future Scenarios for robotic medicine in Kenyan Healthcare



The scenario matrix quadrant was used as is a strategic tool to plan for various potential futures by considering how different levels of social acceptance and data security could interact and influence the trajectory of robotic medicine in society and the healthcare industry.

Each scenario hypothesizes what could happen in the future, helping stakeholders and government agencies to prepare.

(1) Scenario 1: "Successful adoption of robotic medicine"

High social acceptance and high protection of data manipulation characterized this scenario. It implied a future where patients and all medical practitioners widely accept robotic medicine, effectively preventing data manipulation and leading to successful and secure adoption.

Scenario 1 materialized under conditions of high social acceptance and robust protection against data manipulation within robotic medicine technology. "Successful robotic medicine" denotes the AI's capacity to enhance robotic medicine in Kenya. The immutable robotic medicine and good database network infrastructure could mitigate incidents of doctors making treatment errors and long booking queues (Zhang et al., 2023). It could reduce the overhead costs associated with traditional medical services where the patient has to visit the hospital, promoting efficiency in healthcare (Raje et al., 2021a).

Hospitals could track real-time updates of healthcare services provision data flows through robotic medicine, improving healthcare delivery (Bera et al., 2019). Sacha and Varona (2013) advocated for the use of robotic medicine in tracking recovery rates, noting its precision in recovery rates, dates, and times of different patients, which allows improved healthcare distribution and provision (Chan and Muralidharan, 2024). Robotic medicine could help streamline healthcare operations, ensuring access to relevant and high-quality diagnosis, boosting efficiency, reducing medical and logistic costs, and building trust of patients, all of which contribute to the superior provision of healthcare products (Cui et al., 2013).

Robotic medicine has the potential to achieve significant cost reductions in healthcare, which has been a huge problem for many Kenyans. As more medical facilities engage in the globalization of healthcare, robotics becomes more critical (Alip et al., 2022). Robotic medicine could offer a solution to Kenya due to the increase in the number of diseases and the aging population with high cases of cancer-related deaths due to delays in treatment. Telemonitoring facilitated by robotic medicine could remove the need for intermediaries, enhance remote treatment and management of patients remotely, and simplify patient-health practitioner interaction. Healthcare hospitals in Kenya could use robotic medicine to increase the number of surgical operations, resulting in faster delivery and cost reductions (Altyar et al., 2023).

(2) Scenario 2: "Low adoption of robotic medicine"

Low adoption will be in the quadrant with low social acceptance and high protection of data manipulation. This scenario suggests a future where robotic medicine will not be widely accepted and fails to provide adequate data protection, resulting in low adoption rates by patients and medical practitioners.

In Scenario 2, robotic medicine will have a low adoption rate, with inadequate data manipulation safeguards and minimal social acceptance. This scenario suggests that despite the known benefits of robotic medicine, Kenyan patients are reluctant to adopt robotic medicine due to these two prevailing issues. Slow adoption rates may stem from unexpected barriers that hinder healthcare from progressing as desired. Many global hospitals and healthcare firms in India and Europe benefiting from the Kenyan patients visiting them might resist innovation to preserve existing revenue streams (Archibald and Barnard, 2018). Healthcare experts who are resistant to change could be apprehensive about integrating robotic medicine into their healthcare operations (Appio et al., 2023), while other medical intermediaries may fear being made redundant by the new method of operation.

The complexity of robotic medicine might overwhelm individual users, making it difficult for them to understand, adopt, and utilize AI technology (Ahmed et al., 2024). Adoption challenges could be compounded by the time and effort required to transition to new technologies, with some healthcare facilities being early adopters and others remaining cautious or inactive due to limited resources or unconvincing benefits.

Furthermore, lack of education in robotic medicine impedes its broader social acceptance. Many people mistakenly believe robotic medicine could restrict healthcare growth and its potential applications in nursing and drug delivery. Public education will be essential for fostering understanding and effective use of this robotic medicine (Ajmera and Jain, 2019). Given that robotic medicine is a relatively recent innovation, there could be a general mistrust among patients who are unfamiliar with it, especially in developed countries. Significant effort is required before robotic medicine gains widespread trust and recognition (George et al., 2018). Nonetheless, robotic medicine technology will gradually make inroads in medicine.

(3) Scenario 3: "Dark side of robotic medicine"

This scenario, found in the quadrant with high social acceptance but low protection against data manipulation, portrays a paradoxical future where robotic medicine will be socially accepted despite its inability to protect against data manipulation, possibly leading to unforeseen negative consequences.

Scenario 3, termed the "Dark Side of Robotic Medicine," emerges in an environment where technology is widely accepted but the protection against data manipulation is weak. This scenario highlights the potential downsides of robotic medicine in hospitals and patients' concerns about the risks and downsides associated with its implementation. Despite its growing popularity in recent years in developed countries such as Germany, Japan, and India, among others, have embraced robotic medicine despite high investment costs. For instance, buying Da Vinci will cost US$ 3 million, necessitating substantial investment to implement effectively. Adopting robotic medicine will not be without significant expense, including hiring developers, assembling a team of experts, procuring robotic medicine solutions, and other associated costs (Sharma, Rahul and Pavika, 2024). Kenyan hospitals could also factor in ongoing maintenance expenses, which could reach millions of Kenya shillings for commercial robotic medicine projects. More financial resources can delay significantly improving healthcare provision through robotic medicine.

One of the primary disadvantages of robotic medicine is the immutability of its data, as robots have to learn from imputed data (Nelivigi, 2007). This financial barrier could limit access to this advanced medical technology for certain healthcare facilities and patients, hindering the widespread adoption of robotic-assisted procedures and potentially exacerbating already existing disparities in healthcare access in Kenya.

(4.) Scenario 4: "Lack of trust in robotic medicine"

Despite low protection against data manipulation, this quadrant had low social acceptance. This scenario suggests that, even though the technology will be secure, a lack of trust from the public or stakeholders will prevent its widespread adoption.

In Scenario 4, despite high data manipulation protection, the low social acceptance of robotic medicine reflects a pervasive lack of trust. Camarillo et al. (2004) noted that trust bolsters collaborative efforts by increasing the propensity to share information and skills. Given the nascent stage of robotic medicine, its acceptance is limited, necessitating time to win over skeptics of robotic medicine. Establishing robotic medicine in Kenya's healthcare system might face challenges, as skepticism prevails, and participants need more incentives to adhere to rules. The general public's understanding of robotic medicines could often be conflated with high death care due to Internet instability (Jiang et al., 2023).

Government intervention will be required to prevent the misuse of patient data generated within the system. Decentralization of patient data complicates the tracking of illicit activities such as cybercrimes. Some users might overlook these risks, deeming them the price of freedom, but criminal exploitation of networks remains intolerable (Haidegger et al., 2011). The presence of autonomous robots could cause too much dependence on robots, thus threatening the number of medical doctors being hired in hospitals. However, inadequate regulation could undermine public confidence in robotic medicine (Gomes, 2011).

