DATABASE ASPECTS FOR A SINGLE PLATFORM TO TREAT AND CONTROL INFECTIOUS DISEASE USING HEALTHCARE METAVERSE AND DIGITAL TWINNING

BY

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List of Abbreviations

COPD	Chronic Obstructive Pulmonary Disease
CT	Computerized Tomography
DBDL	Database Design Language
DBMS	Database Management System
ECG	Electrocardiogram
ER	Entity Relationship
IDCT	Infectious Disease Control and Treatment
IOT	Internet of Things
MRI	Magnetic Response Imaging
NFT	Non-Fungible Token
PDT	Personal Digital Twin
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
RDBMS	Relational Database Management System
SQL	Structured Query Language
SUS	System Usability Scale

Keywords

Conceptual database design, COVID-19, Digital Twinning, Infectious disease, logical database design, Metaverse, Pandemic, Physical database design

Abstract

The recent global pandemic outbreak has reshaped our understanding of healthcare and the need for an effective management of an infectious disease outbreak scenario. This thesis embarks on a necessity requirement of proposing an architecture for treatment and control of infectious disease outbreak which would be helpful on creating the final artefact.

The thesis is structured in the following manner, introduction section presents the need of a platform to treat and control infectious disease, literature review chapter gives a comprehensive overview about existing literature regarding available methods on infectious disease control and treatment. The methodology section will present the structured approach taken to develop the proposed architecture and the results section will present the artifacts discovered after following the proposed methodology. Analysis section of the thesis will give a comprehensive overview of critical findings of the results, discussion section further interprets the results with original goals and additional findings, and the conclusion would contain the final reflection of the thesis.

One of the key factors behind extremely high mortality rate and economic impact during the last pandemic was the world was not prepared for an infectious disease outbreak. One single platform for infectious disease control and treatment is needed to effectively manage an infectious disease outbreak, because to effectively treat and control an infectious disease outbreak, multiple entities must work synchronously. This thesis contains an architecture with necessary entities to successfully treat and control an infectious disease outbreak using digital twinning and metaverse technologies.

Development of the architecture is done through following design science research methodology which is a six-step process for Information System artifact creation. The uniqueness of design science research is its iterative approach to systematically create the information system in such a way that it will bridge the gap between the problem at hand and the solution. Using the design science research methodology, the design and development phases are undertaken through the design of the database architecture. This encompasses conceptual design, logical design, and the physical designs of the proposed database.

During the analysis, it was observed that the data types required for the architecture can contain structured and unstructured data. Whether the database used is SQL or NOSQL there are certain advantages and disadvantages for both types of databases. Because of that the best option when it comes to the actual implementation is to use a multimodal database which can cater to SQL and NOSQL data. A list of recommended vendor databases is given in this thesis according to the analysis of the results.

The proposed architecture needs to be iteratively improved. Any entity that is required, attribute that is required, should be iteratively added until the final artifact is created. Hence, this is not the final architecture, it is an initial stage of a proposed architecture which should be iteratively improved in the future.

Declaration of Originality

I certify that this thesis:

1. does not incorporate without acknowledgment any material previously submitted for a degree or diploma in any university.
2. and the research within will not be submitted for any other future degree or diploma without the permission of Flinders University; and
3. to the best of my knowledge and belief, does not contain any material previously published or written by another person except where due reference is made in the text.

Signature: ____________________

Date: 2023.10.27

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Chapter 1: Introduction

This chapter outlines the background of infectious disease treatment and control, and context of the research, and its purposes. Section 1.1 describes the background of the research, section 1.2 delves into the context of the research, section 1.3 explores the purpose of the research and section 1.4 presents the significance of the research, section 1.5 covers the scope of the research, section 1.6 provides any definitions that are required, and finally section 1.7 presents the rest of the outline of the thesis.

1.1 BACKGROUND

Infectious disease outbreak can disrupt an entire country and even halt the worlds progression if there is no proper way to treat and control the disease. The last pandemic the world encountered was the COVID-19 outbreak and countries were not appropriately prepared to face the pandemic. COVID-19 was ranked as a leading cause of death during the years of the pandemic compared to cause of death prior to pandemic era, novel COVID-19 ranked only behind heart disease and cancer (Koh et al., 2021). The main reason for this staggering number is that there was lack of proper method to treat and control an infectious disease outbreak.

1.2 CONTEXT

The high mortality rate during a pandemic is main stemmed because of absence of an effective mechanism to treat and control infectious diseases (Madhav et al., 2018). The focus of this thesis is to propose an architecture for infectious disease control and treatment. This research falls under the research domain of digital twinning, healthcare metaverse, database design and infectious disease treatment and control.

1.3 PURPOSE

The main purposes of defining an architecture for the infectious disease control and treatment is as follows.

- Minimize the spread of the infectious disease.

If the spread of the infectious disease is controlled the impact of the infectious disease would be reduced. Hence, the proposed architecture should minimize the spread of the disease.

- Protection of the essential workers

  Essential workers are extremely important to combat an infectious disease outbreak because they are the people who ensure the healthcare sector runs smoothly, without collapsing. Hence, proper measures must be put in place to protect essential workers during an infectious disease outbreak.

- Reduce the chance of healthcare resources being depleted/exhausted.

  Healthcare resources such as hospitals, medication and vaccination can be depleted/exhausted during an infectious disease outbreak. So, proper monitoring of these medication and workers is vital to combat infectious disease.

- Training for healthcare professional

  When there is a new infectious disease outbreak in a country or a region the healthcare professionals should be properly trained to treat the disease. Hence, a knowledge base must be maintained to train healthcare professional for the new infectious disease.

- Multiple sectors need to collaborate to successfully face an infectious disease outbreak.

  Entities such as government, laboratories, healthcare professionals, medical device manufacturers, pharmacies must be in sync to effectively face an outbreak. Because of the actions, inputs and outputs of these entities must be monitored and controlled.

Through this proposed architecture all of the above purposes are fulfilled.

1.4 SIGNIFICANCE

The specific aim of this study is to propose a database architecture for infectious disease treatment and control through metaverse and digital twinning. The thesis would outline the proposed database architecture using a well-grounded database design methodology by systematically going through the conceptual design, logical design, and physical design of the proposed architecture (Connolly & Begg, 2015).

After the actual implementation of the proposed architecture, the proposed database after the full implementation will have the capability to effectively treat and control infectious disease. Significant outcomes of the proposed architecture are as follows.

- Treat and control through one single architecture
- Single platform to collaborate for healthcare workers, patients, government etc.
- Can simulate an infectious disease outbreak prior to the outbreak.
- Healthcare professionals can share the necessary knowledge and expertise.

1.5 SCOPE

This thesis encompasses the following scope.

Thesis does not discuss the digital twinning of the data, the data required is already digitally twinned. This means physical objects, systems, environment, and real time data has already been virtually represented. The architectural proposal is done through the conceptual design, logical design, and physical design phases of the database. The terms defined in this section is defined in the Definitions section.

1.6 DEFINITIONS

Following are the key terms that is iterated throughout the thesis. Below are the exact definitions of the conceptual design, logical design, physical design, digital twinning and metaverse.

- Conceptual design-The process of constructing a model of the data used in an enterprise, independent of all physical considerations (Connolly & Begg, 2015).
- Logical design-The process of constructing a model of the data used in an enterprise based on a specific data model, but independent of a particular DBMS (Database Management System) and other physical considerations (Connolly & Begg, 2015).
- Physical design-The process of producing a description of the implementation of the database on secondary storage (Connolly & Begg, 2015).

- Digital Twin-The Digital Twin is a digital copy obtained by modelling the state of a physical system, collecting data through sensors placed on these systems, and reflecting this data into digital media (Erol et al., 2020)
- Metaverse- A three-dimensional online environment in which users represented by avatars interact with each other in virtual spaces decoupled from the real physical world (Ritterbusch & Teichmann, 2023)

The terms Conceptual design, Logical design and Physical design is used to propose the architecture of infectious disease treatment and control using healthcare metaverse and digital twinning.

1.7 THESIS OUTLINE

Rest of the thesis outline is as follows.

Chapter 2 consists of the literature review of the chosen topic, Chapter 3 presents the methodology section of the thesis, which was done through design science research methodology, Chapter 4 presents the results of the thesis after following the methodology, Chapter 5 would be the analysis of the results, Chapter 6 would be the further discussion of the thesis and finally Chapter 7 outlines the conclusions of the thesis.

Chapter 2: Literature Review

This literature review was done in the form of a scoping review and this chapter is structured as follows.

Section 2.1 of this chapter defines the procedure of identifying the keywords for the search query and search criteria which consists of choosing appropriate databases, inclusion and exclusion criteria and finally arriving at the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) diagram. After analysing of the literature, the literature was grouped into three primary categories.

In section 2.2 use of digital twinning in infectious disease treatment and control is identified, in section 2.3 use of metaverse in infectious disease treatment and control is identified, and in section 2.4 proposed architectures for control and treatment for infectious disease are identified. Finally in section 2.5, summary and implications of the review is presented.

2.1 SCOPING REVIEW

Systematic literature planner was used for deciding on the search query and selecting on the databases (Refer Appendix A). Following the systematic literature planner Science Direct, PubMed, IEEE and Google Scholar databases were used as the databases. Google scholar results were removed as it gave out lot of unnecessary results.

Below query was chosen as the search query to conduct this review.

("Pandemic" OR "Infectious" OR "COVID") AND ("Healthcare" OR "Health System") AND ("Metaverse" OR "Digital Twins") AND ("Treatment" OR "Control")

Main concepts that were used for the thesis were used as keywords in the search query. Since the most recent infectious disease that turned into a pandemic was COVID-19 lot of articles interchanged their keywords to COVID-19 instead of "Pandemic" or "Infectious disease". Hence, to capture all these results "Pandemic", "Infectious" and "COVID" key words had to be used together. Since, "Healthcare" and "Health System" keywords were used interchangeably in articles, these two key words had to be used together using an "OR" operator in the search string. Since the thesis aimed to capture the metaverse and digital twin usage for the infectious disease treatment and control, the "Metaverse" and "Digital Twins" key words were used together using an “OR” operator as well. Most of the scholarly articles only contained the treatment aspect or the control aspect of the infectious disease. Hence, “Treatment” and “Control” keywords were used together to capture both.

Please refer Appendix-A for the process of selecting the search query in detail.

From searching the databases, the search result was amounted to 32 total articles. Articles that were published during the last 5 years were only considered in this scoping review.

From Science Direct data base total of 19 articles, 7 articles from PubMed and 6 articles form IEEE were filtered out.

When analysing, two articles were filtered out due to a duplicating literature. After reading the Title and abstract 5 articles were removed because they were not relevant for the research topic.

After defining the following inclusion and exclusion criteria, further 5 articles were removed. Defined inclusion and exclusion criteria are as follows.

Table 1: Inclusion and Exclusion Criteria

Inclusion Criteria	Exclusion Criteria
Treatment of infectious disease using Metaverse or Digital Twining	Not in English
Control of infectious disease using Metaverse or Digital Twinning	Agriculture related
Architectures that are used treat or control infectious disease outbreak	Regarding ethics/Legislative
	Relating to the Cybersecurity domain
	Not related to supply chain (Mainly addresses the chemical aspect of product manufacturing)
	Leaning towards neuroglial and habitual issues. Not relevant to infectious disease
	Telerehabilitation is discussed through statistical analysis across different demographics. Not relevant when discussing about an infectious disease
	Addresses about the supply chain but it is leaning towards decision making of allocation of resources
	This is regarding mask personalization, hence not relevant
	Post covid-19 and Prioritize 6G development

After applying the inclusion and exclusion criteria to the articles, total of 19 articles were used to conduct the scoping review. The PRISMA diagram of the filtering process is as follows.

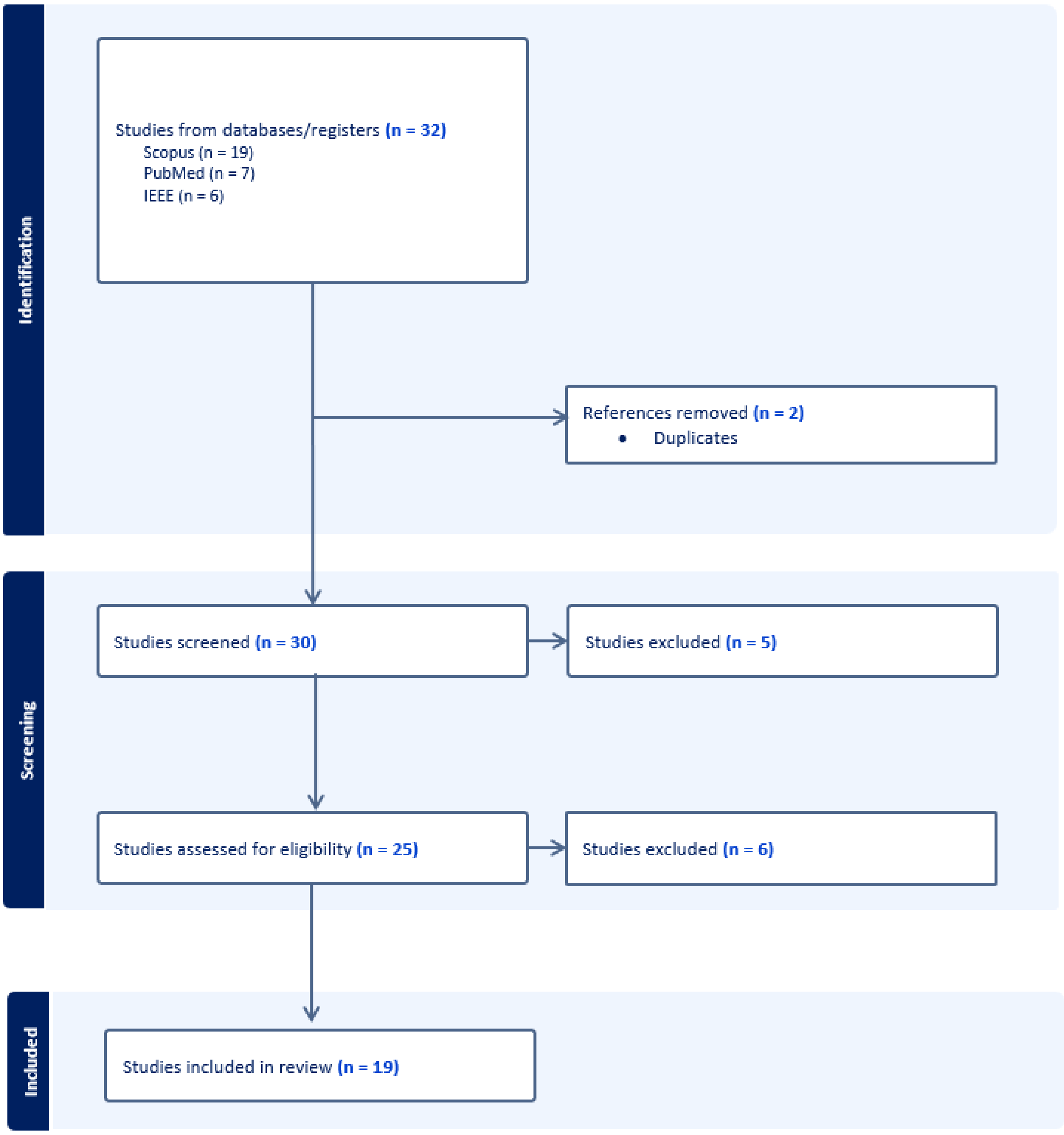

Figure 1:PRISMA diagram

After analysing the 19 articles the results were categorised into 3 sections as follows,

1. Use of Digital Twinning in infectious disease treatment and control
2. Use of Metaverse in infectious disease treatment and control
3. Proposed Architectures to control and treat infectious disease.

Finalised articles that were chosen for the scoping review is as follows,

Table 2: Summary Of Reviewed aticles

Title	Summary	Category
Digital Twins in Healthcare: an architectural proposal and its application in a social distancing case study (Benedictis et al., 2022)	Architecture for social distancing using digital twinning is used to reduce Covid-19 spread. Name of the proposed architecture is "CanTwin" architecture.	Use of Digital Twinning in infectious disease treatment and control
Metaverse and Personal Healthcare (Song & Qin, 2022)	Population density monitored when infected people come to proximity, HL7 diagram is provided on how data acquisition happens using sensors and mobile applications.	
The Digital Twin Revolution in Healthcare (Erol et al., 2020)	With Digital Twinning the hospitals department resources could be viewed from a broader perspective. Digital Twinning is used to model the radiology department, and then real time data was fed into this model which in turn reduced the patient time on CT scan and MRI scan.	
Integrating Digital Twins and Deep Learning for Medical Image Analysis in the era of COVID-19 (Ahmed et al., 2022)	Digitally twinned medical devices enable the capability to check whether the actual physical devices are working properly. This could be used to check whether the actual physical device is working properly.	
Building digital twins of the human immune system: toward a roadmap (Laubenbacher et al., 2022)	Stated how digitally twinned computer simulations could monitor changing conditions and predict catastrophic situations	
Digital Twin Roles in Public Healthcare (Rasubala & Tjahyadi, 2022)	Presented how digital twins can identify lung diseases such as Chronic Obstructive Pulmonary Disease and lung cancer.	
Non-invasive devices for respiratory sound monitoring (Troncoso et al., 2021)	Presented how electronic stethoscope and smart wearables could monitor respiratory sound. These could be used for the digital twin creation phase.	
The novel emergency hospital services for patients using digital twins (Aluvalu et al., 2023)	Stated how digital twinning and blockchain technologies start fast collaboration between hospitals	

	which is important during an infectious disease outbreak.	
Digital twin-driven robust bi-level optimisation model for COVID-19 medical waste location-transport under circular economy (Cao et al., 2023)	Proposed a digital twin driven optimized way of disposing medical waste to prevent the spread of COVID-19	
Public interest in the digital transformation accelerated by the COVID-19 pandemic and perception of its future impact (Park et al., 2022)	Presented information about development of metaverse technologies during the pandemic period.	Use of Metaverse in infectious disease treatment and control
The metaverse in current digital medicine (Sun et al., 2022)	Presented the steps on how to build a medical metaverse and how the medical metaverse development accelerated during the pandemic period.	
Challenges of The Metaverse Adoption for the Health of the Elderly: Case in Surakarta (Nugroho et al., 2022)	Presented the challenges using the metaverse by elderly and how it can be resolved through proper training.	
The paradigm and future value of the metaverse for the intervention of cognitive decline (Zhou et al., 2022)	Has mentioned how COVID-19 demanded the non-face to face healthcare. Explained about the SINSO project which is decentralized medical infrastructure model which uses Non-Fungible Tokens (NFTs).	
CardioVerse: The cardiovascular medicine in the era of Metaverse (Skalidis et al., 2022)	Discussed about the cardiovascular remote consultation, education, and privacy issues. Proposed a method to store the EMR in a personalized Non-Fungible Tokens (NFTs).	
Personal Digital Twin: A Close Look into the Present and a Step towards the Future of Personalised Healthcare Industry (Sahal et al., 2022)	Presented a high-level architecture of infectious disease control and treatment. Government, hospitals, and infected people are involved in the architecture.	Proposed architectures to control and treat infectious disease.
Harnessing the Power of Smart and Connected Health to Tackle COVID-19: IoT, AI, Robotics, and Blockchain for a Better World (Firouzi et al., 2021)	Presented a Personal Digital Twin (PDT) architecture which provides the complete view of healthcare data by synchronising sources such as clinical records, electronic telerecords, IOT devices, smart wearables, and social media.	
Telemedicine System Based on Mixed Reality and Cognitive Speech Service Technologies (Lin et al., 2022)	Presented a system where telemedicine consultation is done through mixed reality integration.	

Decision Support Collaborative Platform for e-Health Integration in Smart Communities Context (Caramihai et al., 2022)	Proposed a decision support collaborative platform for e-Health integration in smart communities. This architecture was mainly proposed to support make appropriate decision making during pandemic period.	
COVID-19 outbreak and the role of digital twin (Alrashed et al., 2022)	Presented the different extraction levels required for digital infrastructure and the importance of the overview visibility for the government when its decision making during a pandemic scenario.	

2.2 USE OF DIGITAL TWINNING IN INFECTIOUS DISEASE TREATMENT AND CONTROL

In this section previous literature that was published to treat and control infectious disease using digital twinning would be identified.

Digital twinning could be used to model an infrastructure and the inhabitant's behaviour within that location. In terms of infectious disease, social distancing is a method of reducing the spread within the community and it could be done using digital twinning. Benedictis et al. (2022) has used digital twinning to control the spread of COVID-19 in a canteen service. This case study was done and developed by '"Hitachi Rail" and was able to digitally twin the canteen service which had 1100 workers (Benedictis et al., 2022). The proposed architecture by Benedictis et al. (2022) is named as "CanTwin" architecture and mainly address how digital twinning was used to resolve the social distancing issue in this specific case study. Further to the social distancing application Benedictis et al. (2022) have explained different layers of the digital twinning process. These are the physical layer, data layer, digital twin layer, connectivity layer, security layer and service layer.

According to Song and Qin (2022) in a pandemic scenario the population density can be monitored and the when infected people come to close proximity a warning can be generated and issued. The article also emphasised the use of blockchain technology to protect the sensitive data within the healthcare sector. Song and Qin (2022) has given out the HL7 diagram on how the data acquisition happened through sensors and mobile apps.

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Figure 2:A Layered Model of digital twin for healthcare (Song & Qin, 2022)

Through this layered model the electronic health records, patient health records, sensor data, user inputs and mobile application inputs can be digitally replicated.

Erol et al. (2020) stated that the COVID-19 pandemic has intensified the demand for hospital during the pandemic process and the digital twinning could be used do get a broad perspective about the resources within the hospital. Erol et al. (2020) predicted that the use of digital twinning would be widespread and would be used to solve the management problem of the hospital system in the future. Erol et al. (2020) has published a digital twin study about "Siemens Healthineers" to improve the hospital process due to high patient demand. During this study, digital twin of the radiology department was fed with the real data. After feeding this data to the digital twin the patient time for the CT scan and MRI scan was drastically reduced.

Ahmed et al. (2022) has proposed a digital twin based smart healthcare system to detect COVID-19 virus. The developed system is using deep learning to detect COVID-19 virus in the infected lungs of patients through x-ray images.

Image removed due to copyright restriction. Original can be accessed at: https://www.sciencedirect.com/science/article/pii/S2096579622000183

Figure 3: Digital twin concept for analysing and detecting COVID-19 (Ahmed et al., 2022)

Ahmed et al. (2022) proposed digital twinning method is suited to monitor the device status and predict the device maintenance requirements. In the figure above the actual lung image of the patient is gathered from the patient and pre-processed to detect the results with the help of training data and testing data (Ahmed et al., 2022). While the digital twin of the virtual device will go through a virtual deep learning model to predict whether the actual physical device gave an accurate result of the patient (Ahmed et al., 2022). If there is a deviation of the results the device should need maintenance. This would be helpful to the hospital staff because they can manage the down time of the available medical device (Ahmed et al., 2022).

Laubenbacher et al. (2022) mentioned that the newly established "DigiTwin Consortium" which consists of academics and industry leaders from 32 different countries expect to develop digital twins for each European citizen for variety of ailments. Further to that according to Laubenbacher et al. (2022), digital twin computer simulations could predict how devices would function under different conditions and this could be used to forecast downtime and maintenance of the equipment which would avert disastrous situation like unexpected downtime. This would be particularly helpful for a pandemic scenario in a country to predict downtime and plan for maintenance.

Rasubala and Tjahyadi (2022) presented the relation of digital twinning to assist lung disease diagnosis. Rasubala and Tjahyadi (2022) discussed how digital twinning would be used to diagnose Chronic Obstructive Pulmonary Disease (COPD) and as well as lung cancer. Chronic Obstructive Pulmonary Disease (COPD) is diagnosed through high quality electrocardiogram (ECG) sensors; it will monitor the patient’s heart rate as the present status of heart rate. As per the lung cancer, researchers are trying to find out methods to find out most effective methods of radiation treatments (Rasubala & Tjahyadi, 2022). To do precise modelling of the most effective method of lung cancer treatment a team in Auckland Bioengineering Institute tried to develop a lung model that imitate the patient’s lung function (Rasubala & Tjahyadi, 2022). Since COVID-19 is also considered a lung disease the lung diseases diagnosis can be also applicable to COVID-19 type of infectious disease (Rasubala & Tjahyadi, 2022).

Troncoso et al. (2021) has proposed a non-invasive method of monitoring respiratory sounds in a digital twin system for personalized health. Non-invasive respiratory sound acquisition method that is proposed is through electronic stethoscope, sound acquisition devices, wearable IOT devices and mobile phones (Troncoso et al., 2021). Smart phones are mainly used to record long hours and detect disorders and to deploy applications to illness diagnosis. Wearable IOT devices would be used to monitor the continuous state of the respiratory system (Troncoso et al., 2021).

Aluvalu et al. (2023) has proposed a novel method for hospital services for patients using digital twins. It states that the digital twins have a fast start collaborating with different hospital stakeholders and systems. Blockchain technology was proposed to communicate and update the data among digital twins of the ER ward. Patient’s details, Treatment plans, Insurance Claims, Health Reports to Personal Health experts, Insurance Claims Companies and Family Members details were updated using the blockchain in Aluvalu et al. (2023)

Cao et al. (2023) has proposed a digital twin driven optimized way of disposing medical waste to prevent the spread of COVID-19. This proposed optimization model from Cao et al. (2023) will provide decision support for the government and the healthcare authorities combat the infectious disease outbreak.

2.3 USE OF METAVERSE IN INFECTIOUS DISEASE TREATMENT AND CONTROL

In this section previous literature that was published to treat and control infectious disease using metaverse would be identified.

Park et al. (2022) has conducted a survey through Google trends data during the pandemic period regrading search interests on key technologies during digital transformation. Park et al. (2022) observed that the most of the key technology areas such as "cloud', "big data" and "coronavirus" showed negative correlation whereas the "metaverse" was the only key term that showed a positive correlation as the pandemic progressed.

Sun et al. (2022) has explained how medical metaverse will go through four different stages. Those are the creation of holograms, hologram simulation, combining the virtual and actual worlds, and the linking the virtual and real world. According to Sun et al. (2022) the COVID-19 outbreak has accelerated the research in medical metaverse as a pandemic would require mass population screening, contact tracing, managing the vaccine and drug supply chains, telemedicine consultations, and e-commerce. Even though the pandemic has accelerated the development of the medical metaverse Sun et al. (2022) emphasise the importance of the security aspect of the medical metaverse. Because the medical metaverse is using technologies such as internet and cloud the patient's privacy is at risk

Another case study was conducted by Nugroho et al. (2022) on challenges of metaverse adoption for the health of the elderly. The case study was conducted among 31 elderlies from aged care centre in Surakarta, Indonesia. Research was conducted through quasi-experimental method to obtain the data. This research from Nugroho et al. (2022) has concluded that to metaverse adoption is extremely beneficial for the elderly during the pandemic duration. But with the case study it was identified that the elderly have very minimal idea of the healthcare metaverse of any other digital health solution. But after proper training was conducted, the adoption of the metaverse has increased in the aged care sector (Nugroho et al., 2022).

Zhou et al. (2022) has mentioned that COVID-19 has demanded the increase of non-face to face healthcare. Zhou et al. (2022) has explained on how to establish a metaverse platform in medicine which requires technologies such as digital twins, internet of things and extended reality. Mirroring of the real world is done through the digital twinning and it act as the basis of the medical metaverse and internet of things would be the sensor entrance for the virtual world (Zhou et al., 2022). As an example, Zhou et al. (2022) mentioned about a project called SINSO which is a decentralized medical infrastructure model where patients could be quickly matched with an expert for consultation. The user data with the SINSO network was converted into non-fungible tokens (NFTS).

Skalidis et al. (2022) has also mentioned that the recent pandemic has brough the adoption of patient care from distance and this new trend has triggered the massive leaps in development in domains of telemedicine virtual reality and augmented reality. Skalidis et al. (2022) also discussed the opportunities that metaverse gives to the healthcare comes with whole new set of challenges. Mainly Skalidis et al. (2022) presented the privacy and security concerns of metaverse and methods on how it can be resolved through the decentralized service such as block chain. Skalidis et al. (2022) mentioned that, to resolve the privacy concern of the metaverse in healthcare how the adoption of storing patient data in non-fungible tokens (NFTs). Non-fungible tokens are considered as certificates of authenticity for a patient and has the capability of holding various data of the patients such as medical history, treatment plan and transactions (Skalidis et al., 2022).

2.4 PROPOSED ARCHITECTURES TO CONTROL AND TREAT INFECTIOUS DISEASE

This section contains details about the identified architectures for infectious control and treatment.

Sahal et al. (2022) has proposed a Personal Digital Twin (PDT) concept to protect against covid-19.

Image removed due to copyright restriction. Original can be accessed at: https://pubmed.ncbi.nlm.nih.gov/35957477/

Figure 4:PDT Collaboration for mitigating COVID-19 contagion(Sahal et al., 2022)

This proposed diagram has entities such as governments, healthcare organizations, hospitals, infected patients, potential infected patients, doctors, and pharmacies. These entities are divided into 3 main subcategories as personal participants, decision making participants and operational participants. Information about infected and potential infected patients would be fed to the blockchain network and the data would be sent to the operational participants to treat and distribute medication. The details would be sent to the decision-making participants to decide whether a lockdown is necessary (Sahal et al., 2022).

Image removed due to copyright restriction. Original can be accessed at: https://ieeexplore.ieee.org/document/9406879

Figure 5:Schematic of the use of PDT in epidemic control (Firouzi et al., 2021)

Firouzi et al. (2021) has proposed that Personal Digital Twins (PDTs) architecture that would provide complete view of the healthcare data by synchronising all sources of data. As the sources of data, it included data such as clinical records, publicly available data, electronic telerecords, IOT devices, wearable devices, and social media. In the above proposed architecture, the healthcare institution will set the parameter that needs to be monitored from the personal digital twins and if it exceeds a certain threshold, from the global analytics Authorities and Healthcare Institutions will enforce the restrictions to the given area (Firouzi et al., 2021). Through an architecture like this Firouzi et al. (2021) has mentioned following advantages such as Self-Generation of Alerts, widespread analytics, clearer focus, lower cost, greater adaptability, better personal awareness, quicker feedback, reduced effort, service development, better resource use and faster triage.

Lin et al. (2022) states that the COVID-19 pandemic, limited medical facilities and increased amount of patients who live in isolation has increased the demand for remote access systems with hybrid reality technologies. Lin et al. (2022) proposed an architecture where the consultation process is recorded and converted into speech using azure cognitive voice service.

Image removed due to copyright restriction. Original can be accessed at: https://ieeexplore.ieee.org/document/9944986

Figure 6: System operation flow chart (Lin et al., 2022)

The figure above shows how the architecture proposed by Lin et al. (2022) conduct remote consultations from a distance. The proposed system can be divided into two sections, one part is the patient side where patient use Azure Kinect DK for telemedicine purposes (Lin et al., 2022). Azure Kinect DK is a sensor that provides computer vision and speech models. The other section is doctor's side which is comprised with HoloLens 2 which is a head mount which is used for mixed reality. The architecture proposed uses a SQL database to store all the required details of the registered patients. the Communication happens through Microsoft teams and after the symptom description happens between doctor and the patient, voice to text is used for result generation and then prescription printing through another application. HoloLens 2 is in the doctors end to zoom in and out of organs models and x-ray results, through eye tracking and gesture recognition capabilities (Lin et al., 2022).

Caramihai et al. (2022) has proposed a decision support collaborative platform for e-Health integration in smart communities. This architecture was mainly proposed to support make appropriate decision making during pandemic period.

Image removed due to copyright restriction. Original can be accessed at: https://www.sciencedirect.com/science/article/pii/S1877050922020026

Figure 7: Proposed components of healthcare sub-systems (Caramihai et al., 2022)

The main stakeholders who interact with the healthcare sub-system are patients, integrated physicians and the medical resource centre(MRC). Caramihai et al. (2022) stated the importance of the research in medical systems because during the pandemic period if the health care data was transferred into useful information the decision-making process of the healthcare sector would have been efficient (Caramihai et al., 2022).

Image removed due to copyright restriction. Original can be accessed at: https://pubmed.ncbi.nlm.nih.gov/35002471/

Figure 8: Digital twin-based government framework (Alrashed et al., 2022)

Alrashed et al. (2022) has stated that the implementation of digital twin can assist the government and be well prepared for unforeseen crisis. Alrashed et al. (2022) has proposed four levels of data extraction which needs to feed into the digital infrastructure. Those are the individual, organizational, e-government and strategic. All the four levels as seen as in the above figure should be used to act efficiently as possible. The individuals need to relate to other entities so that the monitoring of COVID-19 can be done in real time (Alrashed et al., 2022).

At organizational level entities such as hospitals, factories and offices are monitored. In the third level authorities like Health Ministry, Interior Ministry and Education Ministry are placed, top leadership is the decision makers of the region which is the fourth level of the framework (Alrashed et al., 2022).

2.5 SUMMARY AND IMPLICATIONS

From the literature published it is seen that the digital twinning is most prominent method of treatment and control of infectious disease because from the scoping review conducted it was identified 10 articles were purely dedicated for digital twinning. Digital twinning has been used to make sure social distancing is achieved, resource management, medical equipment status monitoring, lung disease diagnosis, faster collaboration among hospitals and waste management.

Compared to digital twinning, the user of metaverse for infectious disease control and treatment is less. Even though Park et al. (2022) mentioned the metaverse is the most used term when during the pandemic period, metaverse development in the academic world is comparatively less. It is observed there is lot of work that is needed to be done in the medical metaverse world available technology is not sufficient to catch up with concepts. But from the case studies which Nugroho et al. (2022) conducted, it is seen that proper training must be conducted for the patients before usage of the medical metaverse; because people which are not well versed in technology may not be used on medical metaverse. Skalidis et al. (2022) and Aluvalu et al. (2023) has emphasised the ethics of using digital twinning and metaverse because of the sensitiveness of the data. The implications are that the patient data or any other sensitive data should be stored in non-fungible tokens (NFTs).

All the published articles discussed the architectures proposed were in high level diagrams. Even these high-level diagrams descriptions are extremely vague for the both the treatment and control aspects for infectious disease. Proposed architecture only covered one aspect of the treatment and control. There was no single architecture to treat and control the infectious disease. As per the architectures proposed in the published articles, none of the proposed architectures were found where both the digital twinning and metaverse is being used.

None of the architectures published discuss about the database aspect of the platform. Only available literature that mentions about the database is the article by Lin et al. (2022), and even that merely mentions the use of SQL database within that architecture. Identification of the potential database vendors and the disk capacity estimation was identified as an important requirement for the developers as well as the management. This is because the type of database vendor that is used and the disk size estimation directly correlates with the cost of the solution.

The literature review was helpful when identifying necessary entities and relationships to be considered when developing the database design. From the architectures proposed by Sahal et al. (2022),Firouzi et al. (2021),Caramihai et al. (2022) and Alrashed et al. (2022) it was seen that the need for the overview status of pandemic outbreak would be necessary, especially to entities such as Government and Healthcare Authorities of that country or region. This is because the regulations and rules that is imposed by the government must be swiftly applied to the healthcare system to effectively manage the pandemic. When creating the architecture, the overview view of the system is made available for healthcare authorities and the hospitals as well, for them to make informed decisions regarding the pandemic.

Chapter 3: Methodology

The content of this Methodology chapter is outlined below.

In section 3.1 methodology and research design employed would be presented, in section 3.2 the participants of the research would be identified, in section 3.3 instruments that were used would be covered, in section 3.4 procedure and timeline of the thesis is described, in section 3.5 the analysis of the results is done after the full implementation of the architecture is explained and finally in section 3.6 ethics and limitation that might be encountered in the research is presented.

3.1 METHODOLOGY AND RESEARCH DESIGN

3.1.1 Methodology

Since the thesis intended output is providing a conceptual architecture Design Science Research Methodology was chosen because its iterative nature which allows to refine the artifact based on the evaluation and communication steps of the design science creation (Peffers et al., 2007). Further to that, design science research is known to be used for information system creation in the research community for design, development, and evaluation of the artifacts (Hevner & Chatterjee, 2010; Hevner et al., 2004).

Image removed due to copyright restriction. Original can be accessed at: https://link.springer.com/chapter/10.1007/978-1-4419-5653-8_2

Figure 9: Design Science Research Methodology (Hevner & Chatterjee, 2010)

Design Science Research consists of six steps (Peffers et al., 2007).

1. Identify problem and motivation.
2. Define objectives of the solution
3. Design and development
4. Demonstration
5. Evaluation
6. Communication

In the Research design section of this chapter, the thesis discusses how the Design Science Research Methodology is applied for the context of the thesis.

3.1.2 Research Design

Following the design research methodology, the following were undertaken in each step of the design research methodology.

1. Identify problem and motivation.

   In this step problem identification and justification of the value of the solution would be discussed (Peffers et al., 2007). Problem identification and motivation for infectious disease and treatment through healthcare metaverse was identified through the literature review of the thesis.

2. Define objectives of the solution

   Through the identified problems the knowledge what is possible and feasible objective of the solution is presented (Peffers et al., 2007). To do this current problem and solutions in the infectious disease treatment and control is needed. This was done in step 1 of the design science research methodology.

3. Design and development

   Design and development section of the research is done through the database design methodology of Connolly and Begg (2015). Which is divided in to three subsections as Conceptual design, logical design, and physical design.

4. Demonstration

   Demonstration of the artifact would be done through user transactions of the conceptual design. User transactions means querying and updating data from the database. This would demonstrate the basic functionality of the database as it is the most suited method for the currently available version of the designed artifact.

5. Evaluation

   Objective of the solution and the outcome of the artifact will be compared. The relevant performance metrics would be decided to evaluate the database model. Based on this the artifact should be evaluated (Peffers et al., 2007).

   In the case of the artifact proposed as it is still in the conceptual stage, after the complete development is done evaluation of the information artifact could be done in form of a survey and a sample evaluation survey is provided.

6. Communication

   The final artifact and the steps of the design process should be published and distributed to the research community. In the context of this research successful completion of this thesis and any publication that would be done in the future would be considered as the communication step of the methodology.

3.2 PARTICIPANTS

After full development of the artifact there would be involvement of multiple participants. Involvement of the participants occur during the evaluation stage of the design science research where the participants would evaluate the proposed conceptual design, logical design, and physical design. Intended participants would be as follows:

- Doctors
- Patients
- Laboratory assistants
- Government regulators
- Medical equipment manufacturers
- Hospital administrators

The evaluation survey of the artifact would be distributed among above participants to get the comments about the functionality of the system and iterate the design with suitable amendments.

3.3 INSTRUMENTS

In design science research methodology, one of the steps is the evaluation step that is required to evaluate the current artifact to make suitable amendments until to develop a newer version of the artifact.

For this in Appendix-B, System Usability Scale (SUS) was used to the get necessary inputs from the participants which were mentioned in section 3.2. SUS provides a quick and reliable measure of usability, making It a valuable tool for UI/UX assessment (Brooke, 1996). According to the feedback of the survey conceptual design, logical design and physical design would be redeveloped until objectives of the developed architecture is met.

3.4 PROCEDURE AND TIMELINE

Problem and motivation identification and defining objectives of the solution phases of design science research was done through literature review section. Past literatures were analysed and there after problems, motivations and objectives of a solution was identified.

During the design and development phase of the research the main procedure employed for developing the artifact was developing database design of the proposed Infectious Disease Treatment and Control platform (IDCT). When proposing the architecture, the conceptual design, logical design, and physical designs of the architecture were developed. Demonstration of the developed artifact was done through using user transaction pathways which tests out the database from querying and updating data from the database. Evaluation of the architecture would be done from the survey, which was developed, which can be used after the complete implementation of the platform. Communication of the research would be done through the completion of this thesis and any future publications.

3.5 ANALYSIS

After the full implementation of the proposed platform, following outcomes could be observed for few of the below scenarios.

Scenario 1- Number of patients entering the hospital has increased due to the ongoing pandemic outbreak.

Through the platform itself patients would be able to get an initial assessment of their symptoms and if the symptoms are severe the patients would be granted the access to the hospital. But if the symptoms are not severe and visiting the hospital is not necessary, the patient would get the necessary treatment from the telemedicine capability from the platform. This would drastically reduce the human traffic entering the hospital and risk of being infected.

Scenario 2- Medical equipment that would be essential for the treatment of infectious disease had an unexpected maintenance requirement.

The platform has digitally twinned the medical devices and would be able to predict unexpected breakdowns or notify when there is a deviation in the proper functionality. This would give the capability to the hospital administration to plan and do the necessary maintenance.

Scenario 3- The government or healthcare authorities have imposed new regulations to combat and control the infectious disease outbreak but there is a delay when hospitals comply to these rules.

The platform has the capability for the government or healthcare authorities to impose the new regulations to the system. Since the government/healthcare authorities have the single pane of view of the overall system, they can check whether the new regulations that have been imposed are properly implemented in the system. Furthermore, this capability would drastically reduce the decision-making delay by the authorities.

Scenario 4- There is a shortage of medication within a hospital that is essential to treat the infectious disease.

Since the hospital administration and the healthcare authorities have a single pane of view of the medication availability such as vaccines, the authorities have the necessary information to make sure that there is no lack of medication required for the hospitals in that region.

Statistical analysis could be done after full implementation on all the above scenarios and check how the platform affected the human traffic, maintenance down time and medical inventory status. This thesis would not cover the actual statistical analysis as it is currently out of scope.

3.6 ETHICS AND LIMITATIONS

Ethical handling patient data is extremely important in the fully developed architecture and must adhere to relevant privacy and regulations in the country where it would be deployed. If the platform is deployed in Australia it must comply with Australian compliance and regulatory acts in Australia. For an example the system must adhere to Privacy act (1988), Notifiable Data Breaches scheme and Healthcare identifiers act 2010 when using patient data within patient metaverse. There would be further compliance required according to the state or the region of the system deployment.

When the actual implementation occurs the metaverse may occur technical challenges because the relevant technologies for metaverse is not fully developed yet. Further to that, after the full implementation of the platform, some patients still may desire the human element of patient care. Hence there may be some reservations during the initial stage of the platform release.

Chapter 4: Results

Results section of this thesis is structured according to the outcomes of following the design science research methodology. Firstly, section 4.1 identified the problem and motivation for a necessity of an architecture to be developed, then the section 4.2 defined what is the objective of a solution for the problems and motivations identified in the previous step. Section 4.3 is the design and development step of design science research, in this step the scoping of the architecture, conceptual design, logical design and physical design of the required database is developed. Section 4.4 is the demonstration step of the proposed architecture is presented, in section 4.5 evaluation of the architecture is done and finally section 4.6 described regarding the communication method of the proposed architecture following design science research methodology.

4.1 STEP 1- IDENTIFY THE PROBLEM & MOTIVATION

Problem and motivation identification phase is the first step of the design science research methodology and on this step the problems and motivations are identified during an infectious disease outbreak.

One of the reasons the most recent pandemic, COVID-19, caused immense havoc is the lack of effective disease control and treatment measures. If there was a proper method to control and treat the outbreak large number of lives would have been saved and impact on the economy would have been far less (Alrashed et al., 2022). Another problem during an infectious disease outbreak is that the healthcare facilities would be overcrowded and the rush for the healthcare services will further, increase the spread. Some rural areas may not have necessary facilities and experienced doctors to identify or treat an infectious disease. Hence, this may lead to delayed diagnosis and treatment of the infectious disease. During an outbreak multiple sectors must work synchronously, and proper decision making must be made, if not it would adversely impact the country or the region. For an example, if the rules and regulations that were brought up by the government or healthcare authorities were not properly imposed to the hospitals, the entire system would be not functioning as intended.

Because of the above identified problems, necessary motivation for a development of an artifact/ architecture was identified. Main motivation is to improve the treatment and control aspect when an infectious disease outbreak happens. This means effective healthcare services, reduce the rush towards hospital during an outbreak, enhancing the access for underserved population which does not have the sufficient facilities and resources, effective monitoring of resources such as medical equipment, and proper communication among entities for the most suitable decision making.

4.2 STEP 2-DEFINE THE OBJECTIVE OF A SOLUTION

Step 2 of the design science research methodology is defining the objectives of proposing an architecture/artifact for infectious disease treatment and control through metaverse and digital twinning. These defined objectives will be fulfilled by the proposed architecture.

Proposed platform would be built in such a way that the only critical and necessary people would enter physically. Hence, reducing the unnecessary patients entering the hospital drastically. Patients would be able to initiate a telemedicine consultation from the platform itself which would lead to enhancement of the patient's engagement. Healthcare professionals would be able to use the platform itself to learn about the infectious disease which is spreading now. Entities such as government, medical equipment manufacturers and laboratories would be an entity inside the platform, which would lead to greater visibility for all the entities. Platform would have the capability to keep track of the spread of the infectious disease with patients who are suspected of the disease after the telemedicine consultation.

4.3 STEP 3- DESIGN & DEVELOPMENT

Step 3 of design science research methodology is the design and development phase of the artifact creation. This is the section where the proposed database architecture is developed. This section of the thesis is structured as follows, firstly the architecture is scoped using a context diagram and the main Purpose of this is to identify entities that are considered and identify the required relationships.

Rest of the design and the development steps of the architecture would be done through the development of the conceptual design, logical design, and physical design of the proposed architecture. The conceptual design is proposed in section 4.3.1.2, logical design is proposed in section 4.3.1.3 and physical design in section 4.3.1.3. The steps to do each of the aforementioned designs are inspired by Connolly and Begg (2015). The design methodology which is mentioned by Connolly and Begg (2015) is an approach to facilitate the process of design and **Some irrelevant parts have been omitted** in the methodology as it does not, add significant value for the purpose of this thesis.

4.3.1 Scoping

The below diagram is a context diagram or in other terms IGOE diagram. Which stands for input, guide, output and enablers (Long, 2012). IGOE diagrams were created for the purpose of service-oriented process and adoption of that to this thesis would help the identification of entities that is introduced during the conceptual design phase. Input part of the IGOE diagram that is something used or consumed by the IDCT platform (Infectious disease control and treatment platform), outputs are a product or a result of the platform, enablers are resