Jezon Ow / Int.Artif.Intell.&Mach.Learn. 2(1) (2022) 75-117
https://doi.org/10.51483/IJAIML.2.1.2022.75-117 ISSN: 2789-2557

SvedbergOpen
DISSEMINATION OF KNOWLEDGE

International Journal of Artificial Intelligence and Machine Learning

Publisher's Home Page: https: / / www.svedbergopen.com /

Research Paper Open Access

How the Utilization of Integrated Industry 4.0 Technologies will Radically Address Medical Data Integrity Concerns in Singapore

Ow Jezon[1*]

[1]International School of Management, 148, rue de Grenelle, Paris, 75007 France. E-mail: jezonow@gmail.com

Article Info

Volume 2, Issue 1, January 2022
Received : 07 November 2021
Accepted : 25 December 2021
Published : 18 January 2022
doi: 10.51483/IJAIML.2.1.2022.75-117

Abstract

Industry 4.0 in the pharmaceutical, medical devices, and healthcare sectors could have a significant impact as they can help maximize productivity by analyzing the data of patients. The application of Industry 4.0 technologies to the pharma, medical, and healthcare sectors may also play an important role in addressing and helping overcome the Covid-19 pandemic, thanks to the latest innovations in the space of biopharma and biotech. This study will explore how the utilization of Blockchain can help to address medical data security concerns to accelerate the utilization of digital health and Telemedicine, which is one of the key concerns cited by both the general public and industry experts, which might impact the adoption of the industrial 4.0 technologies. This research focuses on the Singapore medical industry and on the opinions of Singaporeans and the predictions of industry experts. Using qualitative methodology, this research is exploratory in nature, given the early-stage developments in the implementation of integrated 4.0 technologies in the digital health space. In addition, this study aims to assess the future potential benefits of integrating these advanced technologies into the medical and biopharma industries for the healthcare system of Singapore and its citizens. Finally, this study will seek to contribute to the existing literature in the fields of digital health, Blockchain-based health devices, Internet of Medical Things (IoMT), and Telemedicine, and to the integrated use of these technologies to create new value innovation opportunities and business models in the rapidly expanding digital health space of Singapore.

Keywords: *Digital health, IoMT, Internet of medical things, Singapore, Telemedicine, innovation 4.0 technologies, Blockchain, Sharing of medical data with employers, Medical data integrity.*

1. Introduction

1.1. Medical Data Breach

Three significant medical data breach cases occurred in Singapore, undermining the country's reputation as a technology innovator. The first incident occurred in 2018 when a cyberattack on Singapore's public health system exposed 1.5

* *Corresponding author: Ow Jezon, International School of Management, 148, rue de Grenelle Paris, 75007 France. E-mail: jezonow@gmail.com*

million patients' personal information, including their names, NRIC numbers, addresses, gender, ethnicity, and birth dates. Singapore Prime Minister, Lee Hsien Loong, Emeritus Senior Minister Goh Chok Tong, and several other ministers were among the 1.5 million patients. 160,000 of those had their outpatient dispensed drugs records hacked in the same incident (Kwang, 2018).

The second incident involved the compromise of the medical records of 14,200 HIV-positive patients. In 2016, an American accessed this information from the HIV registry via his Singaporean partner's employment at the ministry. Their names, NRIC numbers, contact information, HIV test results, and related medication information were collected (ChannelNewsAsia, 2019).

The third incident involved the compromise of personal details of 40,000 customer details. The personal details were stolen by hackers and hawked online after a vendor of the private healthcare group suffered a breach. Personal details that were compromised included customer names, NRIC numbers, bank information, employers, medical history, and personal details of the customers' children (Sun, 2021).

1.2. Singapore

According to market research firm Fitch Solutions, Singapore's healthcare sector is predicted to increase to US$29 bn in 2020, a 9% growth over the previous year, and could more than double to US$67 bn by 2029 (Ow, 2021b; and Subhani, 2020). Singapore's healthcare industry is regarded as among the best in the world, as a result of a combination of factors, such as, strong regulatory governance, contributions from medical saving accounts, and a cost-sharing system between the private and public sectors (Ow, 2021b).

Therefore, given these global trends, it is not surprising that the pharmaceutical and biopharmaceutical industries in Singapore produced USD8.1 bn in exports in 2019 and imports close to USD3.19 bn (Subhani, 2020).

Singapore is ranked 1st in the Global Competitiveness Report by the world economic forum, ranking 1st in the healthcare component and 5th in ICT adoption (Schwab, 2019). Singapore currently has more than 50 manufacturing facilities, with eight of the world's ten largest pharmaceutical firms having operations in the country. Abbott, GlaxoSmithKline, Novartis, and Pfizer are among the major players, accounting for more than 40% of Singapore's regional market (Subhani, 2020).

In addition, over 60 multinational medical technology (MedTech) companies leverage Singapore's strong engineering capabilities and high standards of quality assurance to manufacturing high-value products, ranging from life science instruments to contact lenses.

Over the years, we have seen the increase of digital health, Internet of medical things, and Artificial Intelligence in Singapore, boosted by the ICT infrastructure and the Smart Nation Initiatives (Ow, 2021b).

2. Purpose of the Study

As Ow (2021b) discussed and explored how medical industries in Singapore can utilize Artificial Intelligence, Blockchain, Digital health, Internet of Medical Things (IoMT), and Telemedicine as part of the future of the digital health evolution.

This study explores how the utilization of Blockchain can address medical data security concerns to accelerate the utilization of digital health and Telemedicine, which is one of the key concerns cited by both the general public and industry experts, which might impact the adoption of industrial 4.0 technologies.

Secondly, this research aims to provide practical examples of how these technologies are currently being implemented in Singapore and recommendations to facilitate the adoption of IoMT, Blockchain, digital health, and sharing of medical information with the employers. Thirdly, this research aims to gather feedback on the general public and industry experts' views related to the likely introduction in Singapore of these technologies in order to address the medical data integrity concerns. Lastly, this research aims to gather feedback from the industry experts and the general public on the willingness to subscribe to a platform that houses their data protected by encrypted codes that can only be accessed with the patients' explicit consent.

3. Significance of the Study

This research is sited in Singapore; it can be said to be highly representative of the global industry and serves as an optimal singular location to determine the impact of 4.0 without any geopolitical or cultural confounding influences.

Through an in-depth literature review on Industry 4.0, Pharma 4.0, and related topics, the author was able to identify a dearth of comprehensive scholarly publications on the industry's readiness to embrace 4.0 technologies and on the future of healthcare in Singapore.

Several conditions such as, medical data breach, the increased usage of digital health due to Covid-19, and the increase of Internet of Medical Things (IoMT) also provide the researcher the grounds for an innovative outlook of digital health.

In addition, Ow (2021b) had explained in the previous paper, which discussed how the integrated use of industry 4.0 technologies would radically redefine the industry, firms' business model and the doctor-patient relationship where the researcher discussed the present state of the digital health and the utilization of industry 4.0 technologies in healthcare and the future state of digital health evolution. This research act as a continuation of the previous paper, where it seeks to address the concerns on medical data integrity.

This research aims to offer a novel insight into the adoption of the integration of Blockchain, Artificial Intelligence, Telemedicine, digital health, and the IoMT by the Singapore medical industry and the public with a focus on medical data integrity by conducting a comprehensive industry survey and a public survey to gather inputs on as this is one of the key concern raised by both the general public and industry experts in the previous paper.

This research also aims to bridge the gap in the literature regarding the integration of Blockchain, Artificial intelligence, Telemedicine, digital health, and the IoMT in real-life applications in the medical industry and to explore the general public's opinion regarding the implementation of these technologies with regards to medical data integrity.

This research also aims to gather feedback from both the industries and the general public and discuss the common utilization of medical data for digital health, the likelihood to share the information with their employers, and the willingness to subscribe a platform that houses their data protected by encrypted codes that can only be accessed with the patients' explicit consent. The key research questions aligned to the study's goals are located in the first section of the research methodology chapter.

The exploratory research methodology applied in this study is supported by secondary data gathered from websites' materials, press articles, and scientific and academic journals, with primary data gathered from an online survey.

Yin (2018) indicated that using a single case study can be beneficial for exploring and gaining insight into novel, creative, and more complex issues in the real world by analyzing a small number of events or conditions through pattern matching rather than theory testing.

As such, a focus on a particular exploratory study was undertaken to provide in-depth qualitative insights (in real-world contexts) on the the research subject (the examined phenomena) and on its relevant research questions while taking into account environmental characteristics, resource constraints, and the country's economic and cultural characteristics.

4. Literature Review

In the current chapter, the researcher will first provide the theoretical background of industry 4.0 and explore the application and efficacy of the technologies in the healthcare industries, especially during this pandemic situation and for future applications. The researcher would also explore what the participants provided as their inputs when it comes to the initial challenges for the adoption of industry 4.0 technologies in Singapore.

5. Industry 4.0

The term "Industry 4.0" is often used to refer to the fourth industrial revolution, which comprises advanced manufacturing and information technologies that allow humans to meet personalized requirements in a shorter amount of time (Javaid *et al*., 2020; Javaid and Haleem, 2019b; and Oztemel and Gursev, 2018).

5.1. Impact on Business

Schwab (2016) added that the Fourth Industrial Revolution has four major impacts on business: consumer expectations, product enhancement, collaborative innovation, and organizational structures. The rise of global platforms and other new business models requires a rethinking of people, culture, and organization structures.

5.2. Impact on Government

Schwab (2016) commented that the Fourth Industrial Revolution's quick rate of change and vast implications, lawmakers and regulators face unprecedented challenges and, for the most part, are proven incapable of coping.

Therefore, by adopting an "agile" governance approach, similar to how the private sector has increasingly embraced agile approaches to software development and company operations in general, it requires regulators to constantly adapt a changing environment and reinvent themselves in order to really comprehend what they are regulating. Governments and regulatory bodies will need to work closely with industry and civil society to accomplish this.

5.3. Impact on People

Schwab (2016) commented that the Fourth Industrial Revolution would alter what we do and who we are. It would have an impact on our identity and all of the issues that go along with it: our sense of privacy, our concepts of ownership, our consumption patterns, the amount of time we devote to work and leisure, and how we develop our careers, cultivate our skills, meet new people, and nurture relationships.

Schwab (2016) added that "privacy" is one of the most significant individual issues that modern information technology faces. Although, we intuitively understand why it is critical, tracking and exchanging information about us is a critical component of the new connection. Debates over basic problems, such as, the impact of the loss of control over our data on our inner life will only grow in the coming years.

Similarly, the biotechnology and artificial intelligence revolutions that are redefining what it means to be human by pushing back the existing limits of life duration, health, intellect, and capability will drive us to reconsider our moral and ethical bounds (Schwab, 2016).

The researcher has discussed the definition of industry 4.0, the four important principles to keep in mind when thinking about how technologies can create impact, and industry 4.0's impacts on business, government, and people. Next, the researcher will explore how industry 4.0 technologies and their application and efficacy are likely to impact the healthcare industry, especially during the Covid-19 pandemic era.

6. Internet of Medical Things (IoMT)

Chamola *et al*. (2020) characterized IoMT, also known as the healthcare IoT, as an amalgamation of medical devices and software applications providing comprehensive healthcare services connected to the healthcare IT systems.

Chamola *et al*. (2020) commented that the increase in the number of potential applications is due to the fact that a growing number of mobile devices are now fitted with Near Field Communication (NFC) readers, which enable them to communicate with IT systems. IoMT applications encompass monitoring patients remotely, tracking prescription orders, and transmitting health information to appropriate healthcare professionals through wearables. The healthcare and the pharmaceutical sector have recognized the transformative potential of IoMT technologies due to their ability to efficiently capture, interpret, and distribute health data (Hassija *et al*., 2019; and Rodrigues *et al*., 2018).

Wearables are gadgets that enhance connectivity by being worn on the body and linked to an internet source. Wearables, which can track people's physical health and stress levels, are an excellent technology for use in the healthcare field, since these devices, which can be connected to the IoMT, can assist in the collection of critical data (Al-Turjman *et al*., 2020; Chamola *et al*., 2020; and Ray *et al*., 2020).

This is seen in how recently the use of mobile applications and smart platforms have emerged as a prominent technique in fighting the pandemic and to support a better understanding of drugs and medical devices' efficiency. Numerous governments and private organizations worldwide have already built certain applications and platforms for Covid-19 impact management.

7. Telemedicine

Telemedicine, alternatively referred to as telehealth, enables physicians to assess, diagnose, and treat patients without requiring physical interaction. Chamola *et al*. (2020) stated that the advantages of adopting telehealth systems have been twofold; it has alleviated the pressure on the overworked hospital staff, and it has decreased the risk of transmitting the virus from infectious individuals to the healthcare personnel. The medical professional can utilize Telemedicine for Teleconsultation, Teleexpertise, Telemonitoring, and Teleassistance.

Teleconsultation enables the medical practitioner to remotely consult the patient, which is advantageous during pandemic circumstances and when they could be located in a distanced location or a rural area (Bokolo, 2020; and Pezzuto, 2019). Teleexpertise enables medical professionals to collaborate with one another regularly, pool their medical knowledge, and build their mutual competence (Qazi *et al*., 2019). A medical professional can also utilize Telemonitoring to monitor and supervise a patient remotely. Lastly, a medical practitioner can use Teleassistance to support another medical professional remotely during an intervention.

However, despite all these benefits, the true potential of Telemedicine can only be achieved when current telemedicine platforms are combined with other innovations such as Blockchain, smart wearables, and 5G cellular networks.

8. Artificial Intelligence (AI)

Since its inception, AI.has established itself as a game-changing technological advancement. Firstly, AI is utilized for disease surveillance where timely detection and forecast of diseases, especially those with the potential to destabilize the world, is crucial (Chamola *et al*., 2020; and Tayarani, 2020).

Next, Chamola *et al.* (2020) stated that AI is utilized for Risk prediction, and it can be divided into three main categories: predicting the risk of infection, predicting the risk of experiencing serious symptoms once infected, and predicting the risk of treating an infected person with a specific line of treatment. Medical diagnosis and screening are also supported by AI with the use of technologies, such as, face scanners, medical imaging, voice recognition systems, and AI-powered medical diagnosis systems.

Additionally, AI can also be utilized for Curative research, such as, using Machine Learning for drug development and identifying existing drugs or components repurposed. Other areas AI can be used are Virus modeling and analysis.

9. Digital Health

Digital health is described as "the cultural change that occurs as a result of disruptive technologies that make digital and objective data available to both caregivers and patients, resulting in an equitable doctor-patient relationship with shared decision-making and care democratization" (Mesko, 2017).

It encompasses digital therapeutics, wearables, mobile applications, big data, clinical trials utilizing digital tools, Health Information Management Systems (HIMS), electronic medical records, VR and AR, Machine Learning (ML). The consolidation of these technologies with existing digital platforms can enable a more dynamic healthcare ecosystem where the pharmaceutical and medical device companies can collaborate during clinical trial research and provide better medical coverage.

10. Blockchain

Blockchain technology allows individuals and organizations worldwide to become a part of a single interconnected network that allows for the data to be shared securely. The Blockchain's tamper-resistant nature makes it impervious to unauthorized changes, and the utilization of consensus algorithms and smart contracts reduces the possibility of disseminating fake data and fraudulent details (Chen *et al*., 2018; Farouk *et al*., 2020; Hölbl *et al*., 2018; and Tanwar *et al*., 2020).

Apart from securely storing test reports, blockchain-based distributed systems can also serve as a viable option for documenting Covid-19 patient information. Its inherent properties of being timeless and tamper-proof can instill a sense of protection in the patient. With current data on Covid-19 patients, this platform will aid in the analysis of the disease's clinical characteristics and assist all health centers in better understanding the disease's growth pattern (Chamola *et al*., 2020; and Marbouh *et al*., 2020).

Additionally, blockchain technology can be used to control the supply chain and to avoid counterfeit medication and pillage. As an avenue of integration of IoMT devices, blockchain implementation may provide useful governance applications by allowing traceability, documenting ownership, and incentivizing smart contracts that might prevent falsified information and unauthenticated products. Supply chain management systems can also utilize blockchain technology to control hospitals' inventories and regulate the buy-sell process for all hard-medical assets (Agbo *et al*., 2019; Ahmadi *et al*.,2020; and Alblooshi *et al*., 2018).

11. Key Observations from the Previous Paper

Ow (2021b) cited that the majority of the responders from both groups of the participant being surveyed felt that the existing technologies were not able to achieve the full potential of digital health, telemedicine, and remote monitoring, citing several reasons, such as (a) lack of public knowledge and technology advocacy; (b) lack of medical data security, which resulted in data leaks and breaches; and (c) Singapore is in the initial stages of development and implementation.

The majority of the responders from both groups felt that the existing IoMT could not address all the needs of digital health patients, citing reasons, such as (a) lack of advanced and comprehensive monitoring; (b) data security, and public education on IoMT and how it would benefit the public (Ow, 2021b).

Ow (2021b) discussed one of the use cases where Personalized Health Records can be utilized for digital health, and innovative 4.0 technology can aid the patients in terms of personalized medication and detailed patient history.

In 2019, the Korean government launched the voluntary program "MyData," which provides users with improved to access their data stored on portable electronic devices, such as, smartphones (Choi *et al.*, 2020; Ow, 2021b). This program represents a paradigm shift in the storage and management of personal data, propelling the existing institution-centric approach toward a person-centric system, which has already been implemented in various countries' medical fields.

The MyData software has been implemented in a variety of sectors, including the insurance sector, and allows individuals to more actively and efficiently monitor their own health data. This PHR application was created to enable patients to own their medical records, not hospitals, and to empower patients to share that information with healthcare providers when necessary (Ow, 2021b).

Based on the literature review, there is little research done on how these various technologies can be used together. Most of the literature was just focused on the implementation of one or two technologies. Only one study by Chamola *et al.* (2020) managed to cover numerous technologies mentioned such as IoMT, AI, Digital Health, Telemedicine, Blockchain.