Table 5.6 presents various future scenarios for other remaining drivers of change and their archetypes essential for the successful adoption of robotic medicine in Kenya as shown in Table 5.1. It highlighted drivers of change for the different future scenarios of successful adoption of robotic medicine, low adoption of robotic medicine, darkside of robotic medicine, and lack of trust in robotic medicine in terms of technological advancements, regulatory frameworks, economic conditions, and societal readiness.

Each future scenario outlined how these elements interact and influence the integration of robotic medical services in the Kenyan healthcare. The archetypes served as models or patterns that depict potential outcomes, guiding stakeholders in making informed decisions to foster a conducive environment for the widespread implementation of robotic medicine.

Table 5.6: Drivers of Future change and their Archetypes in Robotic Medicine

Drivers of Change	Scenario 1: Successful Adoption	Scenario 2: Low Adoption Scenario	Scenario 3: Chaotic Change	Scenario 4: Rejection of the Adoption
Level of societal acceptance of robotic medicine	• High public trust in technology • Regular use in routine healthcare	• Mixed reactions from different demographics • Limited to certain high-tech hospitals	• Public protests and opposition • Sporadic use due to conflicting opinions	• Widespread fear and mistrust • Minimal adoption and rejection of technology
Medical health experts' awareness and acceptance level	• Comprehensive training programs • High levels of comfort and proficiency	• Limited training leading to partial proficiency • Some skepticism among older professionals	• Resistance due to lack of proper training • Confusion and inconsistent use	• Majority of experts are skeptical • Refusal to adopt new technologies
Compatibility levels of robotic medicine with existing healthcare infrastructure	• Full integration with existing systems • Enhanced efficiency and accuracy	• Requires significant adjustments • Partial integration causing occasional issues	• Frequent compatibility problems • Disruptions in healthcare delivery	• Incompatibility with current systems • Abandonment of robotic technologies
Level of data and Internet infrastructure for AI algorithms for robotic medicine	• Extensive and reliable infrastructure • Supports advanced AI applications smoothly	• Adequate in urban areas but lacking in rural regions • Occasional disruptions	• Unreliable and inconsistent connectivity • Frequent interruptions in services	• Insufficient infrastructure • Prevents deployment of AI-based solutions
Cost of investments in robotic medicine technologies	• High initial costs but justified by long-term savings • Government subsidies and private investments	• Moderate investments with slow returns • Some financial strain on healthcare providers	• Overruns in budget • Financial instability and delays in implementation	• Prohibitive costs • Inability to secure funding, leading to rejection
National budget for Kenyan healthcare	• Significant budget allocation • Focus on modernizing healthcare	• Sufficient but prioritizes basic needs • Limited funds for advanced technology	• Budget constraints and reallocation • Inadequate funding for robotics	• Minimal allocation • Prioritization of other areas over robotic technologies
Level of recyclability of robotic medical technologies waste	• High recyclability ensuring minimal impact • Effective waste management programmes	• Moderate recyclability • Some challenges in managing waste	• Poor recyclability. • Environmental concerns due to improper disposal	• Non-recyclable components • Significant environmental pollution
The amount of robotics medical waste into the environment	• Strict regulations • Efficient disposal systems	• Controlled waste management • Occasional lapses in procedures	• Unregulated disposal • High levels of pollution	• Improper disposal practices • Significant environmental damage
Government legislation, policies, and regulations on robotic medicine in Kenyan healthcare	• Supportive and comprehensive laws • Encourages innovation and adoption	• Basic regulations with gaps • Hindrance to full potential	• Conflicting policies • Regulatory uncertainty	• Lack of supportive legislation • Significant barriers to adoption
Political global collaboration for standardized, safe robotic medicine development and use	• Strong international partnerships • Standardized safety protocols	• Limited collaboration • Inconsistencies in safety standards	• Sporadic and unreliable collaborations • Fragmented safety practices	• No collaboration • Unsafe and isolated practices
Level of AI intellectual property rights, liability issues, and compliance standards	• Well-defined and enforced standards • Protection and compliance ensured	• Partial clarity • Occasional disputes and compliance issues	• Frequent legal battles • Unclear standards and practices	• Lack of clear standards • Widespread legal and compliance issues
The AI ethical issues such as patient data privacy, algorithm transparency, and bias	• High ethical standards • Ensures data privacy and fairness	• Moderate focus on ethics • Occasional transparency and bias issues	• Frequent ethical breaches • Loss of public trust	• Major ethical concerns • Public outcry and rejection

6. Conclusion and Policy Recommendations

6.1 Conclusion

The study sought to explore the adoption of robotic medical services and the future of healthcare in Kenya. The literature review identified twelve drivers of change in the future of the adoption of robotic medicine, including societal and expert acceptance of robotic medicine, compatibility with existing infrastructure, robustness of data and Internet for AI, investment costs, national healthcare budget, recyclability and environmental impact of medical waste, legislative frameworks, global political collaboration, and AI-related intellectual property, liability, and ethical issues such as patient data privacy, transparency, and bias. The stakeholders and experts ranked these drivers of change according to Impact Uncertainty and Cross Impact analysis methodologies.

The drivers with the highest influence and least dependency was the robustness of data and Internet for AI and the societal acceptance of robotic medicine adoption. Based on the study findings, adopting robotic medicine, a key disruptive technology of the Fourth Industrial Revolution (4IR), promises to revolutionize healthcare delivery in Kenya. This initiative aligns with the government's Bottom-Up Transformative Agenda (BETA) and Medium-Term Plan IV (MTP IV), aimed at achieving universal healthcare (UHC), thus enhancing the availability, accessibility, affordability, and efficiency of healthcare, addressing persistent challenges many Kenyans face. As the population increases, the number of people who seek specialized medical services will increase in the future due to existence of many diseases (Cresswell et al., 2018).

The study employed the driving forces to create plausible future scenarios such as Successful Adoption, Low Adoption, Chaotic Change, and Rejection of the Adoption were identified. The main opportunities were identified as rapid AI technological developments, opportunities in medical tourism, and robotic medical innovations. At the same time, the critical challenges in the plausible future were found to be regulatory uncertainty, ethical concerns, data privacy, and public misconceptions from social acceptance levels. These drivers of change will foster robotic medicine adoption in Kenya.

6.2 Policy Gaps

Based on the two key drivers of change or driving forces based on the findings of the study, policy gaps are as follows. One, societal acceptance of robotic medical services is hindered by limited public awareness, as many Kenyans are unfamiliar with these robotic medicine technologies, leading to mistrust and reluctance to embrace AI-powered healthcare. In addition, ethical concerns such as data privacy, algorithmic bias, and potential job placement within the healthcare sector require thorough consideration and mitigation strategies. Cultural considerations, including the role of traditional medicine and cultural beliefs towards healthcare, must also be acknowledged and integrated when adopting AI technologies.

Two, AI algorithms' success in healthcare relies heavily on robust data and Internet infrastructure. Limited access to high-quality anonymized medical data hampers developing and training effective AI models for healthcare applications. Uneven Internet connectivity, particularly in rural areas, restricts the reach and potential benefits of AI-powered healthcare services, which are crucial for remote diagnostics and telepresence surgery. Robust data security frameworks are essential to protect patient privacy and prevent cyberattacks, ensuring AI's safe and effective use in Kenyan healthcare.

