RESEARCH IN MANAGEMENT OF TECHNOLOGY AND BUSINESS
e-ISSN: 2773-5044

RMTB

Vol. 5 No. 1 (2024) 543-562
https://publisher.uthm.edu.my/periodicals/index.php/rmtb

A Foresight Study on the Adoption of Robotic Surgery in Malaysia

Siti Nuranisa Mohd Shahrol[1], Siti Aisyah Salim[1]*

[1] *Department of Management and Technology, Faculty of Technology Management & Business, Universiti Tun Hussein Onn Malaysia, 86400 Batu Pahat, Johor, MALAYSIA*

*Corresponding Author: aisyahs@uthm.edu.my
DOI: https://doi.org/10.30880/rmtb.2024.05.01.039

Article Info

Received: 31 March 2024
Accepted: 30 April 2024
Available online: 30 June 2024

Keywords

Artificial Intelligence (AI), Robotic surgery, Surgical, Efficiency, Ergonomic, User-friendly.

Abstract

Artificial intelligence (AI) has simply transformed the production of science fiction into a well-known phenomenon that has begun to diffuse in our daily lives. The application of robot has touched a wide range of industries, including production, services, research, and medical. Robotic surgery, also known as smart surgical tools, can assist in doing surgery on a single human being with greater efficacy, less injury, greater safety, and greater precision than a surgeon. Robotic surgical procedures can sometimes be complicated and sometimes simple. Moreover, the ethical issues and the successfulness of robotic surgery are still in the development phase since there are many issues and challenges in developing the robotic surgery. Other than that, the discussion on the adoption and the practicality of robotic surgery technology is still lacking in the context of Malaysia. Therefore, this study is being conducted to identify the key drivers of the robotic surgery adoption and determine the future trend of robotic surgery in Malaysia. In this research, the mixed method, which is both a qualitative and quantitative approach is used. The quantitative study is conducted by distributing the questionnaire to the surgeon in Malaysia. Ten merged key drivers and issues had been identified from the STEEPV analysis. A STEEPV analysis is employed as a foresight methodology. Next, impact-uncertainty analysis also been used to identify the future trend of robotic surgery. The response rate of these study is 65%. This study determines that improved surgical efficiency as well as ergonomic and user-friendly designs had the highest impact and uncertainty. Then, these top two drivers have been used in generating the scenario analysis which gives an overview of four alternative possibilities. The four scenarios were new medical norms, not interested in change, enhanced surgeons experience but decreased surgical output and also unsatisfactory technology.

1. Introduction

The term "robot" originated in the early 1900s, indicating the beginning of a significant evolution in robot technology (Robotnik, 2022). The goal of robotics is not to replace humans by digitizing and automating tasks, but rather to find innovative ways for robots to interact more effectively with humans (Rus, 2023). Initially, robots were basic devices created for repetitive tasks. However, current models have evolved substantially, intended to be more human-like in appearance, with some possibly displaying emotions and self-awareness (Daftardar, 2023). Surgery is a medical therapy in which a patient is operated on using manual or instrumental ways to seek or treat a disease or injury (Britannica, 2024). AI technology has grown swiftly and is already revealing new insights on a larger scale in healthcare, including surgeries (Bajwa *et al.*, 2021). Medicine has always been at the forefront of technological advancement. Each new achievement has transformed the way they approach healthcare, from the discovery of antibiotics to the development of improved imaging tools (Esposito, 2023). The incorporation of robotics into various medical operations has been one of the most significant breakthroughs in recent years (Robotnik, 2022). Nowadays, process automation may be applied to any industry, and robots in medicine is widely employed, due to the recent advancement of technology such as 5G, artificial intelligence (AI) and augmented reality (AR) (Robotnik, 2022). Previously, robots began in science fiction, then moved into industries, and now, surgical robots are available commercially (Hockstein *et al.*, 2007). Robotic surgery has evolved in the late 20th century. The first commercial surgical robot was Puma350, had been implemented in the medical sector in 1985 (Graves, 2022). Its objective was to guide a needle for a brain biopsy using computerized scanning. However, this robot was later discontinued because of security concerns (Secoli *et al.*, 2022). Robotic surgery is designed to communicate with patients, examine patients' living conditions, operate in risky and emergency scenarios, conduct data analysis to boost a pharmacy's efficiency, and sterilize rooms in hospitals (University, 2022). Advancement in robotic surgery have produced broad implications toward numerous medical professions, automating the procedures, as well as providing a lot of benefits. For instance, robotic innovations may also benefit minimally invasive surgery. During surgery, small incisions are made to facilitate the insertion of robot-operated equipment. Thus, it will reduce the risk of complications and infections (University, 2022). Robotics in healthcare can reduces time-consuming visits, shortens operation duration, and creates personalized therapies. Surgical robots have been employed in a wide range of usage, from surgery to rehabilitation and even drug administration. Robots can now sew wounds and perform precise eye surgery, which are both demanding procedures that need a high level of accuracy (Esposito, 2023). Other than that, robots in surgical procedures improve surgeon ergonomics and comfort, allowing for higher procedural volumes because surgeons are less fatigued. Meanwhile, robots also aid in the elimination of human mistakes in high-risk procedures where can increases surgery efficiency (Wee *et al.*, 2020). Hence, advancements in robotic surgery in the future will not just save lives and increase efficiency, but healthcare practitioners will also appreciate their contribution in the exciting process of designing extremely advanced robotic systems (Mesko, 2021).

1.1 Research Background

Artificial Intelligence (AI) has transformed the production of science fiction tool into a well-known phenomenon and begun to influence our daily lives activities (Jack Karsten *et al.*, 2023). Further, AI has also a significant impact in altering the course of human history (Thomas, 2023). Various products and services have been successfully innovated with the new technology under the category of AI globally (Daley, 2023). AI technology has grown swiftly and is already revealing new insights on a larger scale in healthcare, including surgeries (Bajwa *et al.*, 2021). The concept of robotics has evolved greatly over time, and its use has touched a wide range of industries, including production, services, research, and medicine. In some cases, robots merely assist people in avoiding unpleasant or harmful jobs. In some areas, robots serve as a more cost-effective and dependable alternative to human labor. However, in other industries, robots improve humans' ability to accomplish complex jobs with precision and accuracy that transcend the limits of manual operation. Over the years, robots have led to important advances in various fields, including industry, military and most recently medicine (Lanfranco *et al.*, 2004a).

According to Fong and Nourbakhsh (2005), intelligent robotic systems will have to be part of mission design in order to reduce human workload, expenses, fatigue-driven error, and risk. The first surgical robotics concept emerged in the late 1980s at the National Aeronautics and Space Centre (NASA) (Fisher *et al.*, 1987). The first commercial surgical robot was Puma350 which had been implemented in the medical sector in 1985 (Graves, 2022). Over the last decade, medical robotics has grown in importance role in the field of robotics due to the recent advancement of technology such as 5G, artificial intelligence (AI) and augmented reality (AR) (Robotnik, 2022). As of 2023, more than 60000 surgeons worldwide had done more than 10 million procedures with this robotic technology and it expected being increased in the future as this technology now available for a variety of surgeries besides gallbladder removals ("Robotics in Healthcare: A look at exciting medical science advancements," 2023). Other than that, robotic surgical advancements have paved the way for new possibilities such as telesurgery, personalized medicine, and the incorporation of artificial intelligence (AI) (Reddy *et al.*, 2023). Meanwhile, Malaysia also committed to embrace the future of medicine. According to Helen Ng Hoy Loon, General Manager of Minimally Invasive Surgery (MIS) Services, Robotic Surgery and Urology at Sunway Medical Centre (SMC), the hospital celebrated its achievement of a thousand robot-assisted surgeries in December 2022 while also introducing a first-in-Malaysia da Vinci Xi 4th Generation Surgical System ("Beyond Tomorrow: The Evolution of Healthcare Technologies," 2023). A surgical robot is a self-powered, computer-controlled manipulator that can be trained to help with instrument positioning and manipulation (Sabiston *et al.*, 2017). Surgical robots, also known as smart surgical tools, can assist in doing surgery on a single human being with greater efficacy, less morbidity, greater safety, and greater precision than a surgeon. While many hospitals have their doctors, there will be a shortage of surgeons as many patients wait for their surgery. In order to solve the shortage of surgeons, it is possible to employ robots for surgeries because there are several types of procedures, we can use a specific robot for specific surgery (Fernando & Fernando, 2019).

There are two kinds of surgical robots in the world. The first is a medical robot that is physically operated by a surgeon, and the second is an AI-powered surgical robot that performs surgeries. According to Phee (2009), there are numerous new surgical robot advances. It includes biomechanics, medicine, materials, computer-aided design, visual representation, mathematical analysis, and also robotics (Phee *et al.*, 2009). There are many robotic in surgery that already being develop worldwide, and one of it is the da Vinci Surgical System. The da Vinci is manufactured by Intuitive Surgical, Inc. The da Vinci consists of a surgeon's console, four robotic arms, and a video tower (Klodmann *et al.*, 2021). In December 2002, the da Vinci have received approval from the US Food and Drug Administration (FDA) for use in surgical procedures (Moran, 2006). This study focuses on the da Vinci surgical system because of its extensive use in diverse subspecialties (Bocca *et al.*, 2007; McLeod *et al.*, 2005; Murphy *et al.*, 2006; Nazemi *et al.*, 2006; Nguyen *et al.*, 2004). These robotic systems are becoming more popular in a variety of surgical specialties, including cardiac, urology, thoracic, gynaecological, paediatrics, and general surgical procedures (Mehta *et al.*, 2022). In 1995, laparoscopic techniques were widely and successfully used for almost 95 % of gall bladder surgeries and a few obstetrics and gynaecology procedures, but for very little else (Moran, 2006). One significant problem for surgeons was that the external surgical movements in a typical laparoscopic procedure had to be done with "reverse" geometry relative to the procedure actually being performed in the body (Moran, 2006). In addition, the range of motion and manoeuvrability within the body cavity were limited along with lack of depth perception, which affecting the surgeon's skill and confidence. Thus, Fred who as one of the recognized visionaries in the world of minimally invasive surgery, knew that this would be a key to the future development of these surgical techniques.