This was the initial literature that kick-started our research topic as it provides some examples of how these technologies are implemented in different countries and how they might change the future of digital health. The other gap in the literature is the lack of research on public and industry responses regarding the utilization of medical data for digital health, the likelihood to share the information with their employers, and the willingness to subscribe to a platform that houses their data protected by encrypted codes that can only be accessed with the patients' explicit consent in Singapore.

12. Summary of Chapter

In the current chapter, the researcher discussed the literature review about the theoretical background of industry 4.0 and the application of selected industry 4.0 technologies. First, the researcher presented the theoretical background of industry 4.0. Next, the researcher presented the different literature reviews regarding each of the chosen industry 4.0 technologies. Next, the researcher presented some of the inputs from both groups of participants on the utilization of digital health data and the current barriers to the adoption of the IoMT and existing technologies. Lastly, the researcher identified the gaps in the literature.

In the following chapter, the researcher will discuss the key research questions and a comprehensive description of the research methodology.

13. Research Methodology

Qualitative research is often used where little, or no evidence about a phenomenon exists, while quantitative research is used to determine the cause-and-effect relationship between variables in order to validate or refute a theory or hypothesis (Creswall, 2002; Feilzer, 2009; and Teddlie and Tashakkori, 2012). In quantitative research, the researcher utilizes a semi-structured questionnaire that allows the study to have both the numerical data and the participants' subjective thoughts behind the question.

Therefore, this study will adopt an exploratory qualitative approach, utilizing survey data from both the public and the selected industry participants. The researcher will then subsequently consolidate the responses and analyze the data to address the research questions.

The research methodology utilized for this research is based on an exploratory (qualitative) study, with the objective of providing answers to the following research questions that are aligned with the research goals. The research questions are separated into two different buckets to cater the different audiences of the research.

14. Key Research Questions

14.1. General Public

1) What are the general public's perspectives on the utilization of digital health services?
2) What are the general public's perspectives on their willingness to subscribe to a platform that houses their data protected by encrypted codes that can only be accessed with the patients' explicit consent?

3) What are the general public's perspective on the public utilization of medical data stored on the digital platforms?
4) What are the general public's perspectives on the likelihood of sharing medical records with the employers via digital health, MedTech, and IoMT?
5) Can the integration of IoMT and digital health with blockchain technologies help address public concerns about personal medical data integrity issues?

14.2. Industry Experts

1) What are the industry expert's views on their willingness to subscribe to a platform that houses their data protected by encrypted codes that can only be accessed with the patients' explicit consent?
2) What are the industry expert's views on the public utilization of medical data stored on the digital platforms?
3) What are the industry expert's perspectives on the likelihood of sharing medical records with the employers via digital health, MedTech, and IoMT?
4) Can the integration of IoMT and digital health with blockchain technologies help address public concerns about personal medical data integrity issues?

15. Data Management

This section discusses the sampling technique used to determine the number of respondents required to gather more information about the phenomenon. The data is subsequently analyzed.

15.1. Sampling Method

15.1.1. General Public.

Collis and Hussey (2009) explained that there are numerous kinds of sampling methods that can be utilized for deriving a specifically targeted sample from a population. This current study utilizes simple random sampling to source for respondents to answer the survey. Simple random sampling is regarded as the most fundamental form of probability sampling. Under the method, participants are drawn at random from the population, with all elements having an equal probability of selection.

15.1.2. Industry Experts

Expert sampling is also beneficial where there is a lack of empirical evidence in an area and high degrees of uncertainty and situations where it may take a long time before the research findings can be uncovered. Therefore, this current study will also use expert contributions to acquire industry experts' responses on forward-looking scenarios.

15.2. Questionnaire Survey

Given the research's explorative nature, a semi-structured online questionnaire has been developed for this study on Survey Monkey, an online survey provider website.

The collected data was then analyzed through Survey Monkey Statistical shareware for descriptive analysis. The demographic section of the survey has been analyzed using descriptive statistics. The researcher performed the following steps: (1) a check of the questionnaires' responses completion; (2) a check of the dataset; (3) a cleaning of the data set; (4) a review the data; (5) an organization of the data; and (6) a completion of the data analysis.

15.3. Preparing and Organizing the Data

The researcher prepared and organized the data before analysis by separating the data collected from the industry experts survey completed by the general public. Next, the researcher further separated the surveys where the participants filled in both the closed-ended and open-ended questions from those surveys, where the participants only filled in the closed-ended questions and partially completed the open-ended questions. The researcher used a classification code like IE to denote the data were collected from industry experts and PS to denote public survey data.

15.4. Conducting Data Analysis

For the analysis of the generated data derived from the survey's closed-ended questions, categorical data will be used. Even though the data values are not able to be quantified numerically, they can be classified into categories. The

researcher can organize the data into more than two sets, which can be ranked. Saunders *et al.* (2019) added that descriptive data could count the number of instances within each category of a variable in order to determine which category has the most cases and how the cases are distributed.

The researcher would utilize survey monkey and excel software to analyze the data, visualize the research findings in the form of diagrams and tables to identify interdependences, and compare proportions, patterns, and conjunctions. The analysis process will focus on the data distribution, specific values, and highest or lowest values as recommended by Saunders *et al.* (2019).

To analyze the data derived from the survey's open-ended questions, the researcher first extracted the data into excel files. The researcher then interpreted the textual responses to open-ended questions by working through question-by-question to identify the key themes that recur across different respondents; then the researcher read the responses to a specific question, looking for any themes that recur in their responses to each question.

Rowley (2014) emphasized that this facilitates the collation of disparate feedback from different respondents but on the same subject, which serves as a foundation for highlighting the frequency of occurrence of themes, any differences in what people say about themes, and identifying some interesting quotes for inclusion in the results write-up.

15.5. Summary of Chapter

In the next chapter, the researcher had discussed the key research questions and a detailed explanation of the research methods and design, which includes the targeted sampling size, the method of data collection, the timeline, and the method of data analysis.

15.6. Presentation of Results

This chapter also explained the main sections of this chapter, which comprised of (a) a description of the sample (participants); (b) the research methodology implemented to the data analysis; (c) data results and analysis from the general public survey; and (d) data results and analysis from the industry experts survey.

16. Demographics of the Survey Participants

16.1. General Public

For the purpose of data collection, the researcher reached out to close to 1,100 participants. 711 of the participants accepted the invitation to participate, but only 623 of the participants completed the survey. The researcher has achieved 56.6% in terms of response rate for the survey. Figure 1 represents the participant demographics.

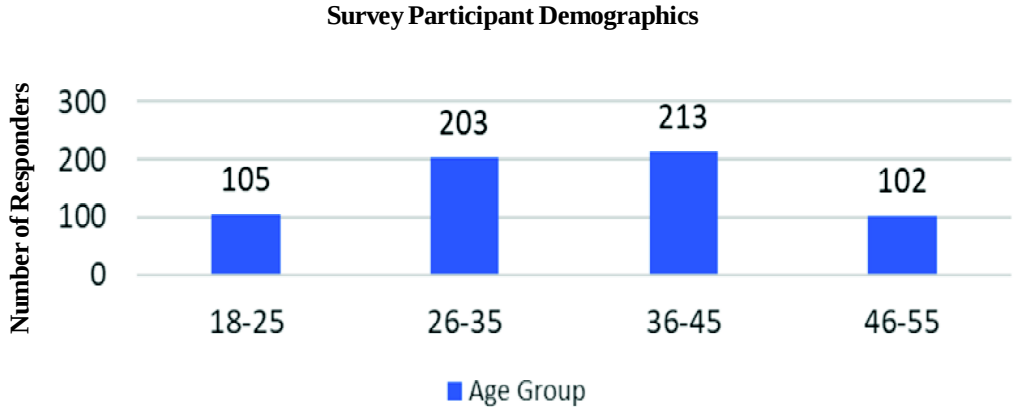

Figure 1: Public Survey Participants Demographics

Source: Online Survey on the Future of Healthcare in Singapore (General Public) (Ow Jezon)

The majority of the participants are from the 26-35 and 36-45 age groups and are working professionals or executives. Most of the drop-out rate came from the 18-25 age group, who skipped several survey questions. The drop-out may be due to a lack of in-depth understanding of the topic.

16.2. Industry Experts

For the purpose of data collection, the researcher has reached out close to 150 participants, who were selected based on their professional expertise, related industry knowledge, and their profile's good fit with the research questions' topics. Close to 50 participants accepted the invitation to participate in the survey, but they requested that their identity be kept "anonymously" as this is still an exploratory study, and 33 of the participants completed the survey. Therefore, circa 33% of the contacted experts agreed to participate in the survey, and that circa 22% completed the survey.

Table 1 presents a summary of the sample demographics.

Table 1: Participants of the Industry Experts Survey

Participant	Role
Participant 1	Executive in an insurance institution
Participant 2	Executive in a Medical Device company
Participant 3	Executive in a healthcare institution
Participant 4	Executive in an insurance institution
Participant 5	Executive in a digital health company
Participant 6	Executive in an insurance institution
Participant 7	Executive in a technological consultancy firm
Participant 8	Medical Doctor
Participant 9	Executive in a technological consultancy firm
Participant 10	Executive in a Pharmaceutical company
Participant 11	Executive in a Medical Device company
Participant 12	Executive in a healthcare institution
Participant 13	Executive in a Medical Device company
Participant 14	Executive in a healthcare institution
Participant 15	Executive in a digital health company
Participant 16	Executive in a Pharmaceutical company
Participant 17	Executive in a digital health company
Participant 18	Executive in a Medical Device company
Participant 19	Medical Doctor
Participant 20	Executive in a healthcare institution
Participant 21	Medical Doctor
Participant 22	Executive in an insurance institution
Participant 23	Executive in a healthcare institution
Participant 24	Executive in a Medical Device company
Participant 25	Executive in a Pharmaceutical company
Participant 26	Medical Doctor
Participant 27	Executive in a Pharmaceutical company
Participant 28	Executive in a digital health company

Table 1 (Cont.)

Participant	Role
Participant 29	Executive in a technological consultancy firm
Participant 30	Executive in a Medical Device company
Participant 31	Executive in a Pharmaceutical company
Participant 32	Executive in a technological consultancy firm
Participant 33	Executive in a Medical Device company

17. Research Methodology Applied to the Data Analysis

As mentioned in the previous chapter, the researcher utilized Survey Monkey and Microsoft Excel software to analyze the data, visualize the research findings in the form of figures and tables to determine interdependences and compare proportions, trends, and conjunctions. The analysis process also centered on the data distribution, specific values, and highest or lowest values as recommended by Saunders *et al.* (2019).

Data analysis was broken into two phases due to some differences in the questionnaires and the level of depth of knowledge. The researcher first extracted the data from both sets of surveys from SurveyMonkey and further split the findings between closed-ended and open-ended questions. The researcher then interpreted the textual responses to open-ended questions by working through each question to identify the key themes that recur across the different respondents' responses.

18. Presentation of Data and Results of the Analysis

18.1. Phase 1 – Public Survey

Q1. The researcher wanted to understand better what are the digital health services that the general public have utilized or would utilize when given the opportunity (Figure 2).

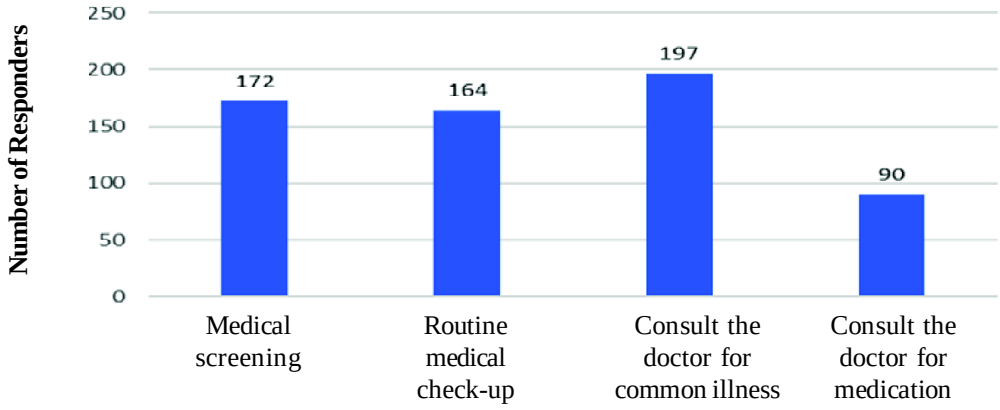

Figure 2: Public Opinion on the Utilization of Digital Health Services

Source: Online Survey on the Future of Healthcare in Singapore (General Public) (Ow Jezon)

To better understand how the public would utilize digital health, the researcher indicated some standard services that most digital health platforms would provide for the participants to select.

32% of the participants indicated that they would utilize or have utilized digital health to consult the doctor for common illnesses. 60% of these participants cited the reason why they utilized it to consult the doctor for common

illnesses is to minimize contact with others during the circuit breaker period (Lockdown period) and the phase 1 and phase 2 periods of the social distancing phases. 40% of these participants cited convenience and short waiting time as reasons why they would utilize digital health to consult the doctor for common illnesses.

28% of the participants indicated that they would utilize or have utilized digital health for a routine medical checkup. 70% of these participants cited convenience, short waiting time, and minimizing social contact as the main reasons, while the remaining 30% of these participants noted they have utilized digital health for Covid-19 testing and obtaining the test results.

26% of the participants indicated that they would utilize or have utilized digital health for medical screening. 75% of these participants cited convenience, short waiting time, and minimizing social contact as the main reasons. The remaining 35% of these participants cited that they have utilized digital health for follow-up consultation or for obtaining their health screening results, and they felt that face-to-face consultation is unnecessary.

The remaining 14% of the participants indicated that they would utilize or have utilized digital health to consult the doctor for medication. 60% of these participants commented that it would be more convenient for them to replenish their routine medications as they did not need to queue to consult the doctor, who would spend less than five minutes on routine questions before prescribing them the same medications.

20% of these participants commented that these services could be extended to the pharmacy, so that they could purchase certain controlled drugs more conveniently. The remaining 20% of these participants commented that it would reduce the travel time to see a doctor just to get some medication for an illness, and it would also cut down on the risk of spreading germs to other people along the way.

Q2. The researcher wanted to gauge how receptive the public is to have a digital platform that houses their medical records, which are protected by encrypted codes and can only be accessed with the patients' explicit consent (Figure 3).

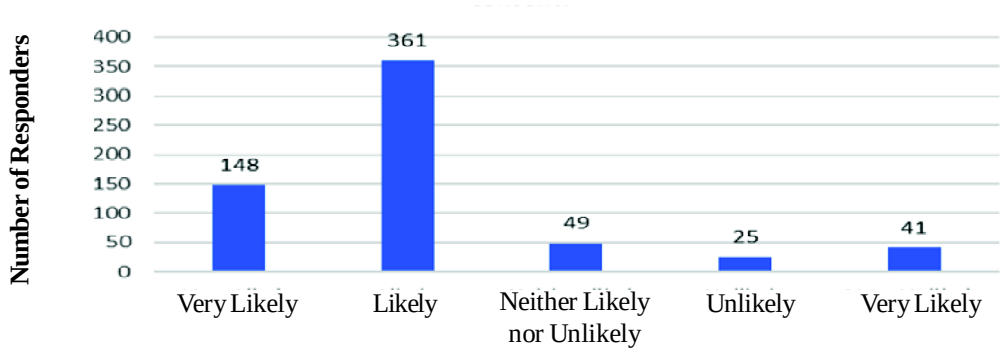

Figure 3: Public Opinion on the Subscription of a Platform that Houses Medical Records with Encrypted Codes

Source: Online Survey on the Future of Healthcare in Singapore (General Public) (Ow Jezon)

The encryption process relates to the Blockchain and digital health integration aspects. Currently, in Singapore, SingPass is a government platform that allows any Singapore citizen to access various information. However, the medical information on this platform only comprises of medical visits to public medical institutions (such as government hospitals and polyclinics).

82% of the participants (58% selected "Likely" and 24% selected "Very likely") are very receptive to having a digital platform. 50% of these participants cited a centralized information database with secure security like SingPass as the main reason why they are willing to subscribe to the digital platform. The remaining 50% of these participants cited reasons like the ease of retrieval of information, ease of sharing data across different healthcare organizations, and the reduced number of hard copies of medical information that might be misplaced, lost or tampered with. They also commented that it also allowed for quicker access to information, especially during an emergency, as a medical professional can access your medical history, such as, drug allergies and other critical details swiftly.

The remaining 18% of the participants (8% selected "neither likely nor unlikely," 4% selected "unlikely," 7% selected "very unlikely") cited data privacy, fear of data breach, and that they were not comfortable letting any organization, even the government, to have extensive access to their personal medical information. They were worried that the data might be utilized for commercial purposes.

Q3. To better understand how the public would utilize the medical data stored on the digital platforms, the researcher indicated some of the common utilization of medical data for the participants to select (Figure 4).

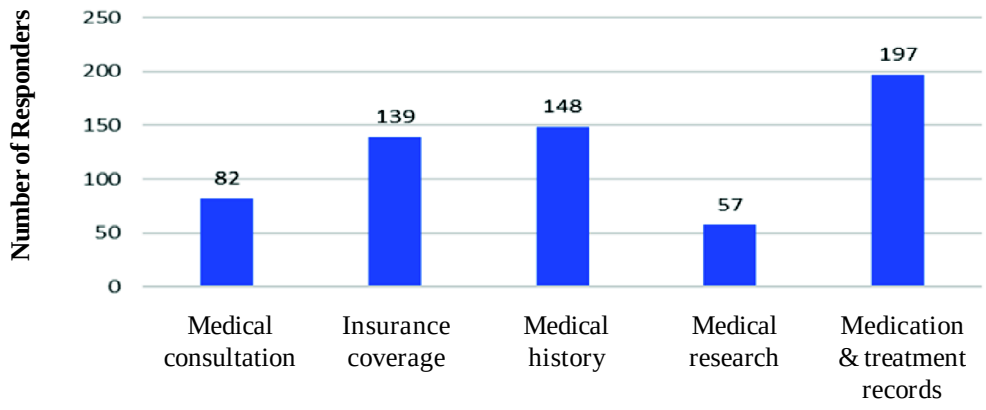

Figure 4: Public Opinion on the Utilization of Medical Data Stored on Digital Platforms

Source: Online Survey on the Future of Healthcare in Singapore (General Public) (Ow Jezon)

32% of the participants selected "medication and treatment records" as the main reason why the relevant stakeholders and the participants would utilize the medical data stored on the digital platforms. 50% of these participants indicated that the centralized information would allow the healthcare professional to know what was the previous medication and treatment prescribed so as to enable the professional to provide better patient care. 50% of these participants indicated that it allowed for quicker medical reviews and therapy planning for the patients and a faster reaction time for emergency cases, such as, drug allergies due to medication and severe adverse reactions.

24% of the participants selected "medical history" as the main reason why the relevant stakeholders and the participants would utilize the medical data stored on the digital platforms. 40% of these participants indicated this should be the primary utilization of medical data as the recording of key and critical medical data is crucial before it can be expanded to other areas of utilization. 60% of these participants indicated that it allowed them to pull out important information that was often forgotten, such as when was the last time they took a vaccination, their health screening results, and the health red flags they needed to focus on.

22% of the participants selected "insurance coverage" as the main reason why the relevant stakeholders and the participants would utilize the medical data stored on the digital platforms. 50% of these participants indicated that it allowed the insurance company to determine the customer's coverage risk and whether to include or exclude certain coverages or exclude the customer entirely for coverage. 50% of these participants indicated that it simplified medical claims and hospitalization and operation claims.

13% of the participants selected "medical consultation" as the main reason why the relevant stakeholders and the participants would utilize the medical data stored on the digital platforms. 60% of these participants commented that it would speed up the process of accessing their medical records when they are consulting medical professionals. 40% of these participants commented that this allowed doctors to do telehealth and telemedicine consultations virtually.

The remaining 9% of the participants selected "medical research" as the main reason why the relevant stakeholders and the participants would utilize the medical data stored on the digital platforms. 90% of the participants indicated that, despite this, it would be their last choice. However, medical research would also be one of the areas where stakeholders and the participants who gave their informed consent can help the pharmaceutical companies understand each clinical trial's results to ensure the drugs' safety and efficacy. 10% of the participants indicated that it would also be utilized for real-world data or late phase data for clinical trials.

Q4. To better understand the public on how likely they are to share their medical records with employers via digital health, MedTech, and IoMT, the researcher decided to survey the participants with a range between very likely to very unlikely (Figure 5).

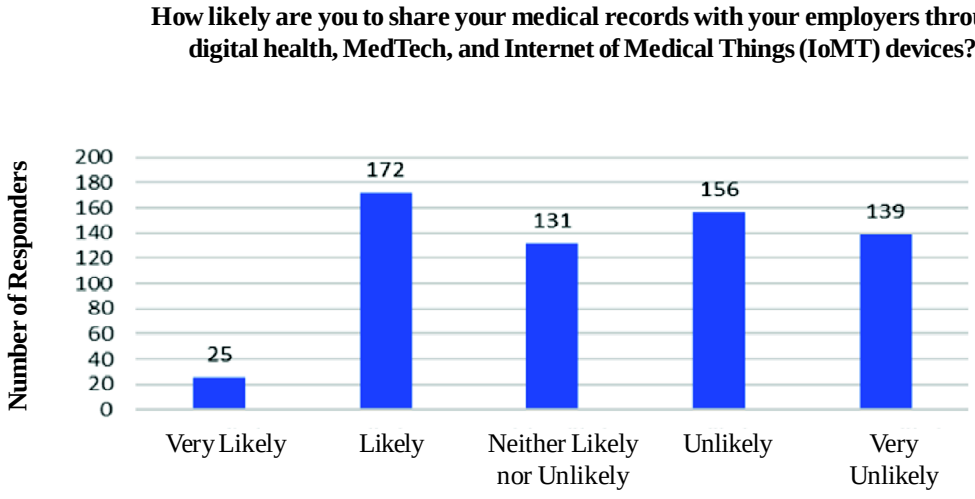

Figure 5: Public Opinion on the Likelihood of Sharing Medical Records with Employees

Source: Online Survey on the Future of Healthcare in Singapore (General Public) (Ow Jezon)

In the context of the likelihood of sharing medical records with employers via digital health, MedTech, and IoMT, 47% of the participants indicated that they are "very unlikely" and unlikely to share their medical records with their employers. 32% of the participants expressed that they are "very likely" and "likely" to share their medical records with their employers, and the remaining 21% of the participants indicated that they are neutral by selecting "Neither likely nor unlikely."

50% of the participants who indicated that they are "very likely" and "likely" to share their medical records with their employers are explained that they would provide those details if they were part of the onboarding and initial employment body assessment. The remaining 50% of these participants cited the ease of retrieval of the medical certificate, allowing the company to know if the employees have any health conditions, so that they can be able to help the employees if anything crops up. It also allow them to gather medical certificates about the health of the multiple employees in order to negotiate better insurance coverage.

30% of the participants who indicated that they are "very unlikely" and unlikely to share their medical records, cited that medical data is personal information which they are not willing to share as there is no legislation or regulations to regulate it, and the lack of trust that information can be handled discreetly and appropriately. 60% of these participants cited personal privacy, possible abuse, or discrimination in the workplace if employers get access to this information, and the fact that their current organization might not have the right systems or processes to handle such information securely and data security.

10% of these participants cited that medical data should be strictly handled by healthcare institutions, and they felt that unless it is for company insurance claims or suspected abuse of medical leaves, employers should not have access to any medical information.

50% of 21% of the participants who indicated that they are neutral about sharing their medical records said they are okay with sharing this if it is for medical certification during their term of employment. 30% of these participants felt that the company might not have the necessary tools to safeguard the data, and the remaining 20% of these participants commented that medical records should only be shared on a need-to-know basis and if medical conditions affect the current role the person is employed for.

Q5. To answer the research question of whether the integration of IoMT and digital health with blockchain technologies can help address public concerns about personal medical data integrity issues, the researcher surveyed the participants with two questions: how concerned they are about their personal medical data privacy and in their opinion, whether the

integration of IoMT and digital health with blockchain technologies could help to address public concerns about personal medical data integrity issues (Figure 6).

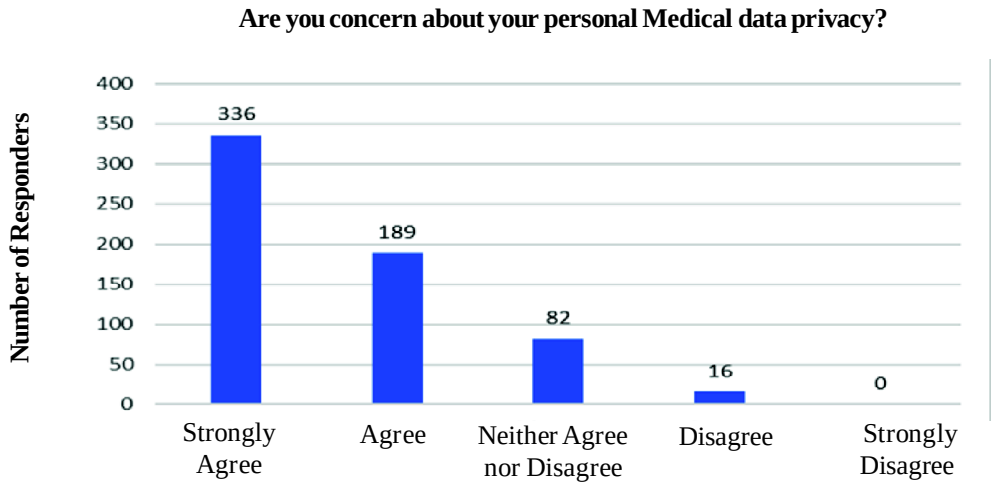

Figure 6: Public Opinions on Personal Medical Data Privacy

Source: Online Survey on the Future of Healthcare in Singapore (General Public) (Ow Jezon)

Close to 84% of the participants indicated that they either agree or strongly agree, that they are concerned about their medical data privacy which suggests that medical data privacy is one of the main deciding factors for the adoption of any technological implementation or new healthcare practices. 13% of the participants indicated that they neither agree nor disagree. The remaining 3% indicated that they are not so concerned about their medical data privacy.

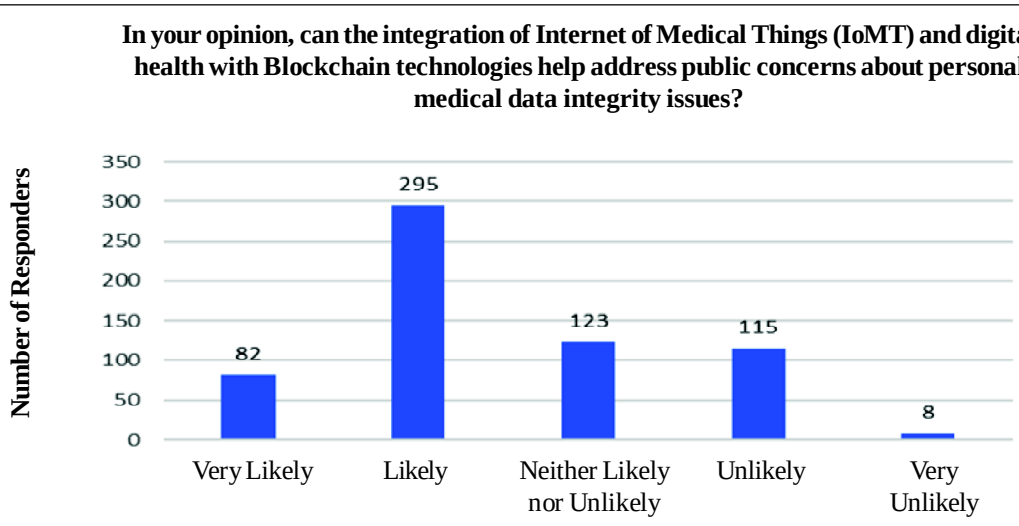

Figure 7: Public Opinions on Integration of IoMT and Digital Health with Blockchain

Source: Online Survey on the Future of Healthcare in Singapore (General Public) (Ow Jezon)

Close to 61% of the participants indicated that integrating IoMT and digital health with blockchain technologies could help to address public concerns about personal medical data integrity issues. 50% of these participants commented that they believed Blockchain is more secure. 30% of these participants commented that Blockchain is tamper-proof and information should be sufficiently encrypted using these technologies to ease people's concerns about data privacy. The remaining 20% commented that if the government were confident enough to roll out this program, it would be secure enough as numerous testing and check and balances would have been done before it was rolled out.

Close to 20% of these participants indicated that they are neutral with regards to the idea that integrating IoMT and digital health with blockchain technologies could help address public concerns about personal medical data integrity issues. 50% of these participants are undecided due to a lack of understanding of blockchain technologies. 50% of these participants commented that while the blockchain and IoMT technologies may be secure, there are still some vulnerabilities against a deliberate data breach or data leak.

The remaining 19% of the participants felt that regardless of the level of integration of these technologies, there are always ways to hack or breach data protection and more data security and regulations should be introduced and legislated. 60% of these participants cited the data breach of the HIV and health databases as a bad experience that shook their confidence in Singapore's medical data integrity. 40% of these participants felt that more public education and social advocacy on Blockchain and IoMT and how they benefit the healthcare industries and patients would increase public confidence in these implementations.

18.2. Phase 2 – Industry Expert Survey

The industry expert participants are representatives from across different healthcare stakeholders, such as, medical doctors, executives from medical device companies, executives from pharmaceutical companies, executives from technological consultancy firms, executives from digital health companies, executives from insurance institutions, and executives from healthcare institutions (Figure 8). They provide their inputs based on their industry expertise.

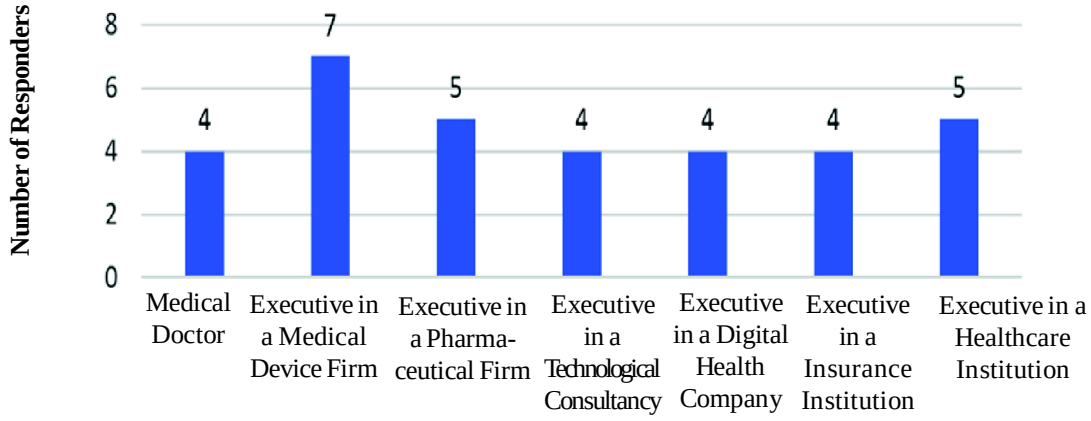

Figure 8: Demographics of the Industry Experts

Source: Online Survey on the Future of Healthcare in Singapore (Industry Expert) (Ow Jezon)

Next, to obtain industry experts' insights on how the public would utilize the innovative 4.0 technologies and willingness to share their medical records. The researcher designed several questions: (1) to understand the willingness to subscribe a platform that houses their data, which is protected by encrypted codes and can only be accessed with the patients' explicit consent; (2) to understand how the public would utilize the medical data stored on the digital platforms; and (3) the likelihood of sharing medical records with employers via digital health, MedTech and IoMT.

Q1. The researcher wanted to gauge how receptive the industry experts are to having a digital platform that houses their medical records protected by encrypted codes and can only be accessed with the patients' explicit consent to compare with the public's survey results (Figure 9).

70% of the participants (33% selected "Likely" and 36% selected "Very likely") were very receptive to having a digital platform that houses their medical records, which are protected by encrypted codes and can only be accessed with the patients' explicit consent. Participant 7, an executive at a technological consultancy firm, commented that SingPass seems to be very widely accepted, especially since it is a government platform. Therefore, for any medical records, SingPass / MyInfo has to be the verifying party in order for people to be confident to utilize it (Ow, 2021).

Participant 13, an executive in a medical device company, commented that the real-time access benefits would far outweigh the lingering worry of a potential data breach if a robust security infrastructure were in place (Ow, 2021).

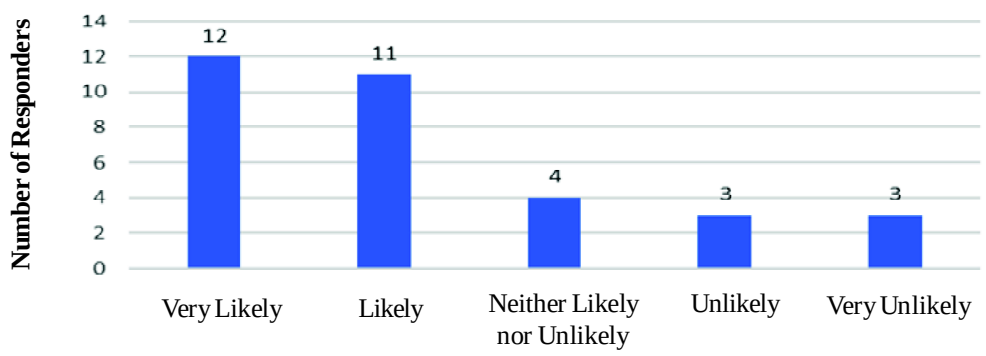

Figure 9: Industry Experts' Opinion on the Subscription of a Platform that Houses Medical Records

Source: Online Survey on the Future of Healthcare in Singapore (Industry Expert) (Ow Jezon)

Participant 3, an executive in a healthcare institution, commented that regulation that prescribes the proper handling of health records still offers the most effective type of data protection. If regulations are in place, the public and stakeholders can use these platforms with ease and convenience (Ow, 2021).

Participant 31, an executive in a pharmaceutical company, commented that SingPass and explicit consent allowed him the option not to trust or grant access to specific vendors, so there is an assurance. He also added that it would make life easier to have these medical records on a protected platform, but only if he had consented to allow the specific healthcare institution or company to access that information (Ow, 2021).

Participant 19, a medical doctor, suggested that if medical records could be stored in one secure portal, it would be very convenient when visiting various doctors for medical appointments. He added that it is convenient for the patient or the medical professional to access all of this information with just a click. It also makes it easier to keep the records and consolidate and send them to whoever needs the patient's medical records when required, such as for insurance applications (Ow, 2021).

18% of the participants (9% selected "unlikely," 9% selected "very unlikely") are not very receptive to having a digital platform to house medical records, which are protected by encrypted codes and can only be accessed with the patients' explicit consent. Participant 18, an executive in a medical device company, commented that it depends on why the data is stored there and how it benefits the user. He added that data protection is very lax in Singapore, and even major private companies and the public sector struggle to ensure data privacy and security with leaks being reported regularly (e.g., SIA, SingTel, HIV register) (Ow, 2021).

The remaining 12% of the participants who selected "neither likely nor unlikely" were neutral and not very receptive to having a digital platform to house medical records protected by encrypted codes and can only be accessed with the patients' explicit consent. Participant 4, an executive in an insurance institution, commented that it is a tug-of-war within. On one side, information accessibility could be crucial in saving one's life as time is of the essence. He added that on the other side, it would also mean that information could be accessible by personnel with malicious or ill intent. Protection by SingPass does not imply a 100% foolproof firewall, as demonstrated by the recent incidents with the Singtel leak or medical record leak of a specific group of patients (Ow, 2021).

Q2. To better understand how the public would utilize the medical data stored on the digital platforms, the researcher indicated some of the common utilization of medical data for the participants to select (Figure 10).

36% of the participants selected "Medication & treatment records" as to how the public would utilize the medical data stored on the digital platforms. Participant 11, an executive in a medical device company, commented that medication and treatment records are valuable for doctors to know how the treatment is done. He added that another important piece of information could be medical history. The participant is firmly against using personal medical history data and personal genetic data for insurance coverage purposes (Ow, 2021).

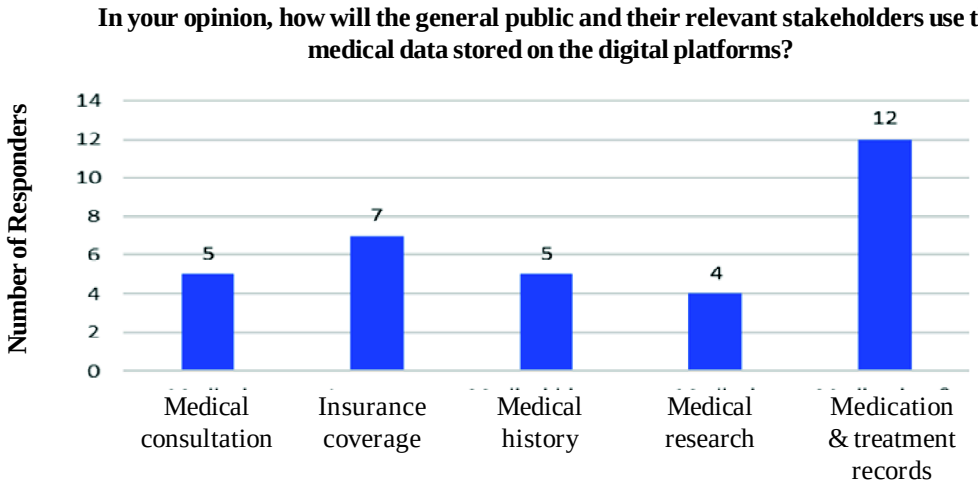

Figure 10: Industry Experts' Opinion on Utilization of Medical Data Stored on Digital Platforms

Source: Online Survey on the Future of Healthcare in Singapore (Industry Expert) (Ow Jezon)

Participant 29, an executive at a technological consultancy firm, commented that medical information could influence public health policies, as proved by the actual challenges policy makers face in driving healthy behavior and lifestyle. He added that the government could also share the statistical information with pharmaceutical and medical device companies to provide them with a holistic view of Singapore's public health domain and challenge these companies to innovate or develop solutions (Ow, 2021).

Participant 19, a medical doctor, commented that a centralized platform to store medical records would allow medical professionals to access the records and provide more precise and efficient treatment and medication with the prior medical data (Ow, 2021).

21% of the participants selected "insurance coverage" as to how the public would utilize the medical data stored on the digital platforms. Participant 4, an executive in an insurance institution, commented that this simplified the claim process as it helped to minimize documentation and unnecessary operation issues (Ow, 2021).

Participant 32, an executive at a technological consultancy firm, commented that dynamic underwriting should be the way to go. The current underwriting methods are too old-school and should be changed to reflect the current technological capabilities (Ow, 2021).

Participant 20, an executive in a healthcare institution, commented that patients would utilize the medical data for insurance coverage to claim hospitalization charges and other medical charges as information, such as, treatment procedures, medication, medical conditions, the period of stay, and class type would be indicated on the documentation (Ow, 2021).

15% of the participants selected "medical consultation" as to how the public would utilize the medical data stored on the digital platforms. Participant 21, a medical doctor, commented that some patients have multiple appointments across different institutions. Therefore, having all their medical records stored in one secure portal will enable physicians in each institution to know what is going on at other institutions and what they have been treated with (Ow, 2021). Participant 33, an executive in a medical device company, concurred with participant 21 that patient care continuance would be critical even if patients choose to switch healthcare providers (Ow, 2021).

Participant 23, an executive in a healthcare institution, commented that the centralized medical data platform would allow medical professionals to know the previous medication that the patients were prescribed. Most patients do not know or remember what medication and the dosage they are taking. For example, it is hard for regular patients to differentiate between paracetamol, aspirin, and ibuprofen even though they are all painkillers, and the dosage strength and form of medication such as 81 mg, 162 mg, 325 mg, and 500 mg (Ow, 2021).

15% of the participants selected "medical history" as to how the public would utilize the medical data stored on the digital platforms. Participant 4, an executive in an insurance institution, commented that medical history is used for

insurance coverage purposes so that the underwriter can know whether to include or exclude particular coverage based on the policyholder's medical history (Ow, 2021).

Participant 15, an executive in a digital health company, commented that medical history would allow the doctor to know the patient's past medication history and drug allergies to treat the patient's conditions better. He added that medical history could also be shared with the employer during the employee's pre-employment medical examination with the patient's consent to ensure that the person they are hiring is physically fit for the role (Ow, 2021).

Participant 8, a medical doctor, commented that centralized access to medical data would allow the doctor to make more informed decisions during their consultation as some patients might not remember their past medical history, especially if they are elderly. It helps the doctor to determine what personalized treatment regimes are (Ow, 2021).

12% of the participants selected "medical research" as to how the public would utilize the medical data stored on the digital platforms. Participant 20, an executive in a healthcare institution, commented that medical data could be used for medical research and clinical trials, such as the effectiveness of drugs, the efficacy of drugs, and the study of a new strain of virus or diseases. However, the healthcare institution needs to obtain consent from the patients before this information can be released to pharmaceutical and medical device companies (Ow, 2021).

Participant 25, an executive in a pharmaceutical company, commented that medical data could be utilized for real-world late phase studies, and data collection through digital technologies can aid in using crowd data for research purposes (e.g., Migraine Buddy app) (Ow, 2021).

Participant 9, an executive at a technological consultancy firm, commented that it was excellent to obtain more medical data for clinical or medical research, it would be beneficial for future generations. He added that it is also beneficial for more public awareness and knowledge sharing of how medical data are utilized for medical research and clinical trials. As there is a certain percentage of the public who still have a stigma about pharmaceutical and medical device companies, these companies might be unethical in the way they handle medical data (Ow, 2021).

Q3. The results are relatively interesting in the context of the likelihood of sharing medical records with employers via digital health, MedTech, and IoMT (Figure 11).

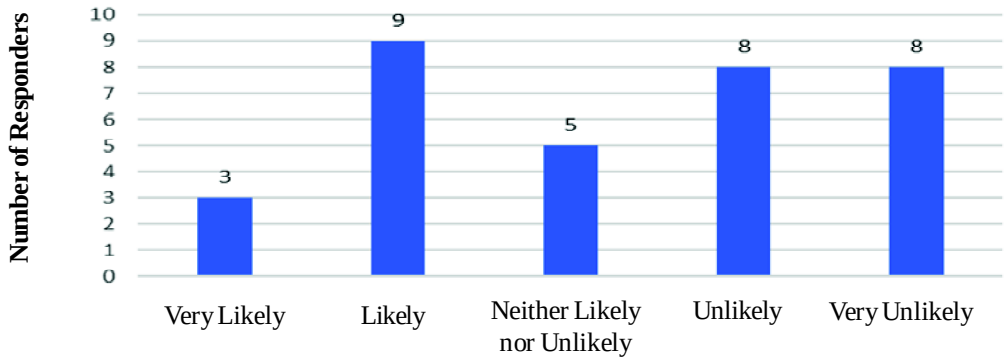

Figure 11: Industry Experts' Opinion on the Likelihood of Sharing Medical Records with Employees

Source: Online Survey on the Future of Healthcare in Singapore (Industry Expert) (Ow Jezon)

48% of the participants indicate they are "very unlikely" and unlikely to share their medical records with their employers, 36% of the participants express that they are "very likely" and "likely" to share their medical records with their employers, and the remaining 15% of the participants indicate they are neutral by selecting "Neither likely nor unlikely."

Among 48% of the participants indicating they are "very unlikely" and unlikely to share their medical records with their employers, participant 1, an executive at an insurance institution, commented that there is a possibility of abuse and

discrimination if any medical information and medical condition is revealed to the employer despite the condition not affecting the productivity nor performance of the work required. He added that unauthorized access to medical information is also a violation of the staff's privacy, especially regarding medical conditions, which are very personal (Ow, 2021).

Participant 16, an executive at a pharmaceutical company, commented that he did not see a benefit or reason for sharing his personal health record or related information with his employer. Finally, healthcare is his responsibility, and unless there is a need for him to share information with his employer, he preferred to keep his personal data to himself. There is always the issue of how this data will be used to their disadvantage, and data privacy is another primary concern (Ow, 2021).

Participant 2, an executive in a medical device company, commented that medical records and conditions are privacy issues. As long as the conditions are not affecting her performance at work, she does not have to disclose them to her employers. She commented that, when employers have employees' medical data, they might use it against employees in hiring, assignment, insurance, promotion, etc. (Ow, 2021).

Among the 36% of the participants who expressed that they are "very likely" and "likely" to share their medical records with their employers, participant 9, an executive at a technological consultancy firm, commented that if there is an incentive for sharing, for, e.g., lowered insurance premiums, then it makes sense to share. If not, then there is no motivation to share any data (Ow, 2021).

Participant 2, an executive in a medical device company, added that sharing medical data allowed the company to understand further what health conditions the employees are in and will allow them to help when problems arise. In a workplace where most employees spend close to 10 hours per day, such information can help when needed (Ow, 2021).

Participant 16, an executive in a pharmaceutical company, commented that the need to share data depends on its intended purpose. If it is for insurance needs, he felt that there were no problems with sharing the data for insurance claims and coverage. However, if it will impact his compensation or career prospects within the company, he will not be willing to share the information (Ow, 2021).

Participant 15, an executive in a digital health company, commented that he felt that, personally, it promotes greater user confidence in a new digital health solution. Electronic copies of these health records can be secured by using encryption methods. The advantage of sharing digital health is that you control your data and authorize access to it each time (Ow, 2021).

Among the remaining 15% of the participants indicated that they were neutral by selecting "Neither likely nor unlikely." Participant 10, an executive in a pharmaceutical company, commented that medical records are private and should only be shared on a need-to-know basis. If employers require a particular medical history, consent needs to be obtained (Ow, 2021).

Participant 7, an executive at a technological consultancy firm, added that insurance claims are submitted online. The medical information may be shared with the employer/Human Resources department. However, the employee might still have Personal Data Protection Act (PDPA) concerns about how the medical information would be utilized (Ow, 2021).

Participant 28, an executive in a digital health company, commented that the current legislation and regulations were unclear. Unless the Ministry of Health and the Ministry of Manpower can clearly define the situations where the data is required to be shared and what kind of data is to be shared, it is highly unlikely that employees will share the information, especially if it affects their livelihood (Ow, 2021).

Q4. The question aims to address the research question of whether the industry experts felt that the integration of IoMT and digital health with blockchain technologies could help address the public concerns about personal medical data integrity issues (Figure 12).

Close to 61% of the participants indicated that integrating IoMT and digital health with blockchain technologies could help to address public concerns about personal medical data integrity issues. Participant 33, an executive in a medical device company, commented that patients could have complete control of their records and be triggered for edits made, access requested to sensitive data, access, and authorization to edit data; hence it would increase public confidence in medical data privacy (Ow, 2021). Participant 10, an executive in a pharmaceutical company, commented that public education and advocacy are vital to building public confidence in medical data integrity (Ow, 2021).

Close to 15% of these participants indicated that they are neutral with regards to the idea that integrating IoMT and digital health with blockchain technologies could help to address public concerns about personal medical data integrity issues.

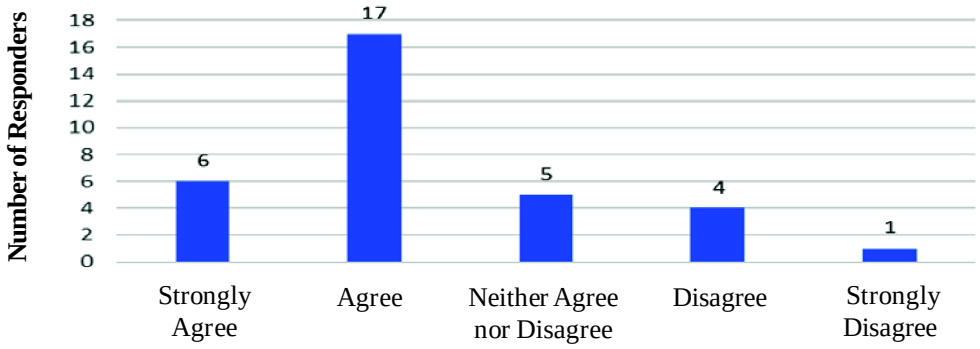

Figure 12: Industry Experts' Opinion on Integration of IoMT and Digital Health with Blockchain

Source: Online Survey on the Future of Healthcare in Singapore (Industry Expert) (Ow Jezon)

Participant 6, an executive in an insurance institution, commented that while technologies could help secure data, technologies could also be used to hack the secured data system. He added that the advancement of technologies made data collection and data analysis cheaper and much easier via wearables. As governments and companies are collecting personal data on an unprecedented scale, to protect the public interests, he commented that there is a need to have updated laws to regulate how companies and governments can use the data (Ow, 2021).

The remaining 15% of the participants felt that regardless of the level of integration of technologies, there were always ways to hack or breach data protection and required more data security and regulations to be introduced and legislated.

Participant 10, an executive at a technological consultancy firm, commented that he agrees that Blockchain possesses the capability to ensure data integrity from a technical aspect. However, when it comes to addressing people's concerns about data integrity, technology must be accepted and perceived as safe and fit for the desired purpose. He did not think that Blockchain is currently a technology well understood and accepted by the majority of the population. In the future, if this changes and Blockchain become the standard, this will most likely change. Therefore, the participant disagreed that Blockchain and IoMT can currently address the medical data integrity issues, but there is potential in the future, depending on the acceptance of this technology (Ow, 2021).

19. Summary of the Chapter

This chapter offered a detailed presentation of the quantitative and qualitative data collected from both the general public survey and the industry input survey. This exploratory study identified the factors that would answer the key research questions and the study's goal.

The researcher reported that the response rate for the general public survey was 56.6%, and the response rate for the industry experts survey was 22%. Also, the researcher reported that due to the study's exploratory nature, most industry experts have requested that their identities be kept anonymous.

In this chapter, the researcher summarized the study findings gathered from the 623 participants from the general public survey and 33 participants from the industry experts survey.

The researcher utilized survey monkey and Microsoft Excel software to analyze the data, visualize the research findings in the form of diagrams and tables to identify interdependences and compare proportions, trends, and conjunctions. The researcher has then interpreted the textual responses to open-ended questions by working through each question to identify the key themes that recur across the different respondents' responses. Data analysis was broken into two phases due to some differences in the questionnaires and the level of depth of knowledge.

In Phase One, the researcher analyzed and reported the data inputs collected from the general public survey, which offers the public perspective on the key research questions. In Phase Two, the researcher analyzed and reported the data inputs collected from the industry experts survey, which offers the industry experts' perspectives on the key research

questions. In order to answer the research questions, the researcher grouped several themes to provide a better perspective and depth of the inputs to answer key research questions.

In the next chapter, the researcher will answer each research question by discussing the inputs from both public and industry experts and supported by external references from literature and external sources.

20. Discussion of Results

This section discusses and interprets the study's results. The results' interpretation was based on the unique participants from both the general public survey and the industry experts. The discussion would include comparing the results of both the general public surveys and industry experts, including practical use cases from other countries and how they can be applied to Singapore.

The researcher's expertise and professional background also affected the interpretation of the results; the researcher would utilize direct quotes to bolster the analysis of the results.

The researcher answered each of the research questions by discussing the inputs from both public and industry experts and supported by external references from literature and external sources.

Q1. What are the general public's perspectives on the utilization of digital health services?

1.1. Public Utilization of Digital Health Services

1.1.1. Consult the Doctor for Common Illness

32% of the participants indicated that they would utilize or have utilized digital health to "consult the doctor for common illnesses." 60% of these participants cited the reason why they utilized it to consult the doctor for common illnesses is to minimize, contact with others during the circuit breaker period (Lockdown period) and the phase 1 and phase 2 periods of the social distancing phases. 40% of these participants cited convenience and short waiting time as reasons why they would utilize digital health to consult the doctor for common illnesses.

1.1.2. Routine Medical Checkup

28% of the participants indicated that they would utilize or have utilized digital health for a "routine medical checkup." 70% of these participants cited convenience, short waiting time, and minimizing social contact as the main reasons, while the remaining 30% of these participants noted they have utilized digital health for Covid-19 testing and obtaining the test results.

1.1.3. Medical Screening

26% of the participants indicated that they would utilize or have utilized digital health for "medical screening." 75% of these participants cited convenience, short waiting time, minimizing social contact as the main reasons. The remaining 35% of these participants cited that they have utilized digital health for follow-up consultation or for obtaining their health screening results, and they felt that face-to-face consultation is unnecessary.

1.1.4. Consult the Doctor for Medication

The remaining 14% of the participants indicated that they would utilize or have utilized digital health to "consult the doctor for medication." 60% of these participants commented that it would be more convenient for them to replenish their routine medications as they did not need to queue to consult the doctor, who would spend less than five minutes on routine questions before prescribing them the same medications.

20% of these participants commented that these services could be extended to the pharmacy so that they could purchase certain controlled drugs more conveniently. The remaining 20% of these participants commented that it would reduce the travel time to see a doctor just to get some medication for an illness, and it would also cut down on the risk of spreading germs to other people along the way.

1.2. Summary

The following use case showcases how the consumer can utilize one instance of digital health services and applications to perform the four common utilization of digital health mentioned in this subsection. Customers can log into their profile on MyDoc to access their personal health records and their own chronic disease management dashboard (as indicated in Figure 13); customers can also utilize the platform for medical consultation regardless of whether their consultation is for a common illness, medical screening, medication or routine checkup (as indicated in Figure 14).

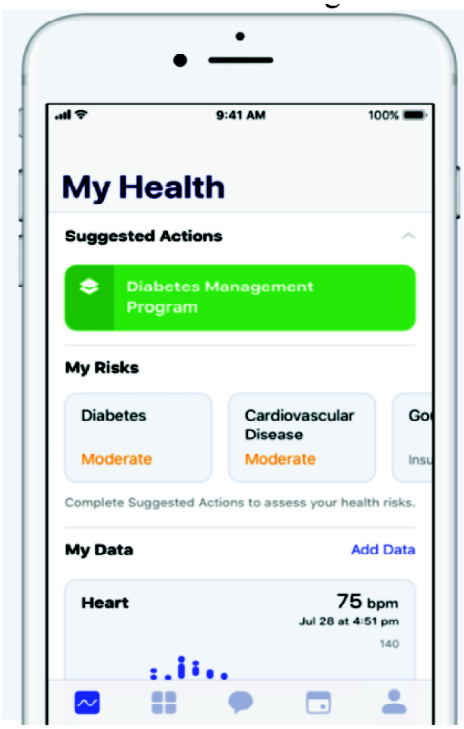

Figure 13: Chronic Disease Management Dashboard

Source: MyDoc, 2020

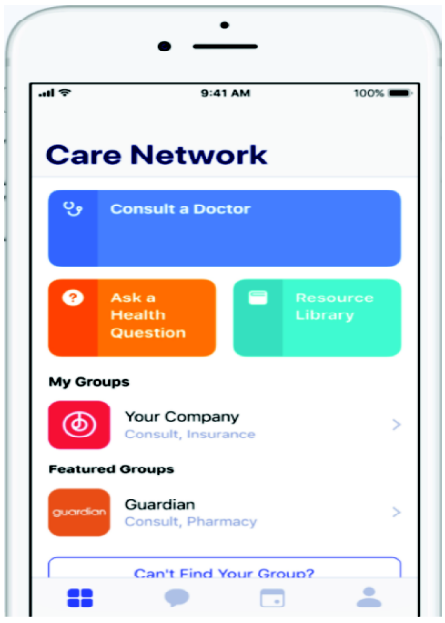

Figure 14: Care Network

Source: MyDoc, 2020

Customers can also get telehealth services such as teleconsultation utilizing the application (as indicated in Figure 15) and record their clinical measurements via IoMT devices or manual entry (as shown in Figure 16).

Figure 15: Teleconsultation

Source: MyDoc, 2020

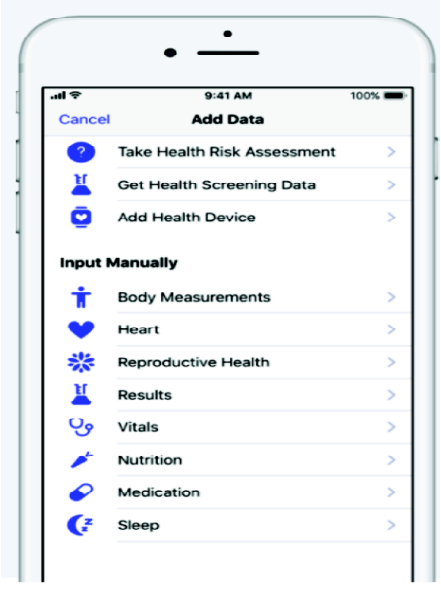

Figure 16: Clinical Measurement

Source: MyDoc, 2020

Customers can also get the lab investigation results (Figure 17) and their E- medical certification and E-prescriptions (Figure 18) via the application after their teleconsultation with the doctor.

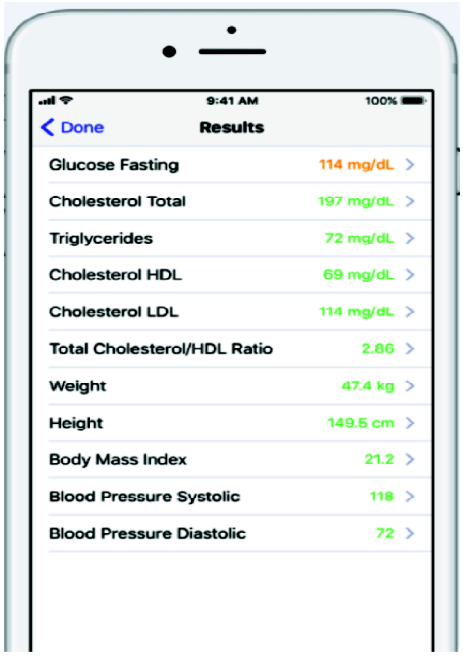

Figure 17: Lab Investigation Results

Source: MyDoc, 2020

Figure 18: E-Medical Certification

Source: MyDoc, 2020

In this subsection, the researcher discussed the results of the general public survey on how they would utilize or have utilized digital health services and shared the existing tools and other applications and tools implemented in Singapore. Next, the researcher surveyed both groups of participants on their perspective on willingness to subscribe to a platform that houses their data, which is protected by encrypted codes and can only be accessed with the patients' explicit consent.

Q2. The willingness to subscribe to a platform that houses their data which are protected by encrypted codes and can only be accessed with the patients' explicit consent.

The researcher surveyed both groups of participants on this question because medical data security and data integrity, and data sharing were a primary concern of the general public, which would be a major hurdle for the implementation of innovative 4.0 technology and digital health in Singapore and around the world.

"Very likely" and "Likely"

The majority of both groups of participants were very receptive to having a digital platform that houses their medical records, which are protected by encrypted codes and can only be accessed with the patients' explicit consent.

2.1. Centralized Database of Medical Information

50% of these participants cited a centralized information database with secure security like SingPass as the main reason why they are willing to subscribe to the digital platform. The remaining 50% of these participants cited reasons like the ease of retrieval of information, ease of sharing data across different healthcare organizations, and reduced number of hard copies of medical information that might be misplaced, lost, or tampered with. They also commented that it also allowed for quicker access to information, especially during an emergency, as a medical professional can access your medical history such as drug allergies and other critical details swiftly.

Participant 19, a medical doctor, suggested that if medical records could be stored in one secure portal, it would be very convenient when visiting various doctors for medical appointments. He added that it is convenient for the patient or the medical professional to access all of this information with just a click. It also makes it easier to keep the records and consolidate and send them to whoever needs the patient's medical records when required, such as for insurance applications (Ow, 2021).

Some of the responders' feedback could be addressed by some of the features of the HealthHub application developed by IHis and the Ministry of Health (Figure 19). The suggestion of making it easier to keep the records and consolidate

Localized and personalized health content	Redeem rewards	Family and Friend's Health services
Access a wide variety of content tailored and adapted to your topics of interest and level of literacy to nudge your behavior change towards healthy living.	Earn and accumulate Healthpoints by sharing health articles, events, and apps. Convert these Healthpoints to rewards, and redeem them for a variety of lifestyle, F&B and grocery vouchers.	Grant caregivers access to your family members' or friend's medical records and appointments to help better manage their health.
Personal Health services	**Children's Health services**	**Patient medication list**
Check your immunization records, latest lab test results, screening records, discharge information, vitals, medical reports, and prescription records.	View your children's appointments and medical records at different public healthcare institutions and school health records or referral letters.	Keep track of patient medication such as reminders, refills, and medication adherence data, which helps your safety.
Directory of healthcare facilities and eServices	**Manage appointments**	**Financial Consent**
Locate your nearest and most appropriate facility for your medical and lifestyle needs.	Schedule your appointments at healthcare facilities to minimize waiting times.	Authorize MOH for the provision of and delivery of government subsidies, Medisave and MediShield Life.
Diabetes Risk Assessment (DRA) tool	**Payments**	**Community Health Assist Scheme (CHAS)**
Calculate your risk for undiagnosed diabetes based on various parameters to proactively monitor and manage your personal health.	Make payment for your medical expenses with ease.	View the transaction history and subsidy balance of your and your family members' CHAS balance.
Screen for Life (SFL)		
Register for health screenings and follow-ups under the National Screening Programme and view your results as well.		

Figure 19: Features of HealthHub

Source: IHis,2020a

and send them to whoever needs the patient's medical records when required, such as, for insurance applications, would be an enhancement to look forward to, provided data security is ensured by the blockchain technology and proper laws and regulations to govern the use of such information.

2.2. Confidence in the SingPass Platform and Convenience

Participant 7, an executive at a technological consultancy firm, commented that SingPass seems to be very widely accepted, especially since it is a government platform. Therefore, for any medical records, SingPass / MyInfo has to be the verifying party in order for people to be confident in using them (Ow, 2021).

Participant 13, an executive in a medical device company, commented that the real-time access benefits would far outweigh the lingering worry of a potential data breach if a robust security infrastructure were in place (Ow, 2021). Participant 3, an executive in a healthcare institution, commented that regulation that prescribes the proper handling of health records still offers the most effective type of data protection. If regulations are in place, the public and stakeholders can use these platforms with ease and convenience (Ow, 2021).

Participant 31, an executive in a pharmaceutical company, commented that SingPass and explicit consent allowed him the option not to trust or grant access to specific vendors, so there is an assurance. He also added that it would make life easier to have these medical records on a protected platform, but only if he had consented to allow the specific healthcare institution or company to access that information (Ow, 2021).

At the end of this section, the researcher will discuss how SingPass has evolved from a portal to log in to government services to a comprehensive digital solution and applications that house numerous confidential personal information of citizens who help to correlate back to the public confidence in the SingPass platform.

On the other hand, the remaining percentile of the participants was not receptive or neutral to having a digital platform that houses their medical records protected by encrypted codes and can only be accessed with the patients' explicit consent.

"Very Unlikely" and "Unlikely"

2.3. Lack of Regulations and Laws and Lack of Public Confidence in the Data Security

The remaining 18% of the participants (8% selected "neither likely nor unlikely," 4% selected "unlikely," 7% selected "very unlikely") cited data privacy, fear of data breach, and that they were not comfortable letting any organization, even the government, have extensive access to their personal medical information. They were worried that the data might be utilized for commercial purposes.

The study's findings are consistent with those of an Accenture study, in which participants' confidence in the institution's capability to keep digital healthcare information secure for technology firms (44%) and the government (71%) declined dramatically as compared to the most trusted healthcare organizations, which included hospitals (85%), doctors (81%), labs (78%), and walk-in clinics (73%) (Khan *et al.*, 2020).

Participant 18, an executive in a medical device company, commented that it depends on why the data is stored there and how it benefits the user. He added that data protection is very lax in Singapore, and even major private companies and the public sector struggle to ensure data privacy and security with leaks being reported regularly (e.g., SIA, SingTel, HIV register) (Ow, 2021).

2.4. Personal Data Protection Act and Public Sector Governance Act

Singapore's Parliament Passed Two Distinct Acts: The Personal Data Protection Act (PDPA) (2012), which is the primary data protection legislation in Singapore, regulating the collection, use, and disclosure of individuals' personal data by private sector organizations; and the Public Sector Governance Act (PSGA) (2018), which regulates data management in the public sector.

Following the 2018 data breach, the Public Sector Data Protection Review Committee was established in March 2019 to conduct an exhaustive review of the entire public service's data security policies (Smart Nation, 2020a). The committee recommended new technological and procedural safeguards to ensure data security and prevent data compromise.

The Public Sector Data Protection Review Committee's recommendations have been incorporated into the IM on IT Management, which details how agencies manage data security (Smart Nation, 2020b). In order to safeguard data against security threats, data security policies define data security standards, which may include technological and procedural safeguards.

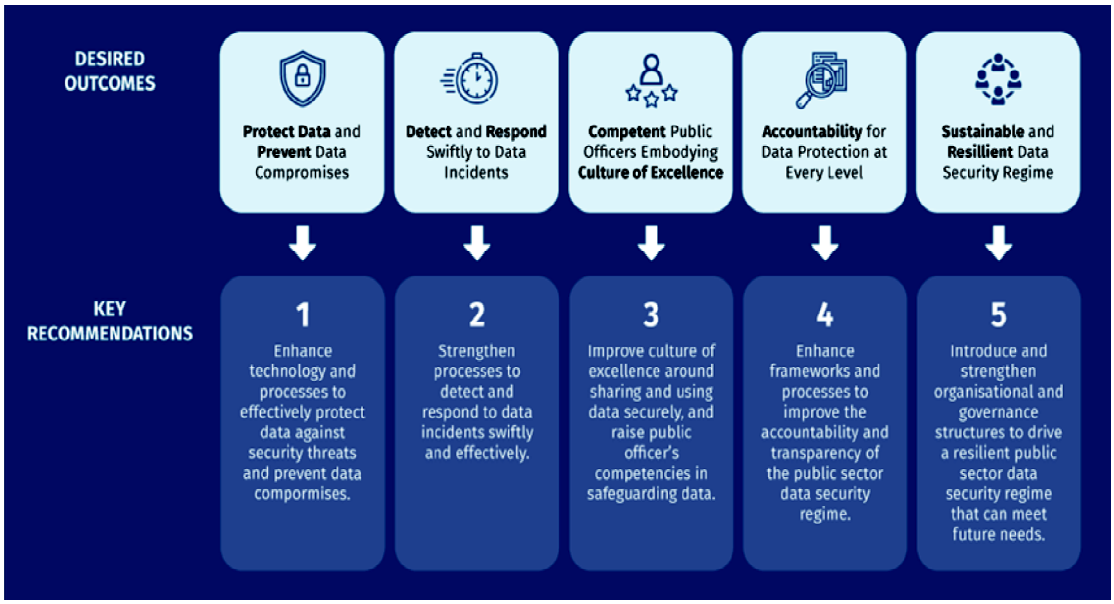

Figure 20: Public Sector Data Security Review Committee Recommended Measures

Source: Smart Nation, 2020b

Although these two acts have been in place for a few years, there are still numerous improvements being made, like the amendment to the PDPA, which was passed in 2020; some of the technical and effects of the act will take several years to implement and take effect.

"Neither likely nor unlikely"

The remaining 12% of the participants who selected "neither likely nor unlikely" were neutral and not very receptive to having a digital platform to house medical records protected by encrypted codes and can only be accessed with the patients' explicit consent. Participant 4, an executive in an insurance institution, commented that it is a tug-of-war within. On one side, information accessibility could be crucial in saving one's life as time is of the essence. He added that on the other side, it would also mean that information could be accessible by personnel with malicious or ill-intent. Protection by SingPass does not imply a 100% foolproof firewall, as demonstrated by the recent incidents with the Singtel leak or medical record leak of a specific group of patients (Ow, 2021).

2.5. SingPass

SingPass, abbreviated for Singapore Personal Access, is Singapore's platform for National Digital Identity (NDI) (Salim, 2021). It is one of Singapore's Smart Nation initiatives, with the goal of improving citizens' lives, expanding business opportunities, and transforming government agencies''capabilities. Singpass began in 2003 as a login portal for government services such as the Central Provident Fund (CPF) and Singapore's Inland Revenue Authority (IRAS).

Numerous enhancements have been made over the years to make it more comprehensive and user-friendly, including the introduction of two-Factor Authentication (2FA) in 2015 as part of efforts to strengthen security on the e-government platform. SingPass now provides access to over 1,400 digital services and empowers over 340 government and private sector organizations (GovTech, 2021; and Salim, 2021).

The SingPass mobile app has added more than ten new features since its October 2018 launch, including digital authentication, face verification, and digital sign-on. Transactions processed on the platform have more than doubled in the last year to more than 170 million, a growth GovTech attributes to an increased number of people using digital platforms in the aftermath of the pandemic (GovTech, 2021; and Salim, 2021).

In recent years, the Singapore government has opened up access to SingPass via APIs (application programming interfaces) and allowed private businesses to access citizen data as part of its effort to expand the platform's capabilities (Yu, 2021). These now include banking and healthcare, as well as the ability to access and digitally sign documents containing personal citizen data. Additionally, users can authenticate transactions through the SingPass app, which eliminates the need for passwords.

The government agency explained that this enhanced not only the customer experience but also the business's performance. By allowing organizations to use SingPass to enable user login, for example, eliminates the need for organizations to maintain their own authentication platform, and users are relieved of the burden of managing several sets of passwords (Yu, 2021). It was noted that cryptographic technology was used to encrypt transactions, such as digitally signed documents.

Among the most recent enhancements is integration with the automated location check-in tool SafeEntry (Figure 21), which is critical to the country's Covid-19 contact tracing efforts. To date, the mobile app has been downloaded more than 2.5 million times, with at least 90% of users using it at least once a month, and its user base has tripled in the last year (GovTech, 2021; and Salim, 2021).

Figure 21: How SafeEntry Works

Source: Salim, 2021

Figure 22: Digital identification Card

Source: Salim, 2021

Apart from digital purchases, the Singpass app has also included a Digital Identification Card (Figure 22) since September 2020 to provide users with an alternative form of identity authentication. Apart from identity cards, Li Soon indicated that additional forms of identification are in the works. The driver's license, in particular, will soon receive a digital version through the Singpass app (Salim, 2021).

According to GovTech, plans are underway to extend support for the SingPass website and app"s "Key transactional sections" to include all of Singapore's four official languages, including Chinese and Malay, by year's end (Figure 23). (Yu, 2021).

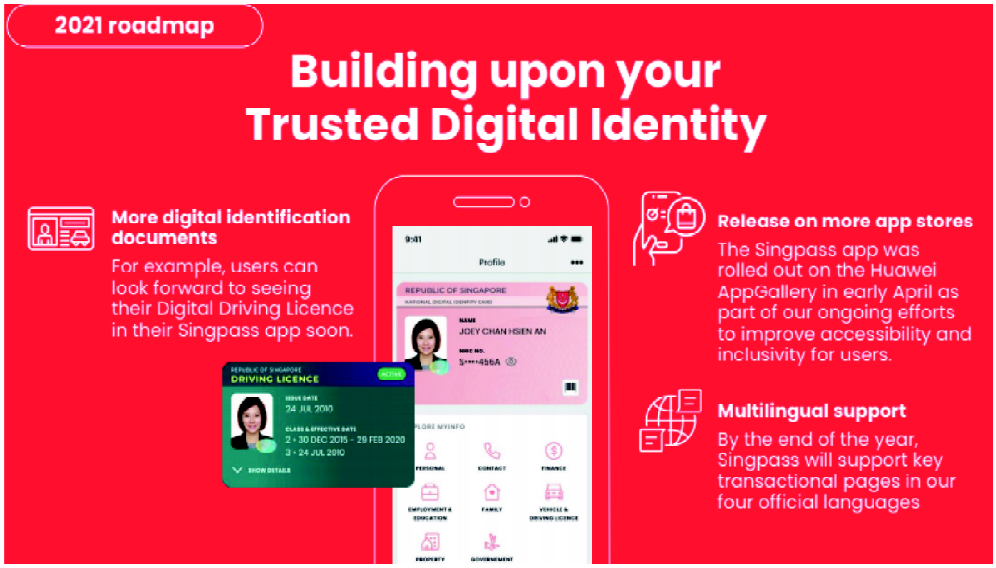

Figure 23: Singpass RoadMap

Source: Salim, 2021

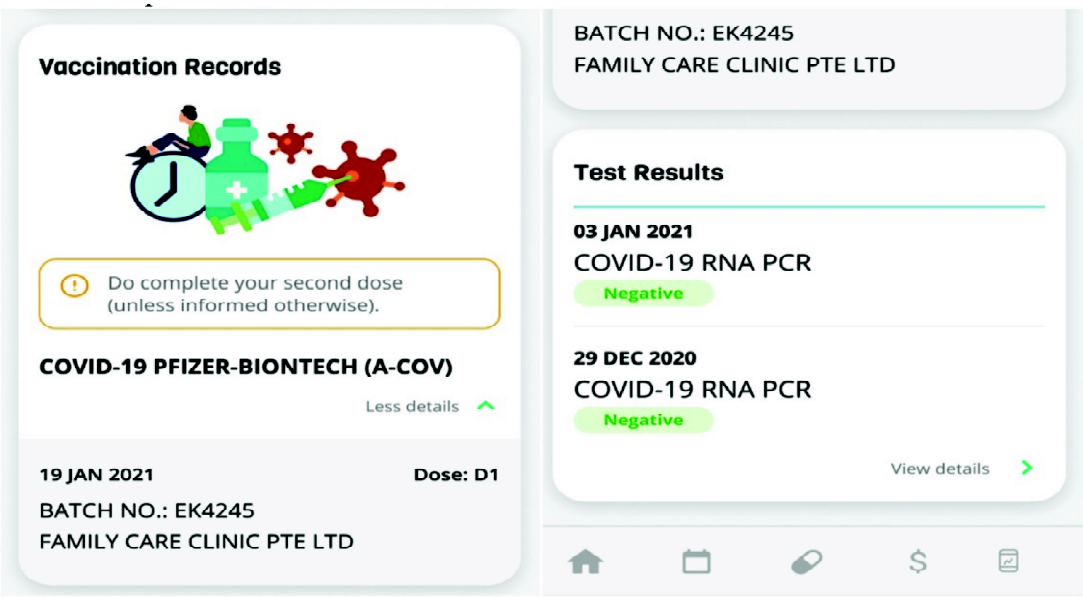

Figure 24: A Mock-Up of Covid-19 Related Health Records that Users can Access in the HealthHub Mobile App

Source: Tan, 2021

Mr. Alan Goh, deputy chairman of the Integrated Health Information Systems (IHiS) VacTech workgroup and chief executive officer of HealthHub, stated: “In addition to offering operators with electronic medical record software that enables safe and efficient vaccinations, we intend to offer vaccinated individuals with convenient access to their Covid-19-related records in a single location, as paper records are becoming obsolete” (Tan, 2021).

After logging into Health Hub, users can access their Covid-19 records by clicking on the “Covid-19 records” tab and logging in with their SingPass.

Vivian Balakrishnan, Minister-in-Charge of the Smart Nation Initiative, said during SingPass's rebranding event last month that “it is not a stretch to imagine that (SingPass) will eventually develop into an international digital identity or passport” (Salim, 2021).

Given SingPass’s foundation in digital identity, it seems inevitable for the app to evolve to meet the ‘new standard’ travel requirements, in which travelers will be required to prove their health status (Salim, 2021).

In this subsection, the researcher discussed the results obtained from both groups of participants and how SingPass, digital passports, Blockchain, and other innovative 4.0 technologies can help to address the concerns about medical data integrity, data security, and data sharing. The researcher also shared some use cases of implementation and how regulations and public education would also help increase public confidence in data protection and boost the utilization of innovative 4.0 technologies and digital health. In the following subsection, the researcher will discuss the results collected from both groups of participants to understand how the public and the relevant stakeholders would most likely to utilize the medical data stored on the digital platforms.

Q3. Public utilization of the medical data stored on the digital platforms

The researcher surveyed both groups of participants on this question to understand both groups of participants' perspectives on how the public and the relevant stakeholders would most likely utilize the medical data stored on the digital platforms. These perspectives allow the researcher to understand the primary utilization of medical data stored on the digital platform and discuss how innovative 4.0 technologies can be applied.

3.1. Medication and Treatment Records

Both the groups of participants chose “medication and treatment records” as the main reason why the relevant stakeholders and the participants would utilize the medical data stored on the digital platforms.

3.2. Previous Medication and Treatment

The majority of both groups of responders indicated that the centralized information would allow the healthcare professional to know what the previous medication and treatment prescribed was so as to enable the professional to provide better patient care.

Participant 11, an executive in a medical device company, commented that medication and treatment records are valuable for doctors to know how the treatment is done. He added that another important piece of information could be medical history. The participant is firmly against using personal medical history data and personal genetic data for insurance coverage purposes (Ow, 2021).

3.3. Quicker Medical Review and Reaction Time

The remaining participants indicated that it allowed for quicker medical reviews and therapy planning for the patients and a faster reaction time for emergency cases, such as, drug allergies due to medication and severe adverse reactions.

Participant 19, a medical doctor, commented that a centralized platform to store medical records would allow medical professionals to access the records and provide more precise and efficient treatment and medication with the prior medical data (Ow, 2021).

3.4. Influencing Public Health Policies

Several industry experts commented that the medical data stored on the digital platform could also influence public health policies. Participant 29, an executive at a technological consultancy firm, commented that medical information could influence public health policies, as it was evidence-based and addressed the actual challenges we are facing in driving healthy behavior and lifestyle. He added that the government could also share the statistical information with pharmaceutical and medical device companies to provide them with a holistic view of Singapore's public health domain and challenge these companies to innovate or develop solutions (Ow, 2021).

3.5. Medical History

"Medical History" was the second-highest choice selected by the general public as the main reason why the relevant stakeholders and participants would utilize the medical data stored on the digital platforms. However, industry experts selected this as the fourth-highest choice as the main reason why the relevant stakeholders and participants would utilize the medical data stored on the digital platforms.

3.6. Centralized Medical Repository

60% of these participants indicated that it allowed them to pull out important information that was often forgotten, such as when was the last time they took a vaccination, their health screening results, and the health red flags they needed to focus on.

Participant 15, an executive in a digital health company, commented that medical history would allow the doctor to know the patient's past medication history and drug allergies to treat the patient's conditions better. He added that medical history could also be shared with the employer during the employee's pre-employment medical examination with the patient's consent to ensure that the person they are hiring is physically fit for the role (Ow, 2021).

3.7. Medical Consultation

40% of these participants indicated this should be the primary utilization of medical data as the recording of key and critical medical data is crucial before it can be expanded to other areas of utilization.

Participant 8, a medical doctor, commented that centralized access to medical data would allow the doctor to make more informed decisions during their consultation as some patients might not remember their past medical history, especially if they are elderly. It helps the doctor determine what personalized treatment regimes are (Ow, 2021).

3.8. Insurance Coverage

Participant 4, an executive in an insurance institution, commented that medical history is used for insurance coverage purposes so that the underwriter can know whether to include or exclude particular coverage based on the policyholder's medical history (Ow, 2021).

3.9. Insurance Coverage

"Insurance coverage" was the third-highest choice selected by the general public as the main reason why the relevant stakeholders and participants would utilize the medical data stored on the digital platforms. On the other hand, industry experts selected this as the second-highest choice as the main reason why the relevant stakeholders and participants would utilize the medical data stored on the digital platforms.

3.10. Coverage

50% of these participants indicated that, it allowed the insurance company to determine the customer's coverage risk and whether to include or exclude certain coverages or exclude the customer entirely from coverage.

Participant 32, an executive at a technological consultancy firm, commented that dynamic underwriting should be the way to go. The current underwriting methods are too old-school and should be changed to reflect the current technological capabilities (Ow, 2021).

3.11. Simplified Medical Claims

50% of these participants indicated that it simplified medical claims and hospitalization and operation claims.

Participant 4, an executive in an insurance institution, commented that this simplified the claim process as it helped to minimize the documentation and unnecessary operation issues (Ow, 2021).

Participant 20, an executive in a healthcare institution, commented that patients would utilize the medical data for insurance coverage to claim hospitalization charges and other medical charges as information, such as treatment procedures, medication, medical conditions, the period of stay, and class type would be indicated on the documentation (Ow, 2021).

3.12. Medical Consultation

"Medical consultation" was the fourth-highest choice chosen by the general public as the main reason why the relevant stakeholders and participants would utilize the medical data stored on the digital platforms. However, it was chosen by industry experts as the third-highest choice as the main reason why the relevant stakeholders the participants would utilize the medical data stored on the digital platforms.

3.13. Speedy Access to Medical Records

60% of these participants commented that it sped the process of accessing their medical records when they were consulting medical professionals.

Participant 23, an executive in a healthcare institution, commented that the centralized medical data platform would allow medical professionals to know the previous medication that the patients were prescribed. Most patients do not know or remember what medication and the dosage they are taking. For example, it is hard for regular patients to differentiate between paracetamol, aspirin, and ibuprofen even though they are all painkillers, and the dosage strength and form of medication such as 81 mg, 162 mg, 325 mg, and 500 mg (Ow, 2021).

3.14. Continuance of Patient Care

40% of these participants commented that this allowed doctors to do telehealth and telemedicine consultations virtually.

Participant 21, a medical doctor, commented that some patients have multiple appointments across different institutions. Therefore, having all their medical records stored in one secure portal will enable physicians in each institution to know what is going on at other institutions and what they have been treated with (Ow, 2021). Participant 33, an executive in a medical device company, concurred with participant 21 that patient care continuance would be critical even if patients choose to switch healthcare providers (Ow, 2021).

3.15. Medical Research

Both groups of participants selected “Medical research” as the main reason why the relevant stakeholders and the participants would utilize the medical data stored on the digital platforms.

3.16. Clinical Trial and Drug Safety

90% of the responders indicated that, despite this, it would be their last choice. However, medical research would also be one of the areas where stakeholders and the participants who gave their informed consent can help pharmaceutical companies understand each clinical trial’s results to ensure the drugs’ safety and efficacy.

Participant 20, an executive in a healthcare institution, commented that medical data could be used for medical research and clinical trials, such as the effectiveness of drugs, the efficacy of drugs, and the study of a new strain of virus or diseases. However, the healthcare institution needs to obtain consent from the patients before this information can be released to pharmaceutical and medical device companies (Ow, 2021).

Participant 9, an executive at a technological consultancy firm, commented that while it was excellent to obtain more medical data for clinical or medical research, it would be beneficial for future generations. He added that it is also beneficial for more public awareness and knowledge sharing of how medical data are utilized for medical research and clinical trials. As there is a certain percentage of the public who still have a stigma about pharmaceutical and medical device companies, these companies might be unethical in the way they handle medical data (Ow, 2021).

3.17. Real-World Late Phase

10% of the participants indicated that it would also be utilized for real-world data or late phase data for clinical trials.

Participant 25, an executive in a pharmaceutical company, commented that medical data could be utilized for real-world late phase studies, and data collection through digital technologies can aid in using crowd data for research purposes (e.g., Migraine Buddy app) (Ow, 2021).

3.18. Summary

There are numerous applications and digital solutions in Singapore that could provide speedy access to medical records and continuance of patient care, such as MyDoc application, Doctor anywhere, SingHealth application, and Raffles connect application. The main challenge is that they are primarily on different platforms, and sharing data is still a challenge unless the patient transfers from one public hospital to another. Even the medical history module on SingPass mobile applications only captures medical information and medical history that patients have from public hospitals.

Even though Singapore's Ministry of Health (MOH) launched the National Electronic Health Record (NEHR) in 2011, adoption has been slow; as of 2019, an estimated 27% of private licensees in ambulatory care (GPs, specialists, and dentists) were accessing and updating NEHR, but only 3% were contributing and submitting data to NEHR (See, 2020).

Integrated Health Information Systems (IHiS), a technology organization serving the public healthcare industry, developed and managed the NEHR. The NEHR's core ethos was “One Patient, One Health Record.” The NEHR provides a consolidated view of a patient’s clinical background, such as admissions and appointments, hospital inpatient discharge

summaries, test reports, medication history, previous surgical history, allergies and adverse drug reactions, and immunization history (See, 2020).

To incentivize healthcare professionals to follow the NEHR, the government set aside $20 mn Singapore dollars to assist private practices (including general practitioners, private hospitals, private specialists, and dentists) with the costs of system updates. Additionally, Singapore's Ministry of Health planned to enact a Healthcare Services Bill in 2018 that would include mandatory data sharing for all healthcare providers (See,2020).

Several barriers were listed, including a lack of technical and financial assistance, patient confidentiality, and data protection. Thus, despite the existence of a National Electronic Health Record system, the slow rate of adoption, and the lack of information being updated to the ERHR, the SingPass application or even the government will use it to provide citizens with a robust system that allows them to access all their medical records and for the government to use medical trends and data to guide public health policy.

Thus, the government should do more to remove obstacles to healthcare professional acceptance, which will benefit the entire ecosystem by improving the patient journey and increasing the effectiveness of current processes.

Next, the researcher will discuss two cases that showcase how the medical data stored on the digital platforms could be utilized for insurance coverage, medical consultation, medical and treatment records and medical history, and medical research.

The following cases highlight an initiative that Singapore is exploring to better understand how the medical data stored on digital platforms could be utilized for insurance coverage, medical consultation, medical and treatment records, and medical history.

3.19. Healthcare-Insurance Industry Pilot (HIIP)

Healthcare-Insurance Industry Pilot (HIIP) is a cross-sector partnership between Singapore's healthcare and insurance sectors that focuses on payor-provider alignment (General Insurance Association, 2021). This partnership (which is represented by the General Insurance Association of Singapore), the Singapore Life Insurance Association, and the Integrated Health Information Systems recently released a Request for Proposals (CFP). To increase patient care and operational quality, the CFP proposes an end-to-end health insurance claims platform (Ang, 2021).

The aforementioned initiative is consistent with Singapore's transition to a new, innovation-driven economy that will provide Singaporeans with a broader range of benefits. The pilot program aims to provide the following services: easy access to patients' insurance policy information, quicker claim processing, streamlined data release authorization, and more timely data exchange (Ang, 2021).

The platform is a technology solution, with healthcare providers and insurers as direct customers. The platform will allow healthcare providers to retrieve detailed information about a patient's policy coverage for Integrated Shield Plans and group hospital and surgical insurance in order to decide whether the patient's admission deposit can be waived.

Patients will be able to use their Singpass app to digitally allow the release of pertinent data to insurers and healthcare providers, such as their medical records and insurance policy information. Additionally, the app seeks to streamline claims management by enabling healthcare providers to send claims to insurers on behalf of patients electronically. Similarly, insurers may receive billing and medical information from healthcare providers.

Additionally, healthcare providers may use the platform to communicate timely billing information and data about a patient's status, such as the duration of their hospital stay, to patients and insurers. This data enables insurers to provide more timely reports on the estimated claimable number.

The following cases highlight how Singapore has utilized the medical data stored on the digital platforms that could be used for medical research, such as a Real-world study.

GSK is partnering with Singapore Health Services and Duke-NUS Medical School to facilitate data integration and the digitization of patients' medical records related to asthma and chronic obstructive pulmonary diseases. The data integration involves the entire SingHealth healthcare cluster.

This project sought to fully exploit the potential of electronic data in the treatment of patients with respiratory disorders, with the ultimate goal of developing an integrated real-time electronic health record system that would enable the conduct of pragmatic clinical and health services trials with minimal intervention into patients' care journeys (Duke-NUS, 2017).

Despite the success and potential of these initiatives, there are still issues that must be resolved before systematic adoption and uptake of RWE can occur. These issues include geographic distribution and completeness of data, data consistency, patient consent, and privacy concerns, as well as ethical data usage.

In this subsection, the researcher discusses both groups of participants' perspectives on how the public and the relevant stakeholders would most likely utilize the medical data stored on the digital platforms. The researcher also shared use cases of implementation and how they can be applied in Singapore to meet the needs of the particular utilization of the medical data stored on the digital platform and to drive the adoption of innovative 4.0 health and digital health.

In the following subsection, the researcher will discuss the results obtained from both groups of participants on their perspective on the likelihood of sharing medical records with employers via digital health, MedTech, and IoMT.