6.3 Policy Recommendations

The recommendations include:

Improve societal acceptance level

- Public Awareness Campaigns: Launch comprehensive campaigns to educate the public on the benefits, safety, and efficacy of robotic medicine. Use various media platforms to reach diverse audiences and dispel myths and misconceptions.
- Community Engagement: Involve community leaders and local organizations in promoting acceptance. Host town hall meetings, workshops, and interactive sessions where citizens can learn about and experience robotic technologies firsthand.
- Patient Education: Develop educational programmes for patients and their families in healthcare settings. Provide detailed information on how robotic medicine works, its advantages, and address any concerns.
- Transparency and Trust: Ensure transparency in the implementation process. Share success stories, clinical trial results, and case studies demonstrating the effectiveness of robotic medicine.
- Regulatory Framework: Establish robust regulatory standards to ensure the safety and ethical use of robotic medicine. Ensure compliance with these standards to build public trust.
- Collaboration with Healthcare Providers: Partner with healthcare professionals to advocate for robotic medicine. Provide training and support to doctors and nurses and other healthcare providers to enhance their confidence and competence in using robotic technologies.

Enhance the level of data and Internet infrastructure for AI

- Investment in Broadband Infrastructure: Prioritize investment in high-speed broadband infrastructure, especially in rural and underserved areas. Collaborate with private sector partners and international donors to expand Internet coverage and improve connectivity.

- Development of Data Centres: Establish state-of-the-art data centres across the country to ensure robust data storage, processing, and management capabilities. Promote public-private partnerships to build and operate these facilities efficiently.
- Regulatory Framework for Data Management: Implement a comprehensive regulatory framework for data management, focusing on data security, privacy, and interoperability. Ensure compliance with international standards to protect patient information and foster trust in AI systems.
- Training and Capacity Building: Invest in training programmes for IT professionals, healthcare providers, and policy makers to enhance their understanding of AI technologies and data management practices. Encourage higher education institutions to offer specialized courses in AI and data science.
- Support for Research and Development: Provide grants and incentives for research and development in AI and data infrastructure. Encourage collaboration between universities, research institutions, and tech companies to drive innovation and create locally adapted solutions.
- Public-Private Partnerships: Foster public-private partnerships to leverage the expertise and resources of the private sector. Encourage tech companies to invest in Kenya's data and Internet infrastructure, offering incentives such as tax breaks and streamlined regulatory processes.
- Monitoring and Evaluation: Establish a monitoring and evaluation framework to track the progress of infrastructure development initiatives. Regularly assess the impact of these initiatives on the healthcare system and make necessary adjustments to ensure continuous improvement.

References

Abdi, J., Al-Hindawi, A., Ng, T. and Vizcaychipi, M.P. (2018), "Scoping review on the use of socially assistive robot technology in elderly care". *BMJ Open*, 8(2), e018815. https://doi.org/10.1136/bmjopen-2017-018815.

Ahmed, S.F., Alam, Md. S.B., Afrin, S., Rafa, S.J., Rafa, N. and Gandomi, A.H. (2024), "Insights into Internet of Medical Things (IoMT): Data fusion, security issues and potential solutions". *Information Fusion*, 102: 102060. https://doi.org/10.1016/j.inffus.2023.102060

Albanese, G.A., Bucchieri, A., Podda, J., Tacchino, A., Buccelli, S., De Momi, E., Laffranchi, M., Mannella, K., Holmes, M.W.R., Zenzeri, J., De Michieli, L., Brichetto, G., and Barresi, G. (2024), "Robotic systems for upper-limb rehabilitation in multiple sclerosis: A SWOT analysis and the synergies with virtual and augmented environments". *Frontiers in Robotics and AI*, 11. https://doi.org/10.3389/frobt.2024.1335147.

Alip, S.L., Kim, J., Rha, K.H., and Han, W.K. (2022), "Future platforms of robotic surgery". *Urologic Clinics*, 49(1): 23-38. https://doi.org/10.1016/j.ucl.2021.07.008.

Altyar, A.E., El-Sayed, A., Abdeen, A., Piscopo, M., Mousa, S.A., Najda, A. and Abdel-Daim, M.M. (2023), "Future regenerative medicine developments and their therapeutic applications". *Biomedicine and Pharmacotherapy*, 158: 114131. https://doi.org/10.1016/j.biopha.2022.114131.

Appio, F.P., Torre, D.L., Lazzeri, F., Masri, H. and Schiavone, F. (2023), *Impact of Artificial Intelligence in business and society: Opportunities and challenges*. Taylor and Francis.

Aragon, M.J.A., Castelli, A., and Gaughan, J. (2017), "Hospital trusts productivity in the English NHS: Uncovering possible drivers of productivity variations". *Plos One,* 12(8), e0182253. https://doi.org/10.1371/journal.pone.0182253.

Archibald, M.M. and Barnard, A. (2018), "Futurism in nursing: Technology, robotics and the fundamentals of care". *Journal of Clinical Nursing*, 27(11–12): 2473-2480. https://doi.org/10.1111/jocn.14081.

Ayentimi, D.T.and Burgess, J. (2019), "Is the fourth industrial revolution relevant to sub-Sahara Africa?" *Technology Analysis and Strategic Management*, 31(6), 641–652. https://doi.org/10.1080/09537325.2018.1542129

Baines, D., Nørgaard, L. S., Babar, Z.-U.-D. and Rossing, C. (2020), "The Fourth Industrial Revolution: Will it change pharmacy practice?" *Research in Social and Administrative Pharmacy*, 16(9): 1279-1281. https://doi.org/10.1016/j.sapharm.2019.04.003.

Bera, K., Schalper, K.A., Rimm, D.L., Velcheti, V. and Madabhushi, A. (2019), "Artificial intelligence in digital pathology—New tools for diagnosis and precision oncology". *Nature Reviews Clinical Oncology*, 16(11), Article 11. https://doi.org/10.1038/s41571-019-0252-y.

Bhatnagar, N. (2020), "Role of robotic process automation in pharmaceutical industries". In A. E. Hassanien, A. T. Azar, T. Gaber, R. Bhatnagar and M. F. Tolba (Eds.), The International Conference on Advanced Machine Learning Technologies and Applications (AMLTA2019) (pp. 497–504). Springer International Publishing. https://doi.org/10.1007/978-3-030-14118-9_50.

Bianchi, G., Martínez-Pérez, A. and de'Angelis, N. (2023), "Robotics". In F. Coccolini and F. Catena (Eds.), *Textbook of Emergency General Surgery: Traumatic and Non-traumatic Surgical Emergencies* (pp. 457–469). Springer International Publishing. https://doi.org/10.1007/978-3-031-22599-4_30.

Camarillo, D.B., Krummel, T.M. and Salisbury, J.K. (2004), "Robotic technology in surgery: Past, present, and future". *American Journal of Surgery*, 188(4A Suppl), 2S-15S. https://doi.org/10.1016/j.amjsurg.2004.08.025.

Cao, Z., Qin, C., Fan, S., Yu, D., Wu, Y., Qin, J. and Chen, X. (2020), "Pilot study of a surgical robot system for zygomatic implant placement". *Medical Engineering and Physics*, 75: 72-78. https://doi.org/10.1016/j.medengphy.2019.07.020.