Robots have progressed from a future notion to today's reality due to the rapid evolution of technology. The current utilization of robotic surgery has evolved into various type of surgeries such as general surgery, gynaecological surgery, urological surgery, cardiac surgery, orthopaedic surgery and also head and neck surgery (Reddy *et al.*, 2023). The latest generation of robotic surgery that has been introduced was Versius, robot powered by AI and machine learning (HospiMedica International, 2023). Versius was created to assist surgeons in performing more limited access surgeries by giving them the flexibility to work in the best way for their patients, with full control over port placement and surgical approach. Although Western countries (such as the United States) contribute the most to the sector, Asian corporations and governments are also heavily investing in the creation of medical robots. After three years of introduction to the rest of the globe, robotic surgery arrived in Malaysia in 2003 (Loon, 2021). Kuala Lumpur Hospital (KLH) was the first hospital in the country to offer robotic surgery in the field of urological cancer surgeries such as prostate cancer surgeries, kidney cancer surgeries, and bladder cancer surgeries. As a result, AI technologies were signalling that they were as valuable as feasible for improving human capacity in the future. According to BIS Research Inc., Asia-Pacific accounted for 17.23% of the worldwide surgical robot market in 2018. The significance of this region is further emphasized by the double-digit growth rate of 14.24% predicted by the end of 2025. Despite this growth, some surgeons in these areas are hesitant to use robotic-assisted surgery. Healthcare professionals, particularly physicians, can slowly adopting new technologies (Yarbrough & Smith, 2007).

1.2 Problem Statement

Surgeries are normally been conducted by a senior doctor or we called it as surgeon and not every doctor could do the surgery since a surgeon undergoes specialized training focusing on the various treatments that surgery offers (DerSarkissian, 2023). A surgeon is a physician who specializes in examining and treating illnesses that necessitate surgery or the physical alteration of the human body, either internally or externally while doctor is a physician who will examining, diagnosing and treating patients for a variety of diseases as well as referring them to specialists when necessary (DerSarkissian, 2023). Thus, a surgeon is more experts than doctors since they can diagnose a disease and treat diseases by surgeries. It is customary to see specialist doctors or surgeons in Malaysian hospitals, but the number of surgeons is always insufficient because there are too many patients waiting to be treated (The Star, 2023). In certain conditions, patients have to wait their turn to undergo surgery especially in government hospitals. Thus, there are many patients who have to wait their turn to undergo surgery. In addition, critical patients who require immediate treatment should be transferred to other hospitals with surgical capabilities because delays in getting treatment will have severe impact.

Next, robotic surgery require high implementation cost (Reddy *et al.*, 2023). These robots need substantial financial investments, including the acquisition of the robotic platform, training of surgeons and operating staff, and ongoing maintenance costs. The high initial costs associated with robotic surgery pose a barrier for smaller hospitals and healthcare institutions in Malaysia to implement it as well as limiting their ability to adopt and integrate this technology into their surgical practices. Therefore, to solve this problem, smaller hospitals that have limited budget can utilize group purchase agreements, financing arrangements or make collaboration with larger hospitals to make robotic surgery readily available (Hinrichs-Krapels *et al.*, 2022).

Moreover, limitation of space and lacking in infrastructure cause a problem in implementing surgical robots in Malaysia. Robotic surgical systems are not universally accessible, particularly in less-developing regions and smaller healthcare facilities. According to Ng (2022), every hospital may not be a good fit for robotic surgery. She says that investing in robotic surgery is unnecessary for smaller hospitals because they won't have enough specialties to support the development (Ng, 2022). Nevertheless, if the hospital is large, provide tertiary or quaternary care, as well as have a team of specialists from many specialties to support the organizations, thus, can absolutely think about outfitting the facility with robotic surgical capabilities. Limitation availability of robotic platforms restricts the number of patients who can benefit from this advanced surgical technique, therefore impeding its widespread adoption.

Other than that, the problem in implementing surgical robots is about privacy and security (E-Spin, 2023). Whenever it relates to adopting robots in healthcare, privacy, and security pose important issues. The implementation of robots in healthcare requires extensive data collection via video cameras, sensors, and other sources. Hackers may use the data obtained, such as video and photos, as well as location of the patients, to commit numerous cybercrimes. It is critical to ensure that healthcare robots have adequate security mechanisms in place to secure private information.

Lastly, power sources are also a problem in implementing a robot in healthcare. The key benefit of robots is that they are able to operate and perform repetitive activities without getting exhausted. However, the advancement of power sources for robots is still insufficient because they continue to rely on outdated generators and storage systems (E-Spin, 2023). As a result, robots consume excessive amounts of energy. Therefore, stronger power sources that can provide enough power for robots to function for extended periods of time are required.

Therefore, to achieve the research objectives the key drivers that lead to robotic surgery adoption in Malaysia is determined. Consequently, the future trend of robotic surgery adoption in Malaysia is identified.

1.3 Scope of Study

The aim of this research is to identify the important factors that influence the adoption of robotic surgery in Malaysia. The factors identified will also applicable for future of robotic surgery in Malaysian hospitals. The time horizon for this technology to be implemented is 10 years ahead or in other words by 2033. The current study focuses on any resources or information connected to the implementation of robotic surgery in Malaysia. All-important data and information are obtained from a range of sources, including journals, conference papers, government-related publications, government organizations, the Internet, YouTube, and various sorts of research materials connected to the adoption of robotic surgery. The target respondent for this study will be chosen from among Malaysian surgeons. Questionnaires will be given to the targeted respondents in order to collect data for analysis.

1.4 Significance of Research

This research will be conducted to look into the drivers of robotic surgery adoption in complex surgery as well as the trend of robotic surgery adoption in Malaysia. Furthermore, this research will assist surgeons in Malaysia, whether from government or private facilities, in using robotic surgery for complicated surgery. This technology will enable doctors to conduct a wide range of complex treatments with greater precision, flexibility, and control than with manual techniques. Meanwhile, this research will aid future researchers since it demonstrates the uncertainties surrounding robotic surgical adoption in Malaysia. As a result of this research, Malaysians will be more familiar with this type of technology, increasing the sophistication and advancement of Malaysia's medical system.

2. Research Methodology

2.1 Research Design

A research design was basically demonstrating a structured outline of variety research methods and techniques that a researcher used. A research design assists a researcher in doing research into the unknown, but with a systematic approach. A research design generally consists of how data being collected, what instruments were used, how the selected instruments being used, and how the data that has been collected were analyzed. There were three categories of research methodologies which quantitative, qualitative, and mixed methods (Pamplona, 2022). In this research, data has been interpreted and analyzed using a mixed methods which it was the combination of qualitative and quantitative approach. Quantitative method was the process of collecting and analyzing numerical or statistical data from questionnaire and survey or by modifying pre-existing statistical data using computer systems. The questionnaire was used to gather information from the surgeon who has been implementing this robotic surgery technology in Malaysia. The questionnaire results aid in the exploration of information regarding future chances to satisfy future requirements and trends. There is no measurement or statistical analysis in the qualitative method. A foresight analytic approach to STEEPV can be gained through journals, websites, and other resources in this research.

2.2 Research Flow Chart

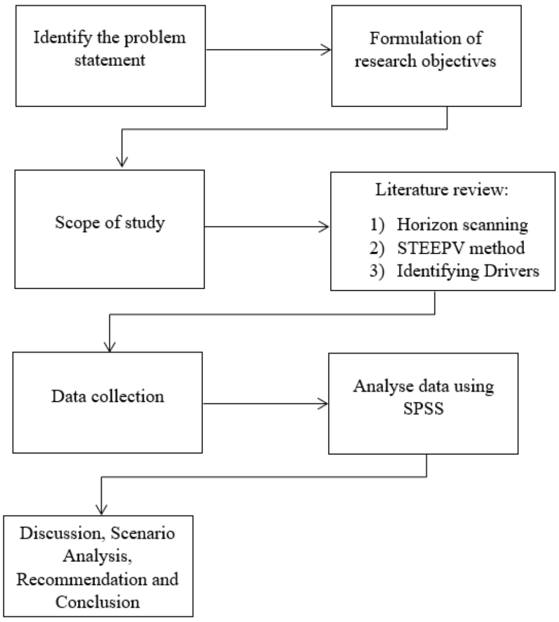

Fig. 1 *Research flow chart*

2.3 Population and Sampling

2.3.1 Population

This research focuses on implementation of Robotic Surgery among surgeon during complex surgery in Malaysia, thus the target population is surgeons in government and private hospital. In total there were around 175 hospitals located in Malaysia where 146 government hospitals (Ministry of health, 2023) and 29 private hospitals (KPJ Healthcare Berhad, 2023). These statistics have been obtained from the official website of the Ministry of health and KPJ Healthcare Berhad.

2.3.2 Sampling Technique

Sampling is known as a process of selecting a subset from the population of interest in research study (Turner, 2020). The sampling process involves selecting a representative sample of the population and collecting data as information for research. In sampling method, there are two types which are probability sampling and non-probability sampling.

In this research, purposive sampling has been used. Purposive sampling or called as judgemental or selective sampling is a non-probability sampling. A purposive sampling is a sampling technique where researchers use their expertise to choose specific participants that can provide the desired information. The sample size for this research has been identified by using Krejcie and Morgan (1970) table. According to Krejcie and Morgan (1970) table, there should have 80 of surgeons from various departments selected from 100 government and private hospitals around in Malaysia.

2.4 Research Instruments

Research instrument is a set of questions designed to collect data from respondents. The research instruments include a questionnaire, observation and reading. Choosing a valid and reliable instrument is important to the researcher for the current research. The research instrument chosen for use in this study is a questionnaire. It is because the data obtained with questionnaire are valid and easy to analyze if constructed correctly. The questionnaire consists of four sections which are Section A, Section B, Section C and Section D.

Table 1 *Structure of the questionnaire*

Section	Item
A	Demographic information of the respondents.
B	The level importance of factors or drivers toward Robotic Surgery adoption in Malaysia
C	The impact of factors or drivers towards Robotic Surgery adoption in Malaysia
D	The uncertainty of factor or drivers towards Robotic Surgery adoption in Malaysia

2.5 Data Collection

Data collection is the systematic process of collecting data and measuring from an extensive variety of sources to get an entirely exact picture and specifically to meet the research objective. Data collection method basically divided into two which are primary data and secondary data.

2.5.1 Primary Data

According to Ajayi (2017) primary data can be defined as original and unique data, as it directly collected by a researcher for the research study from various sources such as surveys, questionnaires, observations, and interview according to his requirements. In a nutshell, primary data is first-hand information gathered by a researcher.

2.5.2 Secondary Data

Secondary data is information gathered from other sources earlier, such as data from scientific journal, such as ResearchGate, Science Direct, and Emerald Insight. Secondary data is freely accessible, but it is not pure because it was previously gathered by someone else and exposed to multiple statistical procedures. Thus, secondary data can also call as past data. The sources of secondary data include government publications, websites, books, journal articles and internal records. By using secondary data, it helped to widen the knowledge regarding the problem and offer a basis for comparing the data obtained.

2.6 Pilot Test

Before start delivering the questionnaire to the target respondents, a pilot test has been run to test the questionnaire. The questionnaire has been distributed to 5 or 10 respondents selectively to determine whether the questions prepared by the researcher understandably by the respondent or not. Cronbach Alpha been used in pilot test to test the reliability and validity of a questionnaire that have been made before conducted the study.

2.7 Data Analysis

2.7.1 Descriptive Analysis

Descriptive analysis is a statistical tool for defining historical data to discover trends or relationships. According to Hussain (2012), descriptive analysis is performed when the aim of the study is to improve the reader's knowledge, understanding as well as about the application of the research. SPSS is used to analyze the result of questionnaire and produce statistics in form of numerical. When the purpose of the study is to improve the reader's knowledge, understanding, and implementation of research, descriptive analysis is used. Descriptive analysis is concerned with characterizing data in terms of frequencies, proportions, means, medians, quartiles, standard deviations, interquartile ranges, and so on (Hussain, 2012).

2.7.2 Reliability Analysis

Cronbach's alpha is used to evaluate the reliability of the questionnaire. SPSS statistical analysis will be used to perform the reliability test. Cronbach's alpha is a measure of internal consistency that can be used to determine how closely a group of things are related. In most research contexts, data with an alpha coefficient greater than 0.7 to 0.9 is immediately accepted and considered reliable. Otherwise, if Cronbach's alpha is below than 0.7, the result is seen as unacceptable and unreliable. In this situation, the questions are reanalyzed to eliminate those that are irrelevant. The results are then double-checked with a pilot test and reliability testing until they are reliable.

Table 2 *Table of reliability*

Cronbach's Alpha	Internal Consistency
$\alpha \geq 0.9$	Excellent
$0.8 \leq \alpha < 0.9$	Good
$0.7 \leq \alpha < 0.8$	Acceptable
$0.6 \leq \alpha < 0.7$	Questionable
$0.5 \leq \alpha < 0.6$	Poor
$\alpha < 0.5$	Unacceptable

2.7.3 Impact-Uncertainty Analysis

This analysis is use to identify the uncertainty of the future trend on robotic surgery adoption in complex surgery around Malaysia. The possible development and implication that determine the uncertain terms can be gained from the list of drivers in STEEPV analysis. Then, SPSS is used to analyze the results of a questionnaire. This software has used to analyze the key drivers that have already been evaluated by the respondents. The mean of key drivers will be listed and tested in impact-uncertainty analysis. All of the factors will be plotted based on the level of impact and uncertainty on the future trend of robotic surgery in Malaysia in the next 5 to 10 years.

2.7.4 Future Scenario Analysis

From the above drivers, it provides an overview of four possible scenarios expected between 2023 and 2033. Creating a scenario has been addressing the potential consequence of Malaysia's expected growth in robotic surgical utilization. The scenario analysis of the robotic surgery adoption in Malaysia can be considered using both positive and negative implications.

3. Literature Review

The literature review section discusses previous studies conducted by other researchers on smart robotic surgery. The literature review is an essential component of any research study since it allows researchers to get an understanding of previous research and debate on a certain topic or area of study, as well as the structure of that knowledge in the form of a written report. The discussion starts by outlining the advantages and disadvantages of adopting robotic surgery for complex surgery. A STEEPV analysis is used to categorize the issues, factors, risks, and difficulties associated with the implementation of robotic surgery in Malaysia. Articles, journals, conference papers, websites, and other sources are commonly used to obtain related information.

3.1 Definition of Robotic Surgery

Since past decades, medical robotics has become increasingly relevant in the field of robotics. According to Fisher *et al.* (1987), the initial idea for surgical robotics emerged in the late 1980s at the National Aeronautics and Space Centre (NASA). Over the years, robots have led to important advances in various fields, including industry, military and most recently medicine (Lanfranco *et al.*, 2004a) while Nancy (2018) suggested that, robotic surgery is the use of robotic tools and machinery to assist a surgeon perform a surgery. It also known as a smart surgical tool where robotic surgery improves effectiveness, reduces complications, increases safety, and improves precision when performing a surgery compared to a human surgeon. It should be noted that the current systems in use are not intended to operate independently or to replace human surgeons but are instead designed to work together with them (Stylopoulos & Rattner, 2018). Instead, these machines act as remote extensions entirely handle by the surgeon.

3.2 Types of Robotic Surgery

Generally, there are two types of surgical robots (Dalela *et al.*, 2019). The first is the medical robot which could be controlled manually by a surgeon and the second one is a surgical robot that can performed the operations using AI technology (Dalela *et al.*, 2019). According to Dalela et al (2019), robotic surgery is a surgical technique that employs tiny surgical equipment attached to a robotic arm. The surgeon will sit at a computer station and controls the robot arm. During the procedure, the surgeon makes small incisions to insert the endoscope into the patient's body which allowing the surgeon to have clear view on the area that needs to be operated. The movement of robotic arm will be based on the surgeon's hand action when carry out the procedure. These are the processes that will take place when using this robotic surgical technique.

One of the examples of robotic surgery is the da Vinci Surgical System. The da Vinci system uses robotic arms to manipulate surgical instruments, allowing surgeons to perform complex procedures with greater accuracy and control (Andellini *et al.*, 2019). The da Vinci obtained FDA approval for general laparoscopic procedures in 2000, and became the first operative surgical robot in the US (Sung & Gill, 2001). The da Vinci robot has been used in numerous important surgeries, including the first robotically assisted heart bypass performed in Germany in May 1998, followed by a similar operation in the United States in September 1999 (Pettinari *et al.*, 2017). Furthermore, it also performed the first totally robotic-assisted in transplant of kidneys in January 2009 (Gomez, 2009). Nevertheless, the Versius Surgical Robotic System appeared as a competitor to the da Vinci Surgical System in 2019, proclaiming better flexibility and responsiveness with its modular arms, which can be rapidly and simply set up. It claims that it's more adaptable and versatile than the da Vinci system.

3.3 The Advantages of Robotic Surgery Technology

Robotic surgery is the use of robotic tools and machinery in assisting a surgeon to perform a surgery (Nancy, 2018). According to Stylopoulos & Rattner (2018), the current systems in use are not intended to operate independently or to replace human surgeons but are instead designed to work together with them. The robotic manipulator acts as a remote arm extension governed by the surgeon's movements (Meadows, 2002; Morris, 2005). It means that the robot will adjust its actions based on the surgeon's hand movements when carry out the procedure with small and tiny instruments. Robotic systems are becoming more popular in a variety of surgical specialties, including cardiac, urology, thoracic, gynecological, pediatrics, and general surgical procedures (Mehta *et al.*, 2022). Using robotic-assisted surgical techniques allows surgeons to carry out more complex treatments than traditional laparoscopic surgery, resulting in better outcomes and performance for certain surgical operations (Lanfranco *et al.*, 2004b).

Technological advancements and improvements in robotic equipment would aid in the reduction of mistakes, resulting in improved outcomes and accelerating market growth throughout the projection period. When the robots can eliminate the mistakes done by a surgeon during operation, it will make the procedure went smoothly and lead to better results. Recent advancements in robotic surgery such as remote telesurgery, may help eliminate the robotic surgery gap in remote areas. Other than that, enhanced 3-D visualization, and simplifies many existing minimally invasive surgery surgical techniques lead to greater surgical precision and better outcomes. Furthermore, when the application of robotic surgery being implemented in surgical area, it offers high precision, which it will not cause to fatigue and tremor (BenMessaoud *et al.*, 2011). Thus, it can eliminate hand tremor. Next, the systems of robotic surgery technology are very flexible, easy to operate, shortens the operation time, reduces tremor, and can provide smooth movements, reasonable dexterity, and better accuracy even in difficult surgical procedures (BenMessaoud *et al.*, 2011). Besides, with robotic surgery it only requires the surgeon makes smaller incisions. Due to that, the risk of blood loss during or after the surgery will be decrease, less pain and also reduced other potential complications which usually occurred in surgery (MayoClinic, 2022).

Moreover, there lower risks of infection and lead to healthier surgical outcomes when handling the surgical procedures with robotic technology. In addition, patients can faster return to normal activities than normal open surgery (Soleimani *et al.*, 2011). Normally, patient can back to their normal life in a period of only 24 to 48 hours after undergoing Robotic Surgery (Haggag, 2005). It is important for quick recovery because patients can back to their normal routine activities quickly. Due to that, the number of staff in the operating room during the surgery and number of days to stay at hospital after the surgeries will be reduced compared to open surgery (Tran, 2018). Other advantages include greater dexterity and accuracy, scalable motions, camera stability, improved surgeon ergonomics whereby give more confidence and comfort to the surgeon in his surgical practice (Haggag, 2005; Nguyen *et al.*, 2004; Tran, 2018). Last but not least, these devices offer a steady camera platform, save space around the operating table and enable laparoscopic surgery without the resident assistance for camera positioning (Healy *et al.*, 2013).

3.4 The Challenges of Robotic Surgery Technology

Despite tremendous advancement, robotic surgical technology has yet to reach its full potential due to certain constraints. The introduction and rapid adoption of the robotic platform has resulted in increased costs without significantly improving outcomes compared with nonrobotic minimally invasive approaches (Klodmann *et al.*, 2021). Concerns have been raised that robotic surgery is more costly (Stahl & Coeckelbergh, 2016). Two recent studies are comparing robotic procedures with conventional operations shows that although the absolute cost for robotic operations is higher, the major part of the increased cost is attribute to the initial cost of purchasing the robot and yearly maintenance (Lotan *et al.*, 2004; Morgan *et al.*, 2005). Both factors are expected to decrease as robotic systems gain more widespread acceptance. However, it is possible that further technical advances may at first drive prices even higher (Brodie & Vasdev, 2018).

Next challenges in order to adopt the Robotic Surgery Technology is get high expectations from patients and medico-legal implications, as well as demands from hospital administrators to maximize results, mean that there is a limited opportunity for residents to train with the system (Chitwood *et al.*, 2001). In other word, lack of any standardized competence-based training curriculum is more significant, which has been consistently underlined in successive literature (Chitwood *et al.*, 2001; Nifong & Chitwood, 2004). The use of robotic systems has been gaining popularity in several surgical subspecialties, such as cardiac, thoracic, urological, gynaecological, paediatrics, and general surgery. However, despite this growth, some surgeons in these specialties are not inclined to adopt robotic-assisted surgery. Thus, healthcare professionals, and especially physicians, can be slow in adopting new technologies (Yarbrough & Smith, 2007). As this technology is implemented, robotic surgeons must be trained to solve problems related to the robotic technology and associated equipment (Finan & Rocconi, 2010). Failure to act might cause robotic cases to be delayed and complicated.

Other challenges to robotic surgery include the lack of the robotic equipment currently in use (Camarillo *et al.*, 2004; Sabiston *et al.*, 2017). A surgical team wants to be as agile as possible in the operating room. Precision and agility in operation performance reduce risk since every minute the patient is on the operating table increases the chance of infection, bleeding, and other problems. Agility fosters speedier patient recovery and improves outcomes. Finally, an agile team can provide constant quality treatment since they can respond quickly to changing occurrences. Considering that things do not always go as planned, a surgical team must have varied tools in order to remain adaptable. Tools have to be constructed and designed to be adaptive. They must be designed to adapt to the demands of the procedure, the operating room, and the whole surgical team. These tools should ideally be able to detect their changing surroundings and make modifications to keep the effort low and efficient. Lastly, shortage of surgeons, lack of training, and network challenges all contribute to inequitable community-wide robotic surgery deployment. In nations that do not provide universal training, training is not standardized, raising the likelihood of medical mistakes and risking patient safety (Holmer *et al.*, 2015). Although simulation training using 3D models may be beneficial, these innovative technologies may not reach underprivileged groups (Witthaus *et al.*, 2020).

3.5 STEEPV Analysis

The factors influencing the adoption of robotic surgery in Malaysia can be determined by the STEEPV factor, namely: social, technological, environmental, economic, political and value factors. STEEPV analysis is one of qualitative data approach that will be use in this study to determine the key drivers, issues and future trend of robotic surgery adoption in Malaysia especially in complex surgery. Table 3 shows the results of output from STTEPV analysis. The full results of the key issues, drivers and trends collected were listed in **Appendix A**.

Table 3 *Results STEEPV analysis*

Factors	Total
Social	14
Technological	25
Environmental	2
Economic	12
Political	2
Value	6

3.6 List of Merged Issues Drivers and Trends

Table 4 *Table with merged issues and drivers*

No	Issues and Drivers
1	Expertise in robotic technology
2	Technology advancement
3	Improve surgical efficiency
4	Ergonomic and user-friendly system designs
5	Safety and health
6	High-risk operation
7	Complex procedures
8	Manpower in the medical field
9	Market demand
10	Purchase, upgrade and maintaining cost

4. Results and Discussion

This chapter discussed the results of the data analysis acquired from distribution of questionnaire personally to the general surgeon who works in government and private hospital with the aid of email and Facebook. The data was analyzed using the Statistical Package for Social Science (SPSS) version 27 to determine the entire demographic information along with the mean of each issue, driver and trend.

4.1 Reliability Test

4.1.1 Pilot Test

In the pilot test, the questionnaire was purposefully distributed to ten respondents selectively to determine whether the questions prepared by the researcher understandably by the respondent or not. The results of the pilot test questionnaire were analyzed using SPSS.

Table 5 *Reliability of pilot test*

Part	Drivers	Cronbach's Alpha	No of Items
B	Importance	0.809	10
C	Impact	0.842	10
D	Uncertainty	0.983	10

The results of the pilot test conducted for this study were shown in Table 5. The questions in this pilot test were divided into three sections which Part B, Part C and Part D. Part B cover the importance of robotic surgery adoption in Malaysia, while Part C cover the impact of robotic surgery adoption in Malaysia and Part D cover the level of uncertainty regarding adoption of robotic surgery in Malaysia. Each section has ten questions. All of the reliability tests for Cronbach's Alpha were more than 0.70, so all parts were acceptable. The value of Cronbach's Alpha for Part B was 0.809, indicates that the research was a good level of reliability. Next, value of Cronbach Alpha for Part C was 0.842, indicates that the research was a good level of reliability. Lastly, value of Cronbach's Alpha for Part D was 0.983, indicates that the research had an excellent in term of level of reliability.

4.1.2 Actual Test

This section detailed the results of data that have been collected from real respondent. In order to get this data, around 52 copies of the questionnaire were distributed for collection purposes. Table 6 shows the outcomes of the reliability test conducted on each variable for the actual study. The number of respondents consisted of 52 surgeons.

Table 6 *Reliability of actual test*

Part	Drivers	Cronbach's Alpha	No of Items
B	Importance	0.835	10
C	Impact	0.826	10
D	Uncertainty	0.980	10

From the above table, it shows that the value of Cronbach's alpha for importance, impact and uncertainty are 0.835, 0.826 and 0.980 respectively, which is above the acceptance level because of it exceed 0.7. The value of Cronbach's alpha should be above 0.7 or a minimum acceptable level of reliability would be 0.7. Based on the result, it demonstrates each of the variables has a reliable value based on Cronbach's Alpha.

4.2 Demographic Analysis

Table 7 *Demographic analysis*

Item	Frequency	Percentage (%)
Gender		
Male	13	25.0
Female	39	75.0
Age		
40 and below	47	90.4
41 - 45	2	3.8
46 - 50	2	3.8

51 and above	1	1.9
Race		
Malay	39	75.0
Chinese	11	21.2
Indian	2	3.8
Agree on robotic surgery		
Yes	39	75.0
No	13	25.0
Opinion toward future robot aiding in surgeries procedures		
Very uncomfortable	4	7.7
Indifferent	18	34.6
Very comfortable	30	57.7

Table 7 shown the result of demographic analysis of respondents. Majority of the respondents were female as compared to male. The majority of respondents are from the age of 40 years and below and almost more than half of the respondents were Malay. Most of the respondent had agreed if human surgery replaced by robotic surgery and majority of respondents voted very comfortable if in the future robots aiding in their surgery.