Q4. Likelihood of sharing medical records with the employers via digital health, MedTech, and IoMT.

The researcher surveyed both groups of participants on this particular question to understand their view of sharing their medical records with their employers, as most of the public in Singapore are covered by company insurance such as medical, dental, and travel. The majority of people also have at least one or two more insurance coverages, such as personal insurance coverage with private insurance firms and a mandatory insurance coverage enforced by the government known as Medishield, which has been replaced by the recently launched Medishield life.

Company insurance coverage premiums are one of the costly components of capital expense; over recent years, insurance firms are starting to partner with digital health firms to improve their services.

"Very unlikely" and "unlikely"

The majority of both groups of participants indicated that they are "very unlikely" and unlikely to share their medical records with their employers.

4.1. Lack of Regulation and Lack of Trust on How the Employer Would Utilize the Information

The majority of the responders cited that medical data are personal information that they are not willing to share as there is no legislation or regulations to regulate it, and the lack of trust that information can be handled discreetly and appropriately. They also cited personal privacy, possible abuse, or discrimination in the workplace if employers get access to this information, and the fact that their current organization might not have the right systems or processes to handle such information securely and data security.

Some of the responders also cited that medical data should be strictly handled by healthcare institutions, and they felt that unless it is for company insurance claims or suspected abuse of medical leaves, employers should not have access to any medical information.

Participant 1, an executive in an insurance institution, commented that there is a possibility of abuse and discrimination if any medical information or medical condition is revealed to the employer despite the condition not affecting the productivity or performance of the work required. He added that unauthorized access to medical information is also a violation of the staff's privacy, especially regarding medical conditions, which are very personal (Ow, 2021).

Participant 16, an executive at a pharmaceutical company, shared the same concern and added that he did not see a benefit or reason for sharing his personal health record or related information with his employer. Finally, health care is his responsibility, and unless there is a need for him to share information with his employer, he preferred to keep his personal data to himself. There is always the issue of how this data will be used to their disadvantage, and data privacy is another primary concern (Ow, 2021).

Participant 2, an executive in a medical device company who shared the same perspective, commented that medical records and conditions are privacy issues. As long as the conditions are not affecting her performance at work, she does not have to disclose them to her employers. She commented that, when employers have employees' medical data, they might use it against employees in hiring, assignment, insurance, promotion, etc. (Ow, 2021).

"Very likely" and "likely"

On the other extreme end, the participants indicated that they are "very likely" and likely to share their medical records with their employers.

4.2. Employment Onboarding

The majority of the responders who indicated that they are "very likely" and "likely" to share their medical records with their employers, explained that they would provide those details if it is part of the onboarding and initial employment body assessment.

Participant 2, an executive in a medical device company who concurred with this perspective, added that sharing medical data allows the company to understand further what health conditions the employees are in and will allow them to help when problems arise. In a workplace where most employees spend close to 10 hours per day, such information can help when needed (Ow, 2021).

4.3. Insurance Coverage

The majority of the responders cited the ease of retrieval of the medical certificate, allowing the company to know if the employees have any health conditions so that they can be able to help the employees if anything crops up. It also allows them to gather information about the employees' health to negotiate for better insurance coverage. Participant 9, an executive at a technological consultancy firm, who shared the same perspective, commented that if there is an incentive for sharing, for, e.g., lowered insurance premiums, it will make sense to share the information. If not, then there is no motivation to share any data (Ow, 2021).

Participant 16, an executive in a pharmaceutical company, added that the need to share data depends on its intended purpose. If it was for insurance needs, he felt that there were no problems with sharing the data for insurance claims and coverage. However, if it will impact his compensation or career prospects within the company, he will not be willing to share the information (Ow, 2021).

Participant 15, an executive in a digital health company, added that it promotes greater user confidence in a new digital health solution from his perspective. Electronic copies of these health records can be secured by using encryption methods. The advantage of sharing digital health is that you control your data, and you authorize access to it each time (Ow, 2021).

"Neither likely nor unlikely"

The remaining percentile of participants indicated neutral by selecting "Neither likely nor unlikely" when it comes to the likelihood of sharing medical records with employers via digital health, MedTech, and IoMT.

4.4. Lack of Regulations to Govern the Utilization of Data

Some of the responders felt that the company might not have the necessary tools to safeguard the data. Participant 28, an executive in a digital health company, echoed this perspective, commented that the current legislation and regulations were unclear. Unless the Ministry of Health and the Ministry of Manpower can clearly define the situations where data is required to be shared and what kind of data to be shared, it is highly unlikely that employees will share the information, especially if it affects their livelihood (Ow, 2021).

4.5. Sharing on a Need-to-Know Basis

Some of the responders commented that medical records should only be shared on a need-to-know basis and if medical conditions affect the current role the person is employed for. Participant 10, an executive in a pharmaceutical company who shared the same perspective, commented that medical records are private and should only be shared on a need-to-know basis. If employers require a particular medical history, consent needs to be obtained (Ow, 2021).

4.6. Insurance Claims and Medical Certifications

For the responders who indicated that they are neutral about sharing their medical records cited, they are okay to share this if it is for medical certifications during their term of employment. Participant 7, an executive at a technological consultancy firm, added that insurance claims are submitted online. The medical information may be shared with the employer/Human Resources department. However, the employee might still have Personal Data Protection Act (PDPA) concerns about how the medical information would be utilized (Ow, 2021).

4.6. Recommendations

Currently, there are no strict regulations or government policies on what medical information employers can obtain or collect. The Personal Data Protection Act, 2012 does not apply to employees. Thus, the employer may receive sensitive information about an employee, which, in most cases, are not related to the occupation or employment.

Hence, Singapore can draft a regulation similar to the Health Insurance Portability and Accountability Act (1996) of the United States of America. HIPAA regulations were implemented in the workplace to safeguard employees' health and medical records while they participate in an employer-sponsored healthcare plan. The laws govern how confidential health information about individuals maintained by a healthcare plan can be shared with employers.

The organization can implement a strict personal data governance policy and be endorsed by the senior leadership, human resources, and legal department on the organization level. The policy could provide transparency and clarity on

how personal medical data is being used and when utilized, such as medical insurance coverage, and strict guidance on who can access the information with written informed consent by the employee and provide the necessary reporting channels, if any abuse is found.

In this subsection, the researcher discussed the results from both groups of participants on their perspective on the likelihood of sharing medical records with employers via digital health, MedTech, and IoMT. The researcher also shared use cases of implementation and how they can be applied to Singapore to improve the adoption of innovative 4.0 technologies and refine how insurance coverage can be increased. Furthermore, business models of different entities related to insurance coverage and doctor-patient relationships are explored.

4.7. Summary of the Section

The researcher started with the discussion of the general public's perspective on the utilization of digital health services, which provided a better perspective on how the general public would utilize digital health services and the applications that can meet this utilization, and what future enhancements are needed.

Next, the researcher discussed the perspective of both groups of participants on the willingness to subscribe to a platform that houses their data, which is protected by encrypted codes and can only be accessed with the patients' explicit consent, which addresses one of the key concerns, which are medical data integrity, data security, and data sharing.

Also, the researcher discussed the perspective of both groups of participants on the public utilization of the medical data stored on the digital platforms, which provide the practical aspects with application use cases that were implemented overseas and the build-up to the intended future state.

Lastly, the researcher also discussed the perspective of both groups of participants on the likelihood of sharing medical records with employers via digital health, MedTech, and IoMT. The discussion was because it is an upcoming trend due to the acceleration of innovative 4.0 technologies and how digital transformation is occurring in the healthcare industry, impacting patients, doctors, employers, and other stakeholders regarding insurance coverage, claims, and other aspects.

One of the participants' key concerns in this section was data security, medical data integrity, and data sharing. Hence, in the next section, the researcher will discuss if the integration of IoMT and digital health with blockchain technologies would help to address public concerns about personal medical data integrity issues, which is the fifth key research question.

Q5. Does the integration of IoMT and digital health with blockchain technologies can help address public concerns about personal medical data integrity issues.

The researcher started by understanding the public perspective on personal medical data, as medical data privacy is one of the main deciding factors for adoption, and it was mentioned numerous times across previous sections. The researcher would then discuss how likely the integration of IoMT and digital health with blockchain technologies would help address public concerns about personal medical data integrity issues, which is the fifth key research question.

5.1 Public Perspective on Personal Medical Data

Close to 84% of the participants indicated that they either agree or strongly agree that they are concerned about their medical data privacy, which suggests that medical data privacy is one of the main deciding factors for the adoption of any technological implementation or new healthcare practices. 13% of the participants indicated that they neither agree nor disagree. The remaining 3% indicated that they are not so concerned about their medical data privacy.

The results collected in this study are further supported by the survey conducted by Accenture, where 1/3 of the participants ranked "concern about my privacy or data security as one of the top barriers to adoption of chatbots, computers, digital services for their health questions and care" (Khan *et al.*, 2020). Next, the researcher would discuss the perspective of both groups of responders on public perspective on whether integrating IoMT and digital health with blockchain technologies would help address public concerns about personal medical data integrity issues.

5.2 Public's Perspective on the Integration of IoMT and Digital Health with Blockchain Technologies

The majority of both groups of participants indicated that integrating IoMT and digital health with blockchain technologies could help address public concerns about personal medical data integrity issues.

5.2.1. Blockchain's Tamperproof Features

50% of these participants commented that they believed Blockchain is more secure. 30% of these participants commented that Blockchain is tamper-proof and information should be sufficiently encrypted using these technologies to ease people's concerns about data privacy.

Participant 33, an executive in a medical device company, commented that the patients can have complete control of their records; can request access to sensitive data, and are authorized to request editing of their data if it is not correct. Thus, all these features can increase public confidence in medical data privacy (Ow, 2021).

5.2.2. Public Education to Build Public Confidence

The remaining 20% commented that if the government were confident enough to roll out this program, it would be secure enough as numerous testing, and check and balances would have been done before it was rolled out.

Participant 10, an executive in a pharmaceutical company, commented that public education and advocacy are vital to building public confidence in medical data integrity (Ow, 2021).

The group of participants (from both public and industry experts) who indicated that they are neutral with regards to the idea that integrating IoMT and digital health with blockchain technologies could help address public concerns about personal medical data integrity issues forms the second percentile.

5.2.3. Regulation and Laws

50% of these participants are undecided due to a lack of understanding of blockchain technologies. 50% of these participants commented that while the blockchain and IoMT technologies may be secure, there are still some vulnerabilities against a deliberate data breach or data leak.

Participant 6, an executive in an insurance institution, commented that while technologies could help secure data, technologies can be used to hack the secured data system. He added that the advancement of technologies had made data collection and data analysis cheaper and much easier via wearables. As governments and companies are collecting personal data on an unprecedented scale, to protect the public interests, he commented that there is a need to have updated laws to regulate how companies and governments can use the data (Ow, 2021).

The remaining percentile of the participants indicated that they felt that regardless of the level of integration of these technologies, there are always ways to hack or breach data protection and more data security and regulations should be introduced and legislated.

5.2.4. Public Education and Social Advocacy of Blockchain and IoMT

60% of these participants cited the data breach of the HIV and health databases as a bad experience that shook their confidence in Singapore's medical data integrity. 40% of these participants felt that more public education and social advocacy on Blockchain and IoMT and how they benefit the healthcare industries and patients would increase public confidence in these implementations.

Participant 10, an executive at a technological consultancy firm, commented that he agrees that blockchain possesses the capability to ensure data integrity from a technical aspect. However, when it comes to addressing people's concerns about data integrity, technology must be accepted and perceived as safe and fit for the desired purpose. He did not think that blockchain is currently a technology well understood and accepted by the majority of the population. In future, if this changes and blockchain become the standard, this will most likely change. Therefore, the participant disagreed that blockchain and IoMT can currently address the medical data integrity issues, but there is potential in the future, depending on the acceptance of this technology (Ow, 2021).

5.3. Recommendations

5.3.1. Regulations and Laws

Singapore has many regulations in place, including the following:

a) The Personal Data Protection Act (PDPA), which was amended in 2020 to include further updated laws and regulations aimed at protecting the public's personal data;

b) New regulatory guidelines for software medical devices were also published in April 2020 to address digital threats, such as cybersecurity, data integrity, and data security;

c) The National Teachable Materials Act; and

d) Telehealth Product Regulatory Guidelines, which define telehealth products, which may include digital health apps classified as medical devices and provide risk classification and regulatory controls for telehealth medical devices and standalone mobile applications classified as medical devices.

These regulations provide the framework for telehealth, medical technology, and cybersecurity while also protecting the public interest in terms of data privacy and security, as well as patient safety and reliability.

Even though numerous regulations are in place, there are currently no provisions for Blockchain technology in the ministry of health guidelines; SGInnovate, a deep tech venture capitalist as part of the Deep Tech Nexus, heavily invests in AI blockchain for healthcare. Hence, they can be the thought leadership to be included during the new digital healthcare ecosystem discussion in the future.

5.4. Public Education to Boost Public Confidence

The government can do more public education on the capabilities of blockchains and some of the cases they are being applied to, such as, Accredify and MediLot, so that it removes the fear of data integrity and security. The government can also do more to share the IoMT, digital health, and blockchain benefits with the healthcare industries and patients, which would increase public confidence in these implementations. Once the public trusts the technologies and see how this would benefit them, it will increase the adoption of the technologies.

In this section, the researcher discussed the participants' primary concerns: medical data privacy and data security, and how the integration of blockchain and IoMT would help address these concerns by providing practical use cases that have been implemented in other countries and recommendations on how to implement them in Singapore. The researcher will discuss the challenges and risks that the public sees with the combination of innovation 4.0 technologies and digital health in the next section.

21. Conclusion Based on the Results

As the researcher mentioned in the introduction chapter, the researcher discussed what are the recent medical data breach in Singapore. In the literature review chapter, the researcher also discussed the numerous industry 4.0 technologies that are utilized in healthcare and mentioned that there was little research done on how these various technologies can be used together, as most of the literature was just focused on the implementation of one or two technologies.

Next, the researcher presented some of the inputs from both groups of participants on the utilization of digital health data and the current barriers of the adoption of the IoMT and existing technologies which were discussed by Ow Jezon (2021b) in the previous research paper.

Next, in the literature review chapter, the researcher also mentioned that this initial gap in the literature kick-started the research topic as it provides some examples of how these technologies are implemented in different countries and how they might change the future of digital health. The other gap in the literature is the lack of research on public and industry responses regarding the utilization of medical data for digital health, the likelihood to share the information with their employers, and the willingness to subscribe to a platform that houses their data protected by encrypted codes that can only be accessed with the patients' explicit consent in Singapore.

In the research methodology chapter, therefore, the researcher set out several key research questions each for both groups of participants to understand the questions related to how the general public utilizes the medical data stored on digital platforms; their perspectives on the subscription model for the use of a platform that houses their medical data, protected by encrypted codes, which can only be accessed with the patients' explicit consent.

The research questions addressed other topics, such as, the likelihood of the general public sharing their medical information with employers; the perspective on the integration of IoMT with blockchain and digital health, the key benefits, key challenges and opportunities of combining 4.0 technologies and digital health platforms.

To answer the key research question number one, the researcher started by discussing the common utilization of digital health services that the public would utilize or have utilized. He also shared use cases of how one single application and service like MyDoc can allow the public to consult a doctor for common illnesses; for medication; for medical screening, and for routine medical checkups.

Next, to answer key research question number two, the researcher discussed the willingness to subscribe to a platform that houses their data protected by encrypted codes and can only be accessed with the patients' explicit consent. The majority of the responders from both groups were very receptive to having a digital platform that houses their data which is protected by encrypted codes and can only be accessed with the patients' explicit consent, citing reasons, such as a centralized database of medical information and confidence in the SingPass Platform and the conveniences it brings. The researcher also discussed the evolution of SingPass and how it might eventually evolve into an international digital identity or passport.

Next, the researcher also discussed the public utilization of the medical data stored in digital platforms to answer key research question number three; the majority of the responders from both groups chose medication and treatment

records as the main reasons citing benefits like access to previous medication and treatment records, quicker medical review, and reaction time and using the medical data to influence public health policies.

The researcher also discussed two cases that showcase how the medical data stored on the digital platforms could be utilized for insurance coverage, medical consultation, medical and treatment records and medical history, and medical research.

For key research question number four, the researcher also discussed both groups' views on the likelihood of sharing medical records with employers via digital health, MedTech, and IoMT. The majority of the responders from both groups indicated they are very unlikely or unlikely to share their medical records with their employers cited lack of regulations and lack of trust in how the employers would utilize the information. The researcher also provided some recommendations for some use cases that might help to address the concerns.

Lastly, to answer key research question number five, the researcher started by discussing how concerned the public is about their medical data privacy (the majority of the responders indicated they are concerned or very concerned). This research finding suggests that medical data privacy is one of the main deciding factors for the adoption of any technological implementation or of new healthcare practices. Data privacy or data security has been mentioned as the primary concern in numerous discussions throughout this chapter.

Next, the researcher discussed the public perspective on how the integration of IoMT and digital health with blockchain technology could help address public concerns about personal medical data integrity issues. The majority of the responders from both groups believed that the integration of IoMT and digital health with blockchain technology could help address public concerns about personal medical data integrity issues, citing reasons such as blockchain's tamperproof features, public education, and public confidence in governments.

The researcher also discussed some of the recommendations to address the other concerns mentioned by the responders who were neutral or felt that integration of IoMT and digital health with blockchain technology would not help to address the public concerns about personal medical data integrity issues. These responders cited reasons, such as, the lack of regulations and laws, the lack of public education, and social advocacy for Blockchain and IoMT.

Therefore, the researcher answered all the key research questions mentioned in the research methodology chapter and closed the gaps indicated in the literature review chapter. The first gap was the lack of research on public and industry responses regarding the application of these technologies in Singapore's medical industries.