Chan, H.Y. and Muralidharan, A. (2024), "Care robots for the elderly: Legal, ethical considerations and regulatory strategies". In N. Naim (Ed.), *Developments in Intellectual Property Strategy: The Impact of Artificial Intelligence, Robotics and New Technologies* (pp. 129–156). Springer International Publishing. https://doi.org/10.1007/978-3-031-42576-9_6.

Cresswell, K., Cunningham-Burley, S., and Sheikh, A. (2018), "Health care robotics: Qualitative exploration of key challenges and future directions". *Journal of Medical Internet Research*, 20(7), e10410. https://doi.org/10.2196/10410.

Cui, P., Jin, S., Yu, L., Wang, F., Zhu, W. and Yang, S. (2013), Cascading outbreak prediction in networks: A data-driven approach. Proceedings of the 19th ACM SIGKDD International Conference on Knowledge Discovery and Data Mining, 901–909. https://doi.org/10.1145/2487575.2487639.

Davenport, T. and Kalakota, R. (2019), "The potential for artificial intelligence in healthcare". *Future Healthcare Journal,* 6(2): 94-98. https://doi.org/10.7861/futurehosp.6-2-94.

De Togni, G., Erikainen, S., Chan, S., and Cunningham-Burley, S. (2021), "What makes AI 'intelligent' and 'caring'? Exploring affect and relationality across three sites of intelligence and care". *Social Science and Medicine*, 277, 113874. https://doi.org/10.1016/j.socscimed.2021.113874.

Deo, N. and Anjankar, A. (2023), "Artificial intelligence with robotics in healthcare: A narrative review of its viability in India". *Cureus*. https://doi.org/10.7759/cureus.39416.

Ebnali, M., Zenati, M. A. and Dias, R.D. (2024), "Artificial intelligence in cardiothoracic surgery: Current applications and future perspectives". In C. Krittanawong (Ed.), *Artificial Intelligence in Clinical Practice* (pp.

217-234). Academic Press. https://doi.org/10.1016/B978-0-443-15688-5.00030-9

Enzer (1971). "Delphi and cross-impact techniques: An effective combination for systematic futures analysis". *Futures*, 3(1): 48-61. https://doi.org/10.1016/S0016-3287(71)80006-X.

Francis, J.N.P. and Mugabo, L. (2022), "Rwanda galvanizes healthcare readiness, citizen support, and technology to flatten the Coronavirus curve in the land of a thousand hills". In I. Shultz Clifford J., D. R. Rahtz, and M. J. Sirgy (Eds.), *Community, Economy and COVID-19: Lessons from Multi-Country Analyses of a Global Pandemic* (pp. 341–366). Springer International Publishing. https://doi.org/10.1007/978-3-030-98152-5_17.

George, E.I., Brand, T.C., LaPorta, A., Marescaux, J. and Satava, R.M. (2018), "Origins of robotic surgery: From skepticism to standard of care". *JSLS : Journal of the Society of Laparoendoscopic Surgeons*, 22(4), e2018.00039. https://doi.org/10.4293/JSLS.2018.00039.

Gomes, P. (2011), "Surgical robotics: Reviewing the past, analysing the present, imagining the future". *Robotics and Computer-Integrated Manufacturing*, 27(2): 261-266. https://doi.org/10.1016/j.rcim.2010.06.009.

Gray, P.S., Williamson, J.B., Karp, D.A. and Dalphin, J.R. (2007), *The research imagination: An introduction to qualitative and quantitative methods*. Cambridge University Press.

Gunderman, A., Montayre, R., Ranjan, A. and Chen, Y. (2023), "Review of robot-assisted HIFU therapy". *Sensors*, 23(7), Article 7. https://doi.org/10.3390/s23073707.

Guo, J. and Li, B. (2018), "The application of medical Artificial Intelligence technology in rural areas of developing countries". *Health Equity*, 2(1): 174-181. https://doi.org/10.1089/heq.2018.0037.

Haidegger, T., Sándor, J. and Benyó, Z. (2011), "Surgery in space: The future of robotic telesurgery". *Surgical Endoscopy*, 25(3): 681-690. https://doi.org/10.1007/s00464-010-1243-3.

Jiang, Z., Salcudean, S.E. and Navab, N. (2023), "Robotic ultrasound imaging: State-of-the-art and future perspectives". *Medical Image Analysis*, 89, 102878. https://doi.org/10.1016/j.media.2023.102878.

Kalan, S., Chauhan, S., Coelho, R.F., Orvieto, M.A., Camacho, I.R., Palmer, K. J. and Patel, V.R. (2010), "History of robotic surgery". *Journal of Robotic Surgery*, 4(3): 141–147. https://doi.org/10.1007/s11701-010-0202-2.

Kasimoglu, Y., Kocaaydin, S., Karsli, E., Esen, M., Bektas, I., Ince, G. and Tuna, E. B. (2020), "Robotic approach to the reduction of dental anxiety in children". *Acta Odontologica Scandinavica*, 78(6): 474–480. https://doi.org/10.1080/00016357.2020.1800084.

King, M.R. (2023), "The future of AI in medicine: A perspective from a chatbot". *Annals of Biomedical Engineering*, 51(2): 291–295. https://doi.org/10.1007/s10439-022-03121-w.

Kumar, A., Gadag, S. and Nayak, U.Y. (2021), "The beginning of a new era: Artificial Intelligence in healthcare". *Advanced Pharmaceutical Bulletin*, 11(3): 414–425. https://doi.org/10.34172/apb.2021.049.

Kyrarini, M., Lygerakis, F., Rajavenkatanarayanan, A., Sevastopoulos, C., Nambiappan, H. R., Chaitanya, K. K., Babu, A. R., Mathew, J., and Makedon, F. (2021), "A survey of robots in healthcare". *Technologies*, 9(1), Article 1. https://doi.org/10.3390/technologies9010008.

Mbunge, E., Batani, J., Gaobotse, G. and Muchemwa, B. (2022), "Virtual healthcare services and digital health technologies deployed during coronavirus disease 2019 (COVID-19) pandemic in South Africa: A systematic review". *Global Health Journal*, 6(2): 102–113. https://doi.org/10.1016/j.glohj.2022.03.001.

McMillan, L. and Varga, L. (2022), "A review of the use of artificial intelligence methods in infrastructure systems". *Engineering Applications of Artificial Intelligence*, 116: 105472. https://doi.org/10.1016/j.engappai.2022.105472.

Mutiso, V.N., Musyimi, C.W., Gitonga, I., Tele, A., Pervez, R., Rebello, T.J., Pike, K.M. and Ndetei, D.M. (2020), "Using the WHO-AIMS to inform development of mental health systems: The case study of Makueni County, Kenya". *BMC Health Services Research*, 20(1): 51. https://doi.org/10.1186/s12913-020-4906-3.

Nasr, M., Islam, Md. M., Shehata, S., Karray, F. and Quintana, Y. (2021), "Smart healthcare in the age of AI: Recent advances, challenges, and future prospects". *IEEE Access*, 9: 145248–145270. https://doi.org/10.1109/ACCESS.2021.3118960.