4.3 Descriptive Analysis

Table 8 *Mean of drivers on importance, impact and uncertainty*

No	Issues, Drivers and Trends	Mean		
		Importance	Impact	Uncertainty
1	Expertise in robotic technology	4.2308	4.2308	2.8654
2	Technology advancement	4.4423	4.3077	2.9423
3	Improve surgical efficiency	4.4231	4.5577	2.8846
4	Ergonomic and user-friendly designs.	4.5385	4.5000	2.9615
5	Safety and health	4.4231	4.4615	2.7885
6	High-risk operation	4.4615	4.3846	2.9231
7	Complex procedures	4.4615	4.4231	2.9231
8	Manpower in the medical field	4.3846	4.3846	3.0000
9	Market demand	4.4423	4.3462	3.0962
10	Purchasing, upgrading and maintaining cost	3.5962	3.7308	3.3077

4.4 Impact-Uncertainty Analysis

Impact-uncertainty analysis is carried out to recognize the main two drivers displaying high impact and uncertainty values. The process for analyzing this analysis was done by plotting the mean of impact and uncertainty variables in a graph. Then, these two drivers with the highest mean value of impact and uncertainty will be used to develop the future scenario analysis. Table 9 shows the mean of the drivers on level of impact and uncertainty. Table 9 shown the results of impact-uncertainty analysis.

Table 9 *Means of the 10 leading drivers on level of impact and uncertainty*

No	Issues, Drivers and Trends	Mean	
		Impact	Uncertainty
1	Expertise in robotic technology	4.2308	2.8654
2	Technology advancement	4.3077	2.9423
3	Improve surgical efficiency	4.5577	2.8846
4	Ergonomic and user-friendly designs.	4.5000	2.9615
5	Safety and health	4.4615	2.7885
6	High-risk operation	4.3846	2.9231
7	Complex procedures	4.4231	2.9231
8	Manpower in the medical field	4.3846	3.0000

9	Market demand	4.3462	3.0962
10	Purchasing, upgrading and maintaining cost	3.7308	3.3077

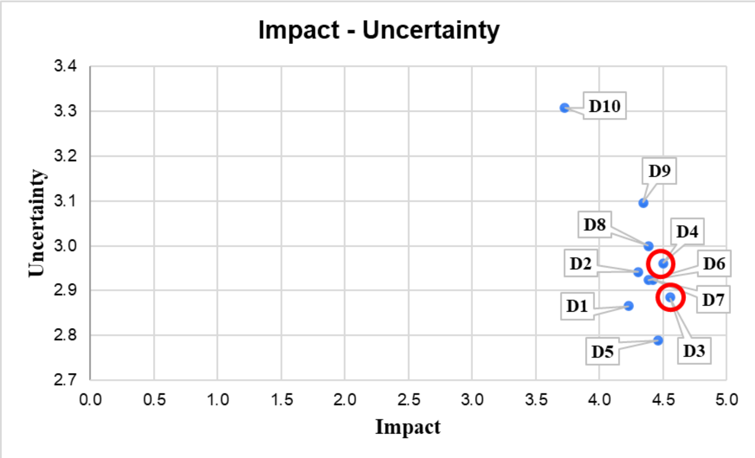

Fig. 2 *Impact-Uncertainty Analysis*

According to Fig. 2, it demonstrates an analysis of impact and uncertainty based on the above results. Two of the drivers with the greatest impact and uncertainty values were identified as D3 and D4. Improved surgical efficiency (D3) denotes as the highest level of impact, while the ergonomic and user-friendly designs (D4) show the greatest uncertainty about the future adoption of robotic surgery in Malaysia. These top two drivers were assigned to form the scenario analysis in chapter 5.

5. Discussion

5.1 Discussion Based on First Research Objective

This research has two objectives which will guiding the researcher along the study's progression. The first objective is to determine the key drivers that lead to robotic surgery adoption in Malaysia by using STEEPV analysis. Identifying the issues, drivers and trends that influence robotic surgery adoption among general surgeons in private hospitals is crucial for future outlook and acceptability. Based on the STEEPV analysis, technological part was the most influential factor in promoting robotic surgical adoption in Malaysia, followed by value, social factors, economic, political and environmental aspects.

5.2 Discussion based on First Research Objective

The second objective of this research is to explore the future trend of robotic surgery acceptance in Malaysia. It explores into the factors that might influence future developments and the potential market for robotic surgery in Malaysia. This exploration accomplished by utilizing the two main influential drivers from the impact-uncertainty analysis to create scenario analysis for four alternative scenarios. The selected drivers have been discussed in the previous chapter on the unpredictability of future development and its impact on the implementation of robotic surgery in Malaysia. These two selected drivers had the significant impact and level of uncertainty compared to the other drivers.

Improved surgical efficiency has the greatest impact and being the most uncertain driver compared to the others (4.5577, 2.8846). The private and government healthcare institutions must consider the robotic surgery in the future. The sophistication of technology and sufficient equipment enable the implementation of robotic surgery. According to Orthopaedic Surgeon at Kuala Lumpur Hospital (HKL), Dr. Kunalan Ganthel @ Annamalai, stated that a robot utilizing the Robotic Surgical Assistant (ROSA) system from a private company in the United States can enhance joint replacement surgery to be nearly 100% faster and more accurate (Zakaria, M., 2022). This is due to they had successfully performed 20 surgeries, even with complex cases and these robots can achieve 98% accuracy compared to the conventional methods, which only achieves 94 to 95 percent accuracy. Therefore, the Ministry of Health (MOH) is urged to establish initiatives to enable Kuala Lumpur Hospital (HKL) to continue using robots for surgical treatment.

The second highest driver is ergonomic and user-friendly designs. The driver's mean impact and uncertainty is (4.5000, 2.9615). According to Dr. Abd Aziz Yahya, an obstetrician, and gynaecologist at Gleneagles Hospital Kuala Lumpur (GKL), the da Vinci Si system consists of a customized surgeon's console that allows the surgeon to control instruments while seeing the patient's internal organs through a high-resolution 3D camera. This setup allows the surgeon to carry out surgery with greater clarity and accuracy. The ergonomic design of robotic consoles enables surgeons to handle them comfortably while seated, reducing physical strain during long surgeries. In summary, the ergonomic and user-friendly designs of robotic surgical systems significantly contribute towards better surgical results, reducing surgeon fatigue and strain problems.

From the above drivers, it provides an overview of four possible scenarios expected between 2023 and 2033. Fig. 3 illustrates an analysis of these four scenarios, addressing the potential consequence of Malaysia's expected growth in robotic surgical utilization.

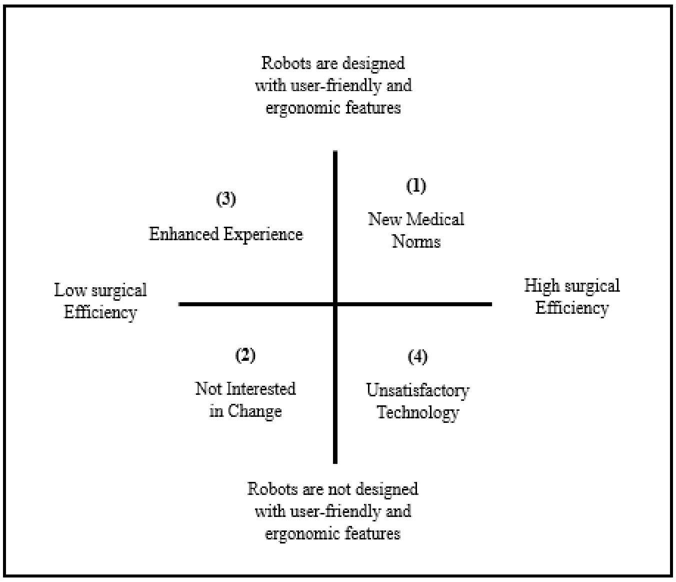

Fig. 3 *Four alternative scenario*

5.2.1 Scenario 1 (New Medical Norms)

The first scenario emerges when the robot is not only designed with user-friendly and ergonomic features but also significantly enhances surgical efficiency. It will create a new kind of normalization within the medical sector, increasing the importance of robot surgeries compared to human surgery. This shift marks a transformative phase and the beginning of new era in healthcare institutions. 'New medical norms' refers to the situation where the use of robots in surgeries becomes widespread throughout all healthcare facilities. This is the best scenario to achieve since it influences the adoption of robotic surgery in Malaysia.

This ideal scenario provides convenience for surgeons during procedures, allowing them to handle surgeries independently without external assistance. Hence, expediting the surgical process. Generally, the main purpose of most surgical robots is to reduce the burden of doctors and medical assistance. For instance, using robotic arms for positioning and holding has eliminated surgical assistants from constant holding tasks, allowing them to focus on other important tasks (Klodmann, 2021). Other than that, a surgeon no longer directly interacts with the patient but controls the systems from the surgeon console. It means the robotic surgery will be a semi-autonomous system or will be controlled by the surgeon during the procedure. Therefore, the robotic system has to build two connections between the surgeon and the patient. At first, it must translate the surgeon's expertise and accuracy into the body of the patient. Second, it must provide the surgeon with detailed information regarding the area to undergo the operation.

Moreover, well-designed systems that emphasise ergonomics and user-friendly not only reduce physical strain and make instrument handling easier, but they also increase surgical accuracy, causing less mental exhaustion for the medical staff. In conclusion, robot inventors will create smart robots with ergonomic and user-friendly designs that will enable surgeons to carry out more complex tasks with higher efficiency and accuracy.