The second gap was what are the other gap in the literature is the lack of research on public and industry responses regarding the utilization of medical data for digital health, the likelihood to share the information with their employers, and the willingness to subscribe to a platform that houses their data protected by encrypted codes that can only be accessed with the patients' explicit consent in Singapore.

22. Limitations of the Study

This exploratory qualitative study may suffer from several limitations, notwithstanding the efforts to make this study analytically defendable. Firstly, one potential limitation could be the composition of the research sample size. Although the researcher tried to recruit industry expert participants from all the relevant industries, most of the participants were from healthcare institutions, pharmaceutical, and medical device manufacturers, insurance firms, digital health, and technology consultancy firms.

It would have been better if the researcher had also included participants from government, statutory boards, and financial institutions. The researcher used purposive snowball sampling to gather participant knowledge about the topic. Although the sample size of the general public is relatively sizeable and feasible, it would have probably been better to have a larger sample size if the researcher did not have resource limitations. Hence, the lack of representativeness of the sample was a limitation in this research.

Next, the second limitation was that as the researcher was basing the study on Singapore alone due to due to limited resources, which has a small population pool compared to countries like China and Malaysia, and the United States. One possible avenue of future research would be to carry out studies in these countries in order to have a more comprehensive and comparative dataset for the study.

23. Expected Outcomes, Results, and Contributions of the Research

This study aims to contribute to the existing literature by exploring the integrated applications of Artificial Intelligence, Blockchain, Digital Health, IoMT, and Telemedicine in Singapore by providing the perspectives of the responders on the current state of the technologies in Singapore, the future state of the technologies in Singapore. This study also aims to

contribute to the existing literature by providing public and industry participants' perspectives on the integration of Blockchain, Telemedicine, and digital health to resolve medical data security concerns.

The study also aims to contribute to the existing literature by providing a perspective on the likelihood of subscribing to a platform that houses medical data protected by encrypted codes and can only be accessed with the patient's explicit consent and the likelihood of sharing medical data with their employers via digital health, IoMT, and Medtech. Lastly, this study aims to contribute to the existing literature by providing future exploratory ideas to accelerate the rate of digital health utilization in Singapore.

24. Implications for Practice and Recommendations for Future Research

The adoption of digital health and innovation 4.0 technologies are on the acceleration due to Covid-19 as they provide convenience, efficiency, and speedy treatment and consultation time which increase access to medical care. The data that it generated could help to improve process efficiency, drugs, and medical device efficacy, develop new medicines and therapy breakthroughs, and improve healthcare standards and access to medical care.

Healthcare institutions, digital health companies, insurance firms, pharmaceutical, and medical devices, and technological consultancy can utilize the results of this research to implement digital health and innovation 4.0 technology that may increase the adoption of general public users. Organizations can also use the results to engage other stakeholders in the healthcare industry to build the ecosystem to drive adoption and provide an end-to-end patient journey.

This study offers a direction for further research into the future of healthcare in Singapore and other countries. The future researcher could replicate the current study in other countries like Malaysia, China, and the other Asia Pacific countries, the USA and UK, utilizing a similar research study approach to innovation 4.0 technologies or inclusive 4.0 technologies in those countries. The results could offer a way to compare similarities and differences in sample demographics.

The future researcher could also do comparison studies across different countries to compare the different adoption rates and different reasons for adoption and the different factors that might influence the adoption or rejection of the innovation 4.0 technologies. Other areas for further research could include the additional spectrum of digital payment and insurance claims to the whole patient journey.

Other areas for further research could also include the four focus areas that APACMed set out to develop standardization and regulations for digital health and other aspects such as data sharing and incentives, and the results of its implementation across Asia Pacific countries.

The future researcher could also include industry 5.0 technologies and how countries are gearing up to prepare for them to be implemented in the healthcare industries.

25. Conclusion

The purpose of this exploratory qualitative study was to explore the general public and industry responses regarding the application of these innovation 4.0 technologies in Singapore's healthcare industry, as well as, to explore what is expected to be the future outlook of digital health in Singapore, and how the integrated use of IoMT, blockchain, digital health, telemedicine are likely to radically address the medical data integrity concerns. The researcher also discussed the use cases of common utilization of digital health medical data and the use cases and recommendation that could address the medical data integrity concerns of both groups of participants in Singapore.

The researcher collected data from 623 general public participants and 33 industry experts via questionnaires using closed-ended and open-ended survey questions.

The researcher utilized survey monkey and Microsoft excel software to analyze the data, visualize the research findings in the form of diagrams and tables to identify interdependences, and compare proportions, trends, and conjunctions. The analysis process will focus on the data distribution, specific values, and highest or lowest values as recommended by Saunders *et al*. (2019).

The researcher first extracted the data derived from the survey's open-ended questions with the support of excel files for the open-ended questions. The researcher then interpreted the textual responses to open-ended questions by working through question-by-question to identify the key themes that recur across different respondents; then the researcher read the responses to a specific question, looking for any themes that recur in their responses to each question.

In the presentation of the results chapter, the researcher then presented the data collected in two separate phases; phase one focusing on the data collected from the general public survey and phase two focusing on the data collected

from industry experts. The researcher correlated the data back to the key research questions that were set out in the research methodology chapter.

Next, the researcher discussed the inputs from the responders from both groups, how they answered the key questions, highlighting the themes of the results, and incorporating use cases from secondary sources, such as, journals and articles from consultancy firms and news articles. The researcher also discussed some of the recommendations for the concerns that the responders raised. The combination of perspectives from the general public and industry experts allows the study to compare the similarities and differences in the viewpoints on the same questions.

The results of this research could help organizations better incorporate the inputs from the responders and the recommendations discussed in this paper on the use cases of common utilization of digital health medical data and the use cases and recommendation that could address the medical data integrity concerns of both groups of participants in Singapore and likelihood to share their medical data with their employers and the willingness to subscribe to a platform that houses their data protected by encrypted codes that can only be accessed with the patients' explicit consent in Singapore and help to address the medical data integrity concerns to increase adoption of industry 4.0 technology in Singapore.

References

Agbo, C., Mahmoud, Q., and Eklund, J. (2019). Blockchain Technology in Healthcare: A Systematic Review. *Healthcare*, 7(2), 56. https://doi.org/10.3390/healthcare7020056

Ahmadi, V., Benjelloun, S., El Kik, M., Sharma, T., Chi, H., and Zhou, W. (2020). Drug Governance: IoT-based Blockchain Implementation in the Pharmaceutical Supply Chain. 2020 Sixth International Conference on Mobile And Secure Services (MobiSecServ). https://doi.org/10.1109/mobisecserv48690.2020.9042950

Al-Turjman, F., Nawaz, M.H., and Ulusar, U.D. (2020). Intelligence in the Internet of Medical Things era: A systematic review of current and future trends. *Computer Communications*, 150, 644-660. https://doi.org/10.1016/j.comcom.2019.12.030

Alblooshi, M., Salah, K., and Alhammadi, Y. (2018). Blockchain-based Ownership Management for Medical IoT (MIoT) Devices. 2018 International Conference on Innovations in Information Technology (I.I.T.). https://doi.org/10.1109/innovations.2018.8606032

Ang, P. (2021). Integrated Platform for Health Insurance Claims in Singapore in the Works. *The Straits Times*, March 15. https://www.straitstimes.com/singapore/health/call-for-proposals-to-develop-integrated-platform-for-health-insurance-claims

Bokolo, A. Jnr. (2020). Use of Telemedicine and Virtual Care for Remote Treatment in Response to COVID-19 Pandemic. *Journal of Medical Systems*, 44(7). https://doi.org/10.1007/s10916-020-01596-5

ChannelNewsAsia. (2019). HIV-positive status of 14,200 people leaked online. *ChannelNewsAsia; ChannelNewsAsia*, January 28. https://www.channelnewsasia.com/news/singapore/hiv-positive-records-leaked-online-singapore-mikhy-brochez-11175718

Chamola, V., Hassija, V., Gupta, V., and Guizani, M. (2020). A Comprehensive Review of the COVID-19 Pandemic and the Role of IoT, Drones, A.I., Blockchain and 5G in Managing its Impact. *IEEE Access*, 8, 1-1. https://doi.org/10.1109/access.2020.2992341

Chen, Y., Ding, S., Xu, Z., Zheng, H., and Yang, S. (2018). Blockchain-Based Medical Records Secure Storage and Medical Service Framework. *Journal of Medical Systems*, 43(1). https://doi.org/10.1007/s10916-018-1121-4

Creswell, J. (2002). *Educational Research: Planning, Conducting, and Evaluating Quantitative and Qualitative Research.* Prentice Hall.

Collis, J. and Hussey, R. (2009). *Business Research: A Practical Guide for Undergraduate and Postgraduate Students.* Palgrave Macmillan.

Duke-NUS. (2017). SingHealth, Duke NUS and GSK to Conduct Large-Scale Big Data Study on Asthma and COPD in Singapore, October 16. www.duke-Nus.edu.sg. https://www.duke-nus.edu.sg/allnews/singhealth-duke-nus-and-gsk-to-conduct-large-scale-big-data-study-on-asthma-and-copd-in-singapore

Farouk, A., Alahmadi, A., Ghose, S., and Mashatan, A. (2020). Blockchain platform for industrial healthcare: Vision and future opportunities. *Computer Communications*, 154, 223-235. https://doi.org/10.1016/j.comcom.2020.02.058

Feilzer, Y. M. (2009). Doing Mixed Methods Research Pragmatically: Implications for the Rediscovery of Pragmatism as a Research Paradigm. *Journal of Mixed Methods Research*, 4(1), 6-16. https://doi.org/10.1177/1558689809349691

General Insurance Association. (2021). Healthcare-Insurance Industry Pilot (HIIP). Gia.org.sg, March 15. https://gia.org.sg/project-hiip.html

Hassija, V., Chamola, V., Saxena, V., Jain, D., Goyal, P., and Sikdar, B. (2019). A Survey on IoT Security: Application Areas, Security Threats, and Solution Architectures. *IEEE Access*, 7, 82721-82743. https://doi.org/10.1109/access.2019.2924045

Hölbl, M., Kompara, M., Kamišali, A., and Nemec Zlatolas, L. (2018). A Systematic Review of the Use of Blockchain in Healthcare. Symmetry, 10(10), 470. https://doi.org/10.3390/sym10100470

GovTech. (2021). Refreshed Singpass reflects improved services and drives digital innovations with private sector, March 4. www.tech.gov.sg; Government Technology Agency. https://www.tech.gov.sg/media/media-releases/2021-03-04-refreshed-singpass

IHis. (2020a). HealthHub. IHis. https://www.ihis.com.sg/Project_Showcase/Mobile_Applications/Pages/HealthHub.aspx

Khan, A., Tham, M., and Tan, P. (2020). Sustaining the growth of digital health. Accenture.com; Accenture, October. https://www.accenture.com/fi-en/insights/health/finland-consumer-survey-2020

Kwang, K. (2018). A total of 1.5 million SingHealth patients' non-medical personal data were stolen, while 160,000 of those had their dispensed medicines' records taken too, according to MCI and MOH. ChannelNewsAsia; ChannelNewsAsia, July 20. https://www.channelnewsasia.com/news/singapore/singhealth-health-system-hit-serious-cyberattack-pm-lee-target-10548318

Javaid, M., and Haleem, A. (2019b). Virtual Reality Applications Toward Medical Field. *Clinical Epidemiology and Global Health*. https://doi.org/10.1016/j.cegh.2019.12.010

Javaid, M., Haleem, A., Vaishya, R., Bahl, S., Suman, R., and Vaish, A. (2020). Industry 4.0 technologies and their applications in fighting COVID-19 pandemic. *Diabetes & Metabolic Syndrome: Clinical Research & Reviews*, 14(4), 419-422. https://doi.org/10.1016/j.dsx.2020.04.032

Marbouh, D., Abbasi, T., Maasmi, F., Omar, I. A., Debe, M. S., Salah, K., Jayaraman, R., and Ellahham, S. (2020). Blockchain for COVID-19: Review, Opportunities, and a Trusted Tracking System. *Arabian Journal for Science and Engineering*. https://doi.org/10.1007/s13369-020-04950-4

Mesko, B. (2017). The Role of Artificial Intelligence in Precision Medicine. *Expert Review of Precision Medicine and Drug Development*, 2(5), 239-241. https://doi.org/10.1080/23808993.2017.1380516

MyDoc. (2021). MyDoc - Value-based digital health for better outcomes. MyDoc. https://my-doc.com/

Ow, J. (2021). Online Survey on the Future of Healthcare in Singapore (Industry Experts). Doctoral research work of Jezon Ow in partial fulfillment of the requirements for the DBA degree at the International School of Management of Paris.

Ow, J. (2021b). The future of healthcare in Singapore. How an integrated use of Industry 4.0 Technologies will radically redefine the industry, firms' business models, and the doctor-patient relationships, November 1. Papers.ssrn.com. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3965115

Ovais Subhani. (2020). Pandemic-driven medicine stockpiling to boost S'pore pharmaceutical exports, output: Report. *The Straits Times*, August 28. https://www.straitstimes.com/business/economy/pandemic-driven-medicine-stockpiling-to-boost-singapore-pharmaceutical-exports

Oztemel, E., and Gursev, S. (2018). Literature review of Industry 4.0 and related technologies. Journal of Intelligent Manufacturing. https://doi.org/10.1007/s10845-018-1433-8

Pezzuto, I. (2019). Making Healthcare Systems More Efficient and Sustainable in Emerging and Developing Economies Through Disruptive Innovation: The Case of Nigeria. *Journal of Management and Sustainability*, 9(2), 1. https://doi.org/10.5539/jms.v9n2p1

Qazi, S., Tanveer, K., ElBahnasy, K., and Raza, K. (2019). From Telediagnosis to Teletreatment. Telemedicine Technologies, 153-169. https://doi.org/10.1016/b978-0-12-816948-3.00010-6

Ray, P. P., Dash, D., and Kumar, N. (2020). Sensors for Internet of medical things: State-of-the-art, security and privacy issues, challenges and future directions. *Computer Communications*, 160, 111-131. https://doi.org/10.1016/j.comcom.2020.05.029

Rodrigues, J. J. P. C., De Rezende Segundo, D. B., Junqueira, H. A., Sabino, M. H., Prince, R. M., Al-Muhtadi, J., and De Albuquerque, V. H. C. (2018). Enabling Technologies for the Internet of Health Things. *IEEE Access*, 6, 13129-13141. https://doi.org/10.1109/ACCESS.2017.2789329

Rowley, J. (2014). Designing and using Research Questionnaires. *Management Research Review*, 37(3), 308-330. https://doi.org/10.1108/mrr-02-2013-0027

Salim, Z. (2021). The Evolution Of Singpass: How Our National Digital Identity Came About. Vulcan Post, April 23. https://vulcanpost.com/742359/evolution-of-singpass-national-digital-identity-singapore/

Saunders, M., Lewis, P., and Thornhill, A. (2019). *Research Methods for Business Students*.8th Edition Pearson Education Limited.

Schwab, K. (2016). The fourth industrial revolution: What it means and how to respond. World Economic Forum, January 14. https://www.weforum.org/agenda/2016/01/the-fourth-industrial-revolution-what-it-means-and-how-to-respond/

Schwab, K. (2019). Global Competitiveness Report 2019. In World Economic Forum. http://www3.weforum.org/docs/WEF_TheGlobalCompetitivenessReport2019.pdf

See, Q.Y. (2020). Attitudes and Perceptions of General Practitioners towards the National Electronic Health Record (NEHR) in Singapore. *European Medical Journal*, March 31. https://www.emjreviews.com/innovations/article/attitudes-and-perceptions-of-general-practitioners-towards-the-national-electronic-health-record-nehr-in-singapore/

Smart Nation. (2020a). Government's Personal Data Protection Laws and Policies. Smart Nation Singapore, December 15. https://www.smartnation.gov.sg/why-Smart-Nation/secure-smart-nation/personal-data-protection

Smart Nation. (2020b). Government's Personal Data Protection Initiatives. Smart Nation Singapore, December 2. https://www.smartnation.gov.sg/why-Smart-Nation/secure-smart-nation/pdp-initiatives

Sun, D. (2021). Fullerton Health vendor's server hacked; personal details of customers sold online. *The Straits Times*, October 25. https://www.straitstimes.com/singapore/courts-crime/fullerton-health-vendor-hacked-personal-details-of-customers-sold-online

Tan, A. (2021). Covid-19 test results, vaccination records now accessible in HealthHub mobile app. *The Straits Times*, February 21. https://www.straitstimes.com/singapore/health/covid-19-related-health-records-accessible-now-through-healthhub-mobile-app

Tanwar, S., Parekh, K., and Evans, R. (2020). Blockchain-based electronic healthcare record system for healthcare 4.0 applications. Journal of Information Security and Applications, 50, 102407. https://doi.org/10.1016/j.jisa.2019.102407

Tayarani-N., M.-H. (2020). Applications of Artificial Intelligence in Battling Against Covid-19: A Literature Review. Chaos, Solitons & Fractals, 110338. https://doi.org/10.1016/j.chaos.2020.110338

Teddlie, C., and Tashakkori, A. (2012). Common "Core" Characteristics of Mixed Methods Research. *American Behavioral Scientist*, 56(6), 774-788. https://doi.org/10.1177/0002764211433795

Yin, R. K. (2018). *Case Study Research and Applications: Design and Methods* (6th ed.). Sage Publications, Inc.

Yu, E. (2021). Singapore Spruces up e-government Platform, Touts Service Portfolio. ZDNet, March 4. https://www.zdnet.com/article/singapore-spruces-up-e-government-platform-touts-service-portfolio/

Cite this article as: Ow Jezon (2022). How the Utilization of Integrated Industry 4.0 Technologies will Radically Address Medical Data Integrity Concerns in Singapore. *International Journal of Artificial Intelligence and Machine Learning*, 2(1), 75-117. doi: 10.51483/IJAIML.2.1.2022.75-117.