Nelivigi, G.G. (2007), "Robotic surgery: India is not ready yet". *Indian Journal of Urology*, 23(3): 240. https://doi.org/10.4103/0970-1591.33443.

Ng, A.T.L. and Tam, P.C. (2014), Current status of robot-assisted surgery. https://doi.org/10.12809/hkmj134167.

Okoroafor, S.C., Kwesiga, B., Ogato, J., Gura, Z., Gondi, J., Jumba, N., Ogumbo, T., Monyoncho, M., Wamae, A., Wanyee, M., Angir, M., Almudhwahi, M. A., Evalyne, C., Nabyonga-Orem, J., Ahmat, A., Zurn, P., and Asamani, J.A. (2022), "Investing in the health workforce in Kenya: Trends in size, composition and distribution from a descriptive health labour market analysis". *BMJ Global Health*, 7(Suppl 1), e009748. https://doi.org/10.1136/bmjgh-2022-009748.

Owolabi, E.O., Mac Quene, T., Louw, J., Davies, J.I., and Chu, K.M. (2022), "Telemedicine in surgical care in low- and middle-income countries: A scoping review". *World Journal of Surgery*, 46(8): 1855-1869. https://doi.org/10.1007/s00268-022-06549-2.

Pandey, V.V., B. Karthiga, Chinnahajisagari Mohammad Akram, Ashok Koujalagi, S. Nanthakumar, Vipin Sharma, Digvijay (2024), "Role of Artificial Intelligence in making wearable robotics smarter". In *Robotics and Automation in Industry 4.0*. CRC Press.

Pradhan, B., Bharti, D., Chakravarty, S., Ray, S.S., Voinova, V.V., Bonartsev, A. P. and Pal, K. (2021), "Internet of Things and robotics in transforming current-day healthcare services". *Journal of Healthcare Engineering*, 2021, e9999504. https://doi.org/10.1155/2021/9999504.

Rahimi, A.O., Ho, K., Chang, M., Gasper, D., Ashouri, Y., Dearmon-Moore, D., Hsu, C.-H., and Ghaderi, I. (2023), "A systematic review of robotic surgery curricula using a contemporary educational framework". *Surgical Endoscopy*, 37(4): 2833-2841. https://doi.org/10.1007/s00464-022-09788-5.

Raje, S., Reddy, N., Jerbi, H., Randhawa, P., Tsaramirsis, G., Shrivas, N.V., Pavlopoulou, A., Stojmenović, M., and Piromalis, D. (2021a), "Applications of healthcare robots in combating the COVID-19 pandemic". *Applied Bionics and Biomechanics*, 2021, 7099510. https://doi.org/10.1155/2021/7099510.

Raje, S., Reddy, N., Jerbi, H., Randhawa, P., Tsaramirsis, G., Shrivas, N.V., Pavlopoulou, A., Stojmenović, M., and Piromalis, D. (2021b), [Retracted] "Applications of healthcare robots in combating the COVID-19 pandemic". *Applied Bionics and Biomechanics*, e7099510. https://doi.org/10.1155/2021/7099510.

Rha, K.H. (2008), "The present and future of robotic surgery". *Journal of the Korean Medical Association*, 51(1): 67-73. https://doi.org/10.5124/jkma.2008.51.1.67.

Sacha, G.M. and Varona, P. (2013), "Artificial intelligence in nanotechnology". *Nanotechnology*, 24(45): 452002. https://doi.org/10.1088/0957-4484/24/45/452002

Sehume, O.L. and Markus, E.D. (2020), "A critical analysis of medical robotic assistive systems for early diagnosis of common ailments in South Africa". *International Journal of Mechanical Engineering and Robotics Research*, 1451-1456. https://doi.org/10.18178/ijmerr.9.10.1451-1456.

Sequeira, J.S. (Ed) (2019), *Robotics in healthcare: Field examples and challenges* (Vol. 1170). Springer International Publishing. https://doi.org/10.1007/978-3-030-24230-5

Sharma, M., Gupta, R. and Acharya, P. (2023), "Adoption and forecasting of technology: Modeling the dynamics of cloud adoption using a system approach". *Journal of Enterprise Information Management*, 36(6): 1647-1676. https://doi.org/10.1108/JEIM-05-2023-0232.

Sharma, P.W., Arun Velu, Rahul Reddy Nadikattu, Pavika (2024), "Reinforcement learning for automated medical diagnosis and dynamic clinical regimes". In *Handbook of Research on Artificial Intelligence and Soft Computing*

Techniques in Personalized Healthcare Services. Apple Academic Press.

Shevtsova, D., Ahmed, A., Boot, I.W.A., Sanges, C., Hudecek, M., Jacobs, J.J.L., Hort, S., and Vrijhoef, H. J. M. (2024)., "Trust in and acceptance of Artificial Intelligence applications in medicine: Mixed methods study". *JMIR Human Factors*, 11(1), e47031. https://doi.org/10.2196/47031.

Siciliano, B. and Khatib, O. (Eds). (2016), *Springer handbook of robotics*. Springer International Publishing. https://doi.org/10.1007/978-3-319-32552-1.

Sood, M. and Leichtle, S.W. (2013), *Essentials of robotic surgery*. Spry Publishing.

Thakur, V. (2021), "Framework for PESTEL dimensions of sustainable healthcare waste management: Learnings from COVID-19 outbreak". *Journal of Cleaner Production*, 287: 125562. https://doi.org/10.1016/j.jclepro.2020.125562.

Vatandoost, M. and Litkouhi, S. (2019), "The future of healthcare facilities: How technology and medical advances may shape hospitals of the future". *Hospital Practices and Research*, 4(1): 1-11. https://doi.org/10.15171/hpr.2019.01.

Wachira, B.W. and Mwai, M. (2021), "A baseline review of the ability of hospitals in Kenya to provide emergency and critical care services for COVID-19 patients". *African Journal of Emergency Medicine*, 11(2): 213-217. https://doi.org/10.1016/j.afjem.2021.01.001.

Wagner, S.A., Vogt, S. and Kabst, R. (2016), "The future of public participation: Empirical analysis from the viewpoint of policy-makers". *Technological Forecasting and Social Change*, 106: 65-73. https://doi.org/10.1016/j.techfore.2016.02.010.

Wiljer, D. and Hakim, Z. (2019), "Developing an Artificial Intelligence-enabled health care practice: Rewiring health care professions for better care". *Journal of Medical Imaging and Radiation Sciences*, 50(4, Supplement 2), S8–S14. https://doi.org/10.1016/j.jmir.2019.09.010.

Winkler, J. and Moser, R. (2016), "Biases in future-oriented Delphi studies: A cognitive perspective". *Technological Forecasting and Social Change*, 105, 63-76. https://doi.org/10.1016/j.techfore.2016.01.021.

Wolbring, G., Diep, L., Yumakulov, S., Ball, N. and Yergens, D. (2013), "Social robots, brain machine interfaces and neuro/cognitive enhancers: Three emerging science and technology products through the lens of technology acceptance theories, models and frameworks". *Technologies*, 1(1), Article 1. https://doi.org/10.3390/technologies1010003.