5.2.2 Scenario 2 (Not Interested in Change)

When robotic surgery lacks a user-friendly design, it can lead to inefficiencies. It will make some of the surgeons not interested in changing to robotic surgery. This resistance is often seen, particularly in older generations of surgeons who are hesitant about utilizing robots to assess patients' conditions. They feel that robots might not correctly examine the surgical locations due to their non-ergonomic design and realizes the complexity of deploying robotic systems to perform certain surgeries or treatments compared to traditional methods. The complexity of robotic system could increase the operation times and reduce efficiency unless surgeons have expert skills to handle it.

Healthcare professionals, especially older generations are not interested in any change even though the growing popularity of robotic systems across various surgical subspecialties, such as urological, cardiac, thoracic, gynaecological and general surgery. One of the common reasons for the lack of acceptance may be attributed to the challenges of coping with new devices, adapting new kinds of instrumentation, and learning new operative techniques (BenMessaoud, 2020). It will make surgeons have to interrupt their practice and take half a day off to attend seminars and training sessions. They will undergo long training requirements and according to surgeons, it takes at least 25 surgeries to gain the ability to 'feel' the details and complexities of a surgical procedure with their own eyes (BenMessaoud, 2020). Moreover, some healthcare professionals especially older generations resist learning new things related to the latest technology because they believe traditional practices are sufficient to treat their patients and also, they think that simple procedures can be performed at a lower cost without the robot. As a result, the resistance to adopting technological innovations among older practitioners will delay the integration of robotic surgery into medical practices.

5.2.3 Scenario 3 (Enhanced Experience)

The third scenario occurs when the robot is designed with user-friendly and ergonomic features but the robot still cannot enhance the surgical efficiency. This condition will make surgeons hesitate to use robots in aiding their surgery due to the robots only enhance the surgeon's experience, but it decreased surgical output. However, the robots still can enhance surgeon's experience because of their ergonomic design which gives comfortable and reduces fatigue during long procedures. This scenario suggests the ability to demand the use of robots in hospitals but cannot increase the surgical efficiency during operation due to their limitations. Generally, robots have their own disabilities and limitations. Therefore, surgeons will apply robotic surgery to replace the human surgery.

This scenario is the second-best scenario for applying robotic surgery to replace the human surgery. This is because there is an opportunity for robotic surgery to grow in the future due to their ergonomic designs that can reduce fatigue among surgeons and contribute to a simplified instrument handling, which further enhances surgical precision (Klodmann, 2021). Moreover, robotic surgery can assist surgeons in many ways. As a conclusion, robotic surgery needs further research and development to enhance surgeons experience and being implemented in the future to replace the human surgery.

5.2.4 Scenario 4 (Unsatisfactory Technology)

The last scenario is produced by the presence of the robot which enhances surgical efficiency, and the robots that are not designed with user-friendly and ergonomic features. Generally, the availability of robots that increase surgical efficiency but lack ergonomic features will lead to the new innovations. This scenario encourages the development of robots to assist surgeons during surgery, but at the same time reduces surgeon comfort due to poor ergonomic design. This scenario highlights the unsatisfactory technology intended for replacing human surgery in healthcare institutions because it degrades user-friendliness and ergonomic design for surgeons.

Although robots can improve surgical efficiency, surgeons still prefer ergonomic robots. It is because ergonomic and user-friendly system designs can reduce fatigue and allow surgeons to operate comfortably and accurately in long procedures. Surgeons are unwilling to change to a non-ergonomic robot and prefer to stay with the traditional methods that they have practiced. Every surgeon agrees that ergonomics is important and influences their daily lives (Fuchs *et al.*, 2023). As a result, unsatisfactory technology will overcome the future robot usage.

5.3 Limitation of Study

This study faces several limitations that emerged during the research process. Firstly, the size of population is too small, restricts access to a diverse range of surgeons and that has an impact on the representation of their opinions regarding the implementation of robotic surgery in Malaysia. Secondly, the study only focuses on a certain group of respondents within the surgical community, facing difficulty in accessing them and obtaining adequate participation from this group due to not all respondents that were chosen willing to participate in survey responses. Next, potential biases regarding how participants were chosen or respondent's perspectives may have influenced on the interpretation of results and the accuracy of the study. Moreover, a time constraint also one of the limitations in this study. The duration of collection data from surgeon in private hospital was limited where less than three months. It had an impact on both the depth and breadth of the research.

5.4 Recommendation

In today's digitalization era, AI technology has making waves across various sectors, sparking significant interest in industries such as manufacturing, automotive, education, healthcare, business and others. The existing status of robotic surgery in Malaysia indicates potential for future advancements. Consequently, the study explored trends and directions for further research on adopting robotic surgery in Malaysia.

5.4.1 Recommendation for Future Study

This study aims to forecast the adoption of robotic surgery in Malaysia within the next 5 to 10 years. However, the use of robotic surgery in Malaysia hasn't been thoroughly explored and developed until now. Consequently, there are some suggestions to overcome these limitations. Firstly, conducting interviews in conjunction with data collection could provide deeper insights. Using open-ended questionnaires, respondents can learn more as well as share their perspectives on robotic surgery in Malaysia. Additionally, researchers have to consider respondents' diverse cultures and backgrounds to ensure that attain accurate results and the perception of respondents in the future for robotic surgery adoption will not represent Malaysia's overall perspective. Hence, future research has to focus on the impact of using robotic technology in surgeries for both older and younger generations, as it will play an important role in predicting and shaping future possibilities.

5.4.2 Recommendation for Robotic Surgery in Malaysia

The impact-uncertainty analysis of the main drivers led to four different scenarios, each with both positive and negative implications for the development of robotic surgery adoption in Malaysia. Therefore, as general industries need to prepare a contingency plan and resolution to turn around the adverse effects identified in scenario building analysis in order to continuously advance and sustain the technology.

5.5 Conclusion

As a conclusion, this research aims to identify the issues and drivers of the future trend of robotic surgery adoption in Malaysia. In order to reach the aims of research, research questions have been developed. After completion of data analysis process, the outcome of the analysis has been given in clear formats and combined in the STEEPV table, where it can aid researchers in conducting each procedure in a more coordinated and proper manner. Lastly, the STEEPV analysis resulted in a total of 10 merged issues and drivers. This merged issues and drivers has been measured and surveyed in a questionnaire that has been distributed to all surgeons from government and private hospitals in Malaysia. As a result, this research will help educate future researchers, surgeons, patients, Internet of things application developers, and healthcare areas about robotic surgery technology.

Acknowledgement

The author would like to thank to the Faculty of Technology Management and Business, Universiti Tun Hussein Onn Malaysia for its support.

Conflict of Interest

Author declares that there is no conflict of interests regarding the publication of the paper.

Author Contribution

The authors confirm contribution to the paper as follows: ***study conception and design****: S.N.M.S. and S.A.S.;* ***data collection:*** *S.N.M.S.;* ***analysis and interpretation of results:*** *S.N.M.S. and S.A.S.;* ***draft manuscript preparation*** *S.N.M.S. and S.A.S. All authors reviewed the results and approved the final version of the manuscript.*

References

Andellini, M., Di Mauro, R., Faggiano, F., Derrico, P., & Ritrovato, M. (2019). PP187 Robotic Surgery, Any Updates? *International Journal of Technology Assessment in Health Care*, *35*(S1), 72–72. https://doi.org/10.1017/S0266462319002757

Ashrafian, H., Clancy, O., Grover, V., & Darzi, A. (2017). The evolution of robotic surgery: Surgical and anaesthetic aspects. *British Journal of Anaesthesia*, *119*, i72–i84. https://doi.org/10.1093/bja/aex383

Asia, H. M. (2022a, March 29). Why Malaysia's Sunway Medical Centre invested in the latest Robotic Surgical System. HMA. https://www.hospitalmanagementasia.com/tech-innovation/why-malaysias-sunway-medical-centre-invested-in-the-latest-robotic-surgical-system/

Bajwa, J. *et al.* (2021) Artificial Intelligence in healthcare: Transforming the practice of medicine, Future healthcare journal. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8285156/ (Accessed: 01 September 2023).

Beyond Tomorrow: The Evolution of Healthcare Technologies. (2023, May 9). *The Malay Mail*. Retrieved from https://www.malaymail.com/news/money/mediaoutreach/2023/05/09/beyond-tomorrow-the-evolution-of-healthcare-technologies/218927.