Wynsberghe, A. van. (2016), *Healthcare robots: Ethics, design and implementation*. Routledge. https://doi.org/10.4324/9781315586397

Yang, G., Pang, Z., Jamal Deen, M., Dong, M., Zhang, Y.T., Lovell, N. and Rahmani, A.M. (2020), "Homecare robotic systems for healthcare 4.0: Visions and enabling technologies". *IEEE Journal of Biomedical* *and Health Informatics*, 24(9), 2535–2549. https://doi.org/10.1109/JBHI.2020.2990529.

Zhang, D., Gorochowski, T.E., Marucci, L., Lee, H.T., Gil, B., Li, B., Hauert, S. and Yeatman, E. (2023), "Advanced medical micro-robotics for early diagnosis and therapeutic interventions". *Frontiers in Robotics and AI*, 9. https://www.frontiersin.org/articles/10.3389/frobt.2022.1086043.

Appendices

Appendix 1: Summary statistics for impact uncertainty analysis

The expert opinion was sought from 200 professional experts with the following distribution:

A1: Distribution of experts under Delphi

Specialist	Title	Number	%
Burns /Plastic Surgeons	Doctor	1	1%
Cardiologist	Doctor	7	4%
Cardiothoracic Surgeons	Doctor	2	1%
Chest Specialists	Doctor	3	2%
Clinical Psychologist	Doctor	1	1%
Dentist	Doctor	7	4%
Dermatologist	Doctor	5	3%
Diagnostic Centres	Doctor	4	2%
Endocrinologists	Doctor	4	2%
ENT	Doctor	10	5%
Facilities	Pharmacy/ Hospital/ Laboratory/ agnostic Cent/ Physiotherapy	26	13%
Gastroenterologist	Doctor	4	2%
General Physician	Doctor	6	3%
Maxillofacial Surgeons	Doctor	5	3%
Neurologist	Doctor	1	1%
Neurosurgeon	Doctor	3	2%
Obs / Gynaecologist	Doctor	18	9%
Oncologist	Doctor	3	2%
Ophthalmologist	Doctor	5	3%
Nurse	Medical Practioner	25	10%
Pediatrician	Doctor	14	7%
Anesthesiologist	Medical Practioner	16	8%

Health Insurance expert	Health Insurance expert	15	8%
Robotic Expert	Robotic Expert	15	10%
Total	**200**	**100%**	

Table A1 presents the distribution of 200 experts involved in a Delphi study, categorized by their medical specialties and roles. The table enumerates each category, detailing the number of professionals and their respective percentages of the total participant pool. The specialties include various types of doctors, such as cardiologists and neurosurgeons, along with nurses, robotic experts, and health insurance experts.

Appendix 2: Summary statistics for cross impact analysis

The expert opinion was sought from 44 professional experts with the following distribution:

A2: Distribution of experts for cross impact analysis

No.	Healthcare Professional/Experts	Experts	%
1	Burns /Plastic Surgeons	2	4.5%
2	Cardiologists	2	4.5%
3	Cardiothoracic Surgeons	2	4.5%
4	Chest Specialists	2	4.5%
5	Dentists	2	4.5%
6	Dermatologists	2	4.5%
7	Diagnostic Centres/Healthcare centres	2	4.5%
8	Endocrinologists	2	4.5%
9	ENTs	2	4.5%
10	Gastroenterologist	2	4.5%
11	General Physicians	2	4.5%
12	Maxillofacial Surgeons	2	4.5%
13	Neurologists	2	4.5%
14	Neurosurgeons	2	4.5%
15	Obs / Gynae	2	4.5%
16	Oncologist	2	4.5%
17	Ophthalmologists	2	4.5%
18	Nurses	2	4.5%
19	Pediatricians/ Anesthesiologists	2	4.5%

20	Researchers	2	4.5%
21	Health Insurance experts/Actuary	2	4.5%
22	Robotic Experts	2	4.5%
Total	**44**	**100%**	

Table A2 illustrates the distribution of 44 experts participating in a Cross Impact Analysis, each category featuring exactly 2 experts, approximately 4.5 per cent of the total panel. These professionals range across various medical and related fields, including surgeons, specialists such as cardiologists and neurologists, and non-medical experts such as robotic experts and health insurance experts. This uniform distribution ensures a balanced representation of diverse fields, facilitating a comprehensive cross-impact evaluation in the healthcare sector.

Appendix 3: Questionnaire for impact uncertainty analysis

Robotic Medical Services: Kenyan Healthcare Foresight

Dear Respondent,

On behalf of KIPPRA, we are conducting a study on the adopting robotic medical services and the future of healthcare in Kenya. Your valuable insights will help us understand the current landscape, challenges, and opportunities in integrating robotic technologies into healthcare practices. Your participation is crucial in shaping the future of healthcare delivery in Kenya.

Thank you for your time and contribution.

SECTION A: IMPACT ANALYSIS

This examines on how the following drivers of change as per STEEPV have an impact on robotic medical services adoption in Kenya.

(a) Social factors influencing adoption of Robotic Medical Services and the future of healthcare in Kenya.

To what level of impact do you consider the following social factors to be influencing adoption of Robotic Medical Services and the future of healthcare in Kenya for sustainable healthcare system in the next 10-20 years? Where very low=1; low=2; moderate=3; high=4 and very high=5

	Very low	Low	Moderate	High	Very high
Level of societal acceptance of robotic medicine.					
Medical health experts' awareness and acceptance level.					

(b) Technological factors influencing adoption of Robotic Medical Services and the future of healthcare in Kenya.

To what l level of impact do you consider the following technological factors to be influencing adoption of Robotic Medical Services and the future of healthcare in Kenya for sustainable healthcare system in the next 10-20 years? Where very low=1; low=2; moderate=3; high=4 and very high=5

	Very low	Low	Moderate	High	Very high
Compatibility levels of robotic medicine with existing healthcare infrastructure.					
Level of data and internet infrastructure for AI algorithms for robotic medicine.					

(c) Economic factors influencing adoption of Robotic Medical Services and the future of healthcare in Kenya.

To what level of impact do you consider the following economic factors to be influencing adoption of Robotic Medical Services and the future of healthcare in Kenya for sustainable healthcare system in the next 10-20years? Where very low=1; low=2; moderate=3; high=4 and very high=5

	Very low	Low	Moderate	High	Very high
Cost of Investments in robotic medicine technologies.					
National budget for Kenyan healthcare.					

.

(d) Environmental factors influencing adoption of Robotic Medical Services and the future of healthcare in Kenya

To what level of impact do you consider the following environmental factors to be influencing adoption of Robotic Medical Services and the future of healthcare in Kenya for sustainable healthcare system in the next 10-20 years? Where very low=1; low=2; moderate=3; high=4 and very high=5

	Very low	low	moderate	high	Very high
Level of recyclability of robotic medical technologies waste					
The amount of robotics medical waste into the environment.					

(e) Political factors influencing adoption of Robotic Medical Services and the future of healthcare in Kenya.

To what level of impact do you consider the following political factors to be influencing adoption of Robotic Medical Services and the future of healthcare in Kenya for sustainable healthcare system in the next 10-20years? Where very low=1; low=2; moderate=3; high=4 and very high=5

Drivers of change	Very low	Low	Moderate	high	Very high
Government legislation, policies, and regulations on robotic medicine in Kenyan healthcare					
Political global collaboration for standardized, safe robotic medicine development and use.					