BenMessaoud, C., Kharrazi, H., & MacDorman, K. F. (2011). Facilitators and barriers to adopting robotic-assisted surgery: Contextualizing the unified theory of acceptance and use of technology. *PLoS ONE*, *6*(1). https://doi.org/10.1371/journal.pone.0016395

Bocca, S., Stadtmauer, L., & Oehninger, S. (2007). Current status of robotically assisted laparoscopic surgery in reproductive medicine and gynaecology. *Reproductive BioMedicine Online*, *14*(6), 765–772. https://doi.org/10.1016/S1472-6483(10)60680-3

Bonsor, K., & Strickland, J. (2000, October 30). *How robotic surgery will work*. HowStuffWorks. https://health.howstuffworks.com/medicine/modern-technology/robotic-surgery.htm

Britannica, T. Editors of Encyclopaedia (2023, December 17). surgery. Encyclopedia Britannica. https://www.britannica.com/science/surgery-medicine

Brodie, A., & Vasdev, N. (2018). The future of robotic surgery. *The Annals of The Royal College of Surgeons of England*, *100*(Supplement 7), 4–13. https://doi.org/10.1308/rcsann.supp2.4

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

Centre for Devices and Radiological Health. (2019, February 28). *Caution with RAS devices in mastectomies.* U.S. Food and Drug Administration. https://www.fda.gov/medical-devices/safety-communications/update-caution-robotically-assisted-surgical-devices-mastectomy-fda-safety-communication

Chitwood, W. R., Nifong, L. W., Chapman, W. H., Felger, J. E., Bailey, B. M., Ballint, T., Mendleson, K. G., Kim, V. B., Young, J. A., & Albrecht, R. A. (2001). Robotic surgical training in an academic institution. *Annals of Surgery*, *234*(4), 475–484; discussion 484-6. https://doi.org/10.1097/00000658-200110000-00007

Cuhls, K. E. (2020). Horizon Scanning in Foresight – Why Horizon Scanning is only a part of the game. *FUTURES & FORESIGHT SCIENCE*, *2*(1). https://doi.org/10.1002/ffo2.23

Daftardar, I. (2023, October 19). *Past And the Present: The History and Evolution of Robots*. Science ABC. https://www.scienceabc.com/innovation/history-evolution-robots-robotics-pathfinder-hal-nadine.html

Daley, S. (2023) 38 artificial intelligence examples shaking up business across industries, Built In. Available at: https://builtin.com/artificial-intelligence/examples-ai-in-industry (Accessed: 10 September 2023).

DerSarkissian, C. D. (2023, July 13). What is a surgeon? what they do and when to see one. WebMD. https://www.webmd.com/a-to-z-guides/what-is-surgeon

Engineering & Technology. (2023, July 24). Robotics in Healthcare: A look at exciting medical science advancements. GCU. https://www.gcu.edu/blog/engineering-technology/robotics-healthcare-look-exciting-medical-science-advancements

E-Spin. (2023a, February 21). Challenges of adopting robots in Healthcare: Addressing emotional support, social acceptance, privacy, security, and power sources: E-SPIN group. E. https://www.e-spincorp.com/challenges-of-adopting-robots-in-healthcare-addressing-emotional-support-social-acceptance-privacy-security-and-power-sources/

Esposito, M. (2023, July 16). *The Evolution of Medical Robots: A Historical Overview*. The BLife MovementTM. https://www.theblifemovement.com/the-evolution-of-medical-robots-a-historical-overview/

Fernando, D., & Fernando, W. D. R. (2019). *Robotics for surgeries Sinhala Handwritten Character Segmentation View project Robotics for surgeries*. https://www.researchgate.net/publication/345319191

Finan, M. A., & Rocconi, R. P. (2010). Overcoming technical challenges with robotic surgery in gynaecologic oncology. *Surgical Endoscopy*, *24*(6), 1256–1260. https://doi.org/10.1007/s00464-009-0756-0

Fisher, S. S., McGreevy, M., Humphries, J., & Robinett, W. (1987). Virtual environment display system. *Proceedings of the 1986 Workshop on Interactive 3D Graphics, I3D 1986*, *1987-January*, 77–87. https://doi.org/10.1145/319120.319127

Fuchs, H., Müller, D., Ahn, J., Brunner, S., Poggemeier, J., Storms, C., Reisewitz, A., Schmidt, T., & Bruns, C. (2023). Ergonomics in robot-assisted surgery in comparison to open or conventional laparoendoscopic surgery: A narrative review. *International Journal of Abdominal Wall and Hernia Surgery*, 6(2), 61–66. https://doi.org/10.4103/ijawhs.ijawhs_52_22

Gomez, D. M. (Ed.). (2009). New York Health News*. New Robot Technology Eases Kidney Transplants - wcbstv.com.* https://web.archive.org/web/20090804104220/http:/wcbstv.com/health/da.vinci.robot.2.1055154.html

Graves, P. (2022, February 23). *History of Robotics in Medicine: Medical Uses for Robots*. GWS Robotics. https://www.gwsrobotics.com/blog/history-robotics-medicine-medical-uses-robots

Haggag, A. A. (2005). *Robotic Surgery: When Technology Meets Surgical Precision A Haggag*.

Healy, D. A., Murphy, S. P., Burke, J. P., & Coffey, J. C. (2013). Artificial interfaces ("AI") in surgery: Historic development, current status and program implementation in the public health sector. *Surgical Oncology*, *22*(2), 77–85. https://doi.org/10.1016/j.suronc.2012.12.003

Hinrichs-Krapels, S., Ditewig, B., Boulding, H., Chalkidou, A., Erskine, J., & Shokraneh, F. (2022). Purchasing high-cost medical devices and equipment in hospitals: a systematic review. *BMJ Open*, *12*(9), e057516. https://doi.org/10.1136/bmjopen-2021-057516

Hockstein, N. G., Gourin, C. G., Faust, R. A., & Terris, D. J. (2007). A history of robots: from science fiction to surgical robotics. *Journal of Robotic Surgery*, *1*(2), 113–118. https://doi.org/10.1007/s11701-007-0021-2

Holmer, H., Lantz, A., Kunjumen, T., Finlayson, S., Hoyler, M., Siyam, A., Montenegro, H., Kelley, E. T., Campbell, J., Cherian, M. N., & Hagander, L. (2015). Global distribution of surgeons, anaesthesiologists, and obstetricians. *The Lancet Global Health*, *3*, S9–S11. https://doi.org/10.1016/S2214-109X(14)70349-3

Home. OARC Stats. (n.d.). https://stats.oarc.ucla.edu/spss/faq/what-does-cronbachs-alpha-mean/#:~:text=Cronbach's%20alpha%20is%20a%20measure, that%20the%20measure%20is%20unidimensional.

Hussain, M. (2012). *Descriptive statistics - presenting your results I*. 741–743. https://www.researchgate.net/publication/228094603_Descriptive_statistics_-_presenting_your_results_I

Jennifer Whitlock, R. (2023, April 7). What does it take to become a surgeon? Very well Health. https://www.verywellhealth.com/how-to-become-a-doctor-or-a-surgeon-3157309

Klodmann, J., Schlenk, C., Hellings-Kuß, A., Bahls, T., Unterhinninghofen, R., Albu-Schäffer, A., & Hirzinger, G. (2021). An Introduction to Robotically Assisted Surgical Systems: Current Developments and Focus Areas of Research. *Current Robotics Reports*, *2*(3), 321–332. https://doi.org/10.1007/s43154-021-00064-3

KPJ Healthcare Berhad. Our hospitals. (n.d.). https://www.kpjhealth.com.my/our-hospitals/

Loon, D. W. L. H. (2021, February 14). Robotic Surgery. Retrieved May 16, 2023, from https://www.nst.com.my/lifestyle/heal/2021/02/665516/robotic-surgery.

Lanfranco, A. R., Castellanos, A. E., Desai, J. P., & Meyers, W. C. (2004a). Robotic surgery: a current perspective. *Annals of Surgery*, *239*(1), 14–21. https://doi.org/10.1097/01.sla.0000103020.19595.7d

Lanfranco, A. R., Castellanos, A. E., Desai, J. P., & Meyers, W. C. (2004b). Robotic surgery: a current perspective. *Annals of Surgery*, *239*(1), 14–21. https://doi.org/10.1097/01.sla.0000103020.19595.7d

Lotan, Y., Cadeddu, J. A., & Gettman, M. T. (2004). THE NEW ECONOMICS OF RADICAL PROSTATECTOMY: COST COMPARISON OF OPEN, LAPAROSCOPIC AND ROBOT ASSISTED TECHNIQUES. *Journal of Urology*, *172*(4 Part 1), 1431–1435. https://doi.org/10.1097/01.ju.0000139714.09832.47

Marescaux, J., & Rubino, F. (2005). Robotic surgery: potentials, barriers, and limitations. *European Surgery*, *37*(5), 279–283. https://doi.org/10.1007/s10353-005-0182-z

MayoClinic. (2022, May 6). Robotic surgery. Mayo Clinic. https://www.mayoclinic.org/tests-procedures/robotic-surgery/about/pac-20394974

McLeod, I. K., Mair, E. A., & Melder, P. C. (2005). Potential applications of the da Vinci minimally invasive surgical robotic system in otolaryngology. *Ear, Nose, & Throat Journal*, *84*(8), 483–487.

Meadows, M. (2002). Robots lend a helping hand to surgeons. *FDA Consumer*, *36*(3), 10–15.

Mehta, A., Cheng Ng, J., Andrew Awuah, W., Huang, H., Kalmanovich, J., Agrawal, A., Abdul-Rahman, T., Hasan, M. M., Sikora, V., & Isik, A. (2022). Embracing robotic surgery in low- and middle-income countries: Potential benefits, challenges, and scope in the future. *Annals of Medicine and Surgery (2012)*, *84*, 104803. https://doi.org/10.1016/j.amsu.2022.104803

Mesko, Dr. B. (2021, May 27). *The Technological Future of Surgery*. The Medical Futurist. https://medicalfuturist.com/the-technological-future-of-surgery/

Monson, J. R., & Weiser, M. R. (2008). Sabiston Textbook of Surgery, 18th ed. The Biological Basis of Modern Surgical Practice. *Diseases of the Colon & Rectum*, *51*(7), 1154. https://doi.org/10.1007/s10350-008-9293-5

Moran, M. E. (2006). The da Vinci Robot. *Journal of Endourology*, *20*(12), 986–990. https://doi.org/10.1089/end.2006.20.986

Morgan, J. A., Thornton, B. A., Peacock, J. C., Hollingsworth, K. W., Smith, C. R., Oz, M. C., & Argenziano, M. (2005). Does Robotic Technology Make Minimally Invasive Cardiac Surgery Too Expensive? A Hospital Cost Analysis of Robotic and Conventional Techniques. *Journal of Cardiac Surgery*, *20*(3), 246–251. https://doi.org/10.1111/j.1540-8191.2005.200385.x

Morris, B. (2005). Robotic surgery: applications, limitations, and impact on surgical education. *MedGenMed: Medscape General Medicine*, *7*(3), 72.

Murphy, D. A., Miller, J. S., Langford, D. A., & Snyder, A. B. (2006). Endoscopic robotic mitral valve surgery. *The Journal of Thoracic and Cardiovascular Surgery*, *132*(4), 776–781. https://doi.org/10.1016/j.jtcvs.2006.04.052

Nazemi, T., Galich Anton, Smith, L., & Balaji, K. (2006). Robotic urological surgery in patients with prior abdominal operations is not associated with increased complications. *International Journal of Urology*, *13*(3), 248–251. https://doi.org/10.1111/j.1442-2042.2006.01273.x

Nguyen, N. T., Hinojosa, M. W., Finley, D., Stevens, M., & Paya, M. (2004). Application of Robotics in General Surgery: Initial Experience. *The American Surgeon*, *70*(10), 914–917. https://doi.org/10.1177/000313480407001019

Nifong, L. W., & Chitwood, W. R. (2004). Building a surgical robotics program. *American Journal of Surgery*, *188*(4A Suppl), 16S-18S. https://doi.org/10.1016/j.amjsurg.2004.08.026

Othman, W., Lai, Z.-H. A., Abril, C., Barajas-Gamboa, J. S., Corcelles, R., Kroh, M., & Qasaimeh, M. A. (2022). Tactile Sensing for Minimally Invasive Surgery: Conventional Methods and Potential Emerging Tactile Technologies. *Frontiers in Robotics and AI*, *8*. https://doi.org/10.3389/frobt.2021.705662

Pamplona, F. (2022, October 18). What is methodology in research and how can we write it? Mind the Graph Blog. https://mindthegraph.com/blog/what-is-methodology-in-research/#:~:text=The%20three%20types%20of%20methodology,%2C%20quantitative%2C%20and%20mixed%20methods.

Pettinari, M., Navarra, E., Noirhomme, P., & Gutermann, H. (2017). The state of robotic cardiac surgery in Europe. *Annals of Cardiothoracic Surgery*, *6*(1), 1–8. https://doi.org/10.21037/acs.2017.01.02

Phee, S. J., Low, S. C., Huynh, V. A., Kencana, A. P., Sun, Z. L., & Yang, K. (2009). Master and slave transluminal endoscopic robot (MASTER) for natural Orifice Transluminal Endoscopic Surgery (NOTES). *2009 Annual International Conference of the IEEE Engineering in Medicine and Biology Society*, 1192–1195. https://doi.org/10.1109/IEMBS.2009.5333413

Proskuryakova, L., Saritas, O., & Rospatent, E. K. (2015). *Water resources-an analysis of trends, weak signals and wild cards with implications for Russia Participative Foresight for Smarter Cities: From a Vision over Scenarios to Road mapping View project Global Challenges and Long-term Trends in Innovation Development View project*. https://www.researchgate.net/publication/274566158

Reddy, K., Gharde, P., Tayade, H., Patil, M., Reddy, L. S., & Surya, D. (2023). Advancements in Robotic Surgery: A Comprehensive Overview of Current Utilizations and Upcoming Frontiers. *Cureus*. https://doi.org/10.7759/cureus.50415

Robotnik. (2022, January 27). *Applications of robotics in medicine*. Robotnik. https://robotnik.eu/applications-of-robotics-in-medicine/

Rozbruch, L. (Ed.). (2018, March 16). *Litigation & robotic surgery: Product liability or medical malpractice?* Penn Undergraduate Law Journal. https://www.pulj.org/the-roundtable/litigation-robotic-surgery-product-liability-or-medical-malpractice

Rus, D. (2023). *A Decade of Transformation in Robotics*. OpenMind BBVA. https://www.bbvaopenmind.com/en/articles/a-decade-of-transformation-in-robotics/

Sabiston, Beauchamp, R. D., Townsend, C. M., Evers, B. M., & Kenneth L., M. (2017). *Sabiston textbook of surgery: the biological basis of modern surgical practice*.

Secoli, R., Matheson, E., Pinzi, M., Galvan, S., Donder, A., Watts, T., Riva, M., Zani, D. D., Bello, L., & Rodriguez y Baena, F. (2022). Modular robotic platform for precision neurosurgery with a bio-inspired needle: System overview and first in-vivo deployment. *PLOS ONE*, *17*(10). https://doi.org/10.1371/journal.pone.0275686

Senarai Hospital Kerajaan. Portal Rasmi Kementerian Kesihatan Malaysia. (n.d.). https://www.moh.gov.my/index.php/database_stores/store_view/82?items=25&page=6

Sheetz, K. H., Claflin, J., & Dimick, J. B. (2020). Trends in the Adoption of Robotic Surgery for Common Surgical Procedures. *JAMA Network Open*, *3*(1), e1918911. https://doi.org/10.1001/jamanetworkopen.2019.18911

Soleimani, F., Moll, F., Wallace, D., Bismuth, J., Geršak, B., & Gersak, B. (2011). Izobraževanje/Education robots and Medicine-Shaping and Defining the Future of Surgery robots and Medicine-Shaping and Defining the Future of Surgery, endovascular Surgery, electrophysiology and Interventional radiology Robot in medicina-oblikovanje in opredelitev prihodnosti kirurgije, endovaskularne kirurgije, elektrofiziologije in interventne radiologije. In *Zdrav Vestn | julij-avgust*.

Stahl, B. C., & Coeckelbergh, M. (2016). Ethics of healthcare robotics: Towards responsible research and innovation. *Robotics and Autonomous Systems*, *86*, 152–161. https://doi.org/10.1016/j.robot.2016.08.018

Stylopoulos, N., & Rattner, D. (2018). Robotics and ergonomics. *Surgical Clinics of North America*, *83*(6), 1321–1337. https://doi.org/10.1016/S0039-6109(03)00161-0

Sung, G. T., & Gill, I. S. (2001). Robotic laparoscopic surgery: a comparison of the da Vinci and Zeus systems. *Urology*, *58*(6), 893–898. https://doi.org/10.1016/S0090-4295(01)01423-6

Surgical Robots Market Size, share & growth report, 2030. Surgical Robots Market Size, Share & Growth Report, 2030. (n.d.). https://www.grandviewresearch.com/industry-analysis/surgical-robot-market

The Star. (2023, June 12). Doctors question ministry's oversupply projection. https://www.thestar.com.my/news/nation/2023/06/12/doctors-question-ministrys-oversupply-projection

Tran, N. (2018). *Robotic surgery*. Robotic Surgery. https://roboticsurgery.yolasite.com/

Turner, D. P. (2020). Sampling Methods in Research Design. *Headache: The Journal of Head and Face Pain*, *60*(1), 8–12. https://doi.org/10.1111/head.13707

University, A. (2022, February 10). *Robotics in Healthcare: Past, Present, and Future*. AdventHealth University. https://www.ahu.edu/blog/robotics-in-healthcare#:~:text=Since%20their%20humble%20beginnings%20in,more%20precise%20and%20efficient%20care.

Villegas, F. (2023, March 20). *Study population: Characteristics & Sampling Techniques*. QuestionPro. https://www.questionpro.com/blog/study-population/#:~:text=The%20study%20population%20is%20the,surveys%2C%20thereby%20increasing%20response%20rates.

Walsh, F. (2018, September 3). *New Versius Robot Surgery System Coming to NHS*. BBC News. https://www.bbc.com/news/health-45370642

Wang, Y., Cao, D., Chen, S.-L., Li, Y.-M., Zheng, Y.-W., & Ohkohchi, N. (2021). Current trends in three-dimensional visualization and real-time navigation as well as robot-assisted technologies in hepatobiliary surgery. World Journal of Gastrointestinal Surgery, 13(9), 904–922. https://doi.org/10.4240/wjgs.v13.i9.904

Wee, I. J. Y., Kuo, L., & Ngu, J. C. (2020). A systematic review of the true benefit of robotic surgery: Ergonomics. *The International Journal of Medical Robotics and Computer Assisted Surgery*, *16*(4). https://doi.org/10.1002/rcs.2113

Witthaus, M. W., Farooq, S., Melnyk, R., Campbell, T., Saba, P., Mathews, E., Ezzat, B., Ertefaie, A., Frye, T. P., Wu, G., Rashid, H., Joseph, J. V., & Ghazi, A. (2020). Incorporation and validation of clinically relevant performance metrics of simulation (CRPMS) into a novel full-immersion simulation platform for nerve-sparing robot-assisted radical prostatectomy (NS-RARP) utilizing three-dimensional printing and hydroge. *BJU International*, *125*(2), 322–332. https://doi.org/10.1111/bju.14940

Yarbrough, A. K., & Smith, T. B. (2007). Technology Acceptance among Physicians. *Medical Care Research and Review*, *64*(6), 650–672. https://doi.org/10.1177/1077558707305942