(f) Value factors influencing adoption of Robotic Medical Services and the future of healthcare in Kenya.

To what level of impact do you consider the following value factors to be influencing adoption of Robotic Medical Services and the future of healthcare in Kenya for sustainable healthcare system in the next 10-20 years? Where very low=1; low=2; moderate=3; high=4 and very high=5

	Very Low	Low	Moderate	High	Very high
Level of AI Intellectual property rights, liability issues, and compliance standards					
The AI ethical issues like patient data privacy, algorithm transparency, and bias.					

SECTION B: UNCERTAINTY ANALYSIS

This examines on how the following drivers of change as per STEEPV have an uncertainty on robotic medical services adoption in Kenya.

(a) Social factors influencing adoption of Robotic Medical Services and the future of healthcare in Kenya.

To what level of uncertainty do you consider the following social factors to be influencing adoption of Robotic Medical Services and the future of healthcare in Kenya for sustainable healthcare system in the next 10-20 years? Where very low=1; low=2; moderate=3; high=4 and very high=5

	Very low	Low	Moderate	High	Very high
Level of societal acceptance of robotic medicine.					
Medical health experts' awareness and acceptance level.					

(b) Technological factors influencing adoption of Robotic Medical Services and the future of healthcare in Kenya.

To what level of uncertainty do you consider the following technological factors to be influencing adoption of Robotic Medical Services and the future of healthcare in Kenya for sustainable healthcare system in the next 10-20 years? Where very low=1; low=2; moderate=3; high=4 and very high=5

	Very low	Low	Moderate	High	Very high
Compatibility levels of robotic medicine with existing healthcare infrastructure.					
Level of data and internet infrastructure for AI algorithms for robotic medicine.					

(c) Economic factors influencing adoption of Robotic Medical Services and the future of healthcare in Kenya.

To what level of uncertainty do you consider the following economic factors to be influencing adoption of Robotic Medical Services and the future of healthcare in Kenya for sustainable healthcare system in the next 10-20years? Where very low=1; low=2; moderate=3; high=4 and very high=5

	Very low	Low	Moderate	High	Very high
Cost of Investments in robotic medicine technologies.					
National budget for Kenyan healthcare.					

(d) Environmental factors influencing adoption of Robotic Medical Services and the future of healthcare in Kenya.

To what level of uncertainty do you consider the following environmental factors to be influencing adoption of Robotic Medical Services and the future of healthcare in Kenya for sustainable healthcare system in the next 10-20 years? Where very low=1; low=2; moderate=3; high=4 and very high=5

	Very low	Low	Moderate	High	Very high
Level of recyclability of robotic medical technologies waste					
The amount of robotics medical waste into the environment.					

(e) Political factors influencing adoption of Robotic Medical Services and the future of healthcare in Kenya

To what level of uncertainty do you consider the following political factors to be influencing adoption of Robotic Medical Services and the future of healthcare in Kenya for sustainable healthcare system in the next 10-20years? Where very low=1; low=2; moderate=3; high=4 and very high=5

Drivers of change	Very low	Low	Moderate	High	Very high
Government legislation, policies, and regulations on robotic medicine in Kenyan healthcare					
Political global collaboration for standardized, safe robotic medicine development and use.					

(f) Value factors influencing adoption of Robotic Medical Services and the future of healthcare in Kenya.

To what level of uncertainty do you consider the following value factors to be influencing adoption of Robotic Medical Services and the future of healthcare in Kenya for sustainable healthcare system in the next 10-20 years? Where very low=1; low=2; moderate=3; high=4 and very high=5

	Very low	Low	Moderate	High	Very high
Level of AI Intellectual property rights, liability issues, and compliance standards					
The AI ethical issues like patient data privacy, algorithm transparency, and bias.					

Appendix 4: Questionnaire for Cross Impact Analysis

Robotic Medical Services Adoption and the future of Healthcare in Kenya

Dear Respondent,

On behalf of KIPPRA, we're conducting research on the adoption of robotic medical services in Kenya on cross impact analysis and would value your insights. Could you spare a few minutes to fill out our questionnaire? Your input will help shape our research. Your responses will be kept confidential.

Thank you for your participation.

Q1:

How does Government legislation, policies, and regulations on robotic medicine in Kenyan healthcare affect the following:

High=3, Moderate=2, and Low=1

	Low	Moderate	High
Political global collaboration for standardized, safe robotic medicine development and use.			
Cost of Investments in robotic medicine technologies.			
National budget for Kenyan healthcare.			

Level of societal acceptance of robotic medicine.			
Medical health experts' awareness and acceptance level.			
Compatibility levels of robotic medicine with existing healthcare infrastructure.			
Level of data and internet infrastructure for AI algorithms for robotic medicine.			
Level of recyclability of robotic medical technologies waste			
The amount of robotics medical waste into the environment.			
Level of AI Intellectual property rights, liability issues, and compliance standards.			
The AI ethical issues like patient data privacy, algorithm transparency, and bias			

Q2: How does Political global collaboration for standardized, safe robotic medicine development affect the following:

High=3, Moderate=2, and Low=1

	Low	Moderate	High
Government legislation, policies, and regulations on robotic medicine in Kenyan healthcare			
Cost of Investments in robotic medicine technologies.			
National budget for Kenyan healthcare.			
Level of societal acceptance of robotic medicine.			
Medical health experts' awareness and acceptance level.			
Compatibility levels of robotic medicine with existing healthcare infrastructure.			
Level of data and internet infrastructure for AI algorithms for robotic medicine.			
Level of recyclability of robotic medical technologies waste			
The amount of robotics medical waste into the environment.			

Level of AI Intellectual property rights, liability issues, and compliance standards.			
The AI ethical issues like patient data privacy, algorithm transparency, and bias			

Q3: How does the Cost of Investments in robotic medicine technologies affect the following:

High=3, Moderate=2, and Low=1

	Low	Moderate	High
Government legislation, policies, and regulations on robotic medicine in Kenyan healthcare			
Political global collaboration for standardized, safe robotic medicine development and use.			
National budget for Kenyan healthcare.			
Level of societal acceptance of robotic medicine.			
Medical health experts' awareness and acceptance level.			
Compatibility levels of robotic medicine with existing healthcare infrastructure.			
Level of data and internet infrastructure for AI algorithms for robotic medicine.			
Level of recyclability of robotic medical technologies waste			
The amount of robotics medical waste into the environment.			
Level of AI Intellectual property rights, liability issues, and compliance standards.			
The AI ethical issues like patient data privacy, algorithm transparency, and bias			

Q4: How does the National budget for Kenyan healthcare affect the following:

High=3, Moderate=2, and Low=1

	Low	Moderate	High
Government legislation, policies, and regulations on robotic medicine in Kenyan healthcare			
Political global collaboration for standardized, safe robotic medicine development and use.			
Cost of Investments in robotic medicine technologies.			
Level of societal acceptance of robotic medicine.			
Medical health experts' awareness and acceptance level.			
Compatibility levels of robotic medicine with existing healthcare infrastructure.			
Level of data and internet infrastructure for AI algorithms for robotic medicine.			
Level of recyclability of robotic medical technologies waste			
The amount of robotics medical waste into the environment.			
Level of AI Intellectual property rights, liability issues, and compliance standards.			
The AI ethical issues like patient data privacy, algorithm transparency, and bias			

Q5: How does the Level of societal acceptance of robotic medicine affect the following:

High=3, Moderate=2, and Low=1

	Low	Moderate	High
Government legislation, policies, and regulations on robotic medicine in Kenyan healthcare			
Political global collaboration for standardized, safe robotic medicine development and use.			
Cost of Investments in robotic medicine technologies.			
National budget for Kenyan healthcare.			

Medical health experts' awareness and acceptance level.			
Compatibility levels of robotic medicine with existing healthcare infrastructure.			
Level of data and internet infrastructure for AI algorithms for robotic medicine.			
Level of recyclability of robotic medical technologies waste			
The amount of robotics medical waste into the environment.			
Level of AI Intellectual property rights, liability issues, and compliance standards.			
The AI ethical issues like patient data privacy, algorithm transparency, and bias			

Q6: How does medical health experts' awareness and acceptance level affect the following:

High=3, Moderate=2, and Low=1

	Low	Moderate	High
Government legislation, policies, and regulations on robotic medicine in Kenyan healthcare			
Political global collaboration for standardized, safe robotic medicine development and use.			
Cost of Investments in robotic medicine technologies.			
National budget for Kenyan healthcare.			
Level of societal acceptance of robotic medicine.			
Compatibility levels of robotic medicine with existing healthcare infrastructure.			
Level of data and internet infrastructure for AI algorithms for robotic medicine.			
Level of recyclability of robotic medical technologies waste			
The amount of robotics medical waste into the environment.			

Level of AI Intellectual property rights, liability issues, and compliance standards.			
The AI ethical issues like patient data privacy, algorithm transparency, and bias			

Q7: How do Compatibility levels of robotic medicine with existing healthcare infrastructure affect the following:

High=3, Moderate=2, and Low=1

	Low	Moderate	High
Government legislation, policies, and regulations on robotic medicine in Kenyan healthcare			
Political global collaboration for standardized, safe robotic medicine development and use.			
Cost of Investments in robotic medicine technologies.			
National budget for Kenyan healthcare.			
Level of societal acceptance of robotic medicine.			
Medical health experts' awareness and acceptance level.			
Level of data and internet infrastructure for AI algorithms for robotic medicine.			
Level of recyclability of robotic medical technologies waste			
The amount of robotics medical waste into the environment.			
Level of AI Intellectual property rights, liability issues, and compliance standards.			
The AI ethical issues like patient data privacy, algorithm transparency, and bias			

Q8: How Level of data and internet infrastructure for AI algorithms for robotic medicine affect the following:

High=3, Moderate=2, and Low=1

	Low	Moderate	High
Government legislation, policies, and regulations on robotic medicine in Kenyan healthcare			
Political global collaboration for standardized, safe robotic medicine development and use.			
Cost of Investments in robotic medicine technologies.			
National budget for Kenyan healthcare.			
Level of societal acceptance of robotic medicine.			
Medical health experts' awareness and acceptance level.			
Compatibility levels of robotic medicine with existing healthcare infrastructure.			
Level of recyclability of robotic medical technologies waste			
The amount of robotics medical waste into the environment.			
Level of AI Intellectual property rights, liability issues, and compliance standards.			
The AI ethical issues like patient data privacy, algorithm transparency, and bias			

Q9: How does the Level of recyclability of robotic medical technologies waste affect the following:

High=3, Moderate=2, and Low=1

	Low	Moderate	High
Government legislation, policies, and regulations on robotic medicine in Kenyan healthcare			
Political global collaboration for standardized, safe robotic medicine development and use.			
Cost of Investments in robotic medicine technologies.			

National budget for Kenyan healthcare.			
Level of societal acceptance of robotic medicine.			
Medical health experts' awareness and acceptance level.			
Compatibility levels of robotic medicine with existing healthcare infrastructure.			
Level of data and internet infrastructure for AI algorithms for robotic medicine.			
The amount of robotics medical waste into the environment.			
Level of AI Intellectual property rights, liability issues, and compliance standards.			
The AI ethical issues like patient data privacy, algorithm transparency, and bias			

Q10: How does the amount of robotics medical waste in the environment affect the following:

High=3, Moderate=2, and Low=1

	Low	Moderate	High
Government legislation, policies, and regulations on robotic medicine in Kenyan healthcare			
Political global collaboration for standardized, safe robotic medicine development and use.			
Cost of Investments in robotic medicine technologies.			
National budget for Kenyan healthcare.			
Level of societal acceptance of robotic medicine.			
Medical health experts' awareness and acceptance level.			
Compatibility levels of robotic medicine with existing healthcare infrastructure.			
Level of data and internet infrastructure for AI algorithms for robotic medicine.			
Level of recyclability of robotic medical technologies waste			

Level of AI Intellectual property rights, liability issues, and compliance standards.			
The AI ethical issues like patient data privacy, algorithm transparency, and bias			

Q11: How do the level of AI Intellectual property rights, liability issues, and compliance standards affect the following:

High=3, Moderate=2, and Low=1

	Low	Moderate	High
Government legislation, policies, and regulations on robotic medicine in Kenyan healthcare			
Political global collaboration for standardized, safe robotic medicine development and use.			
Cost of Investments in robotic medicine technologies.			
National budget for Kenyan healthcare.			
Level of societal acceptance of robotic medicine.			
Medical health experts' awareness and acceptance level.			
Compatibility levels of robotic medicine with existing healthcare infrastructure.			
Level of data and internet infrastructure for AI algorithms for robotic medicine.			
Level of recyclability of robotic medical technologies waste			
The amount of robotics medical waste into the environment.			
The AI ethical issues like patient data privacy, algorithm transparency, and bias			

Q12: How does The AI ethical issues like patient data privacy, algorithm transparency, and bias affect the following:

High=3, Moderate=2, and Low=1

	Low	Moderate	High
Government legislation, policies, and regulations on robotic medicine in Kenyan healthcare			

Political global collaboration for standardized, safe robotic medicine development and use.			
Cost of Investments in robotic medicine technologies.			
National budget for Kenyan healthcare.			
Level of societal acceptance of robotic medicine.			
Medical health experts' awareness and acceptance level.			
Compatibility levels of robotic medicine with existing healthcare infrastructure.			
Level of data and internet infrastructure for AI algorithms for robotic medicine.			
Level of recyclability of robotic medical technologies waste			
The amount of robotics medical waste into the environment.			
Level of AI Intellectual property rights, liability issues, and compliance standards.			

ISBN 978 9914 738 63 6

Kenya Institute for Public Policy Research and Analysis
Bishops Garden Towers, Bishops Road
PO Box 56445, Nairobi, Kenya
tel: +254 20 2719933/4, 2714714/5, 2721654, 2721110
fax: +254 20 2719951
email: admin@kippra.or.ke
website: http://www.kippra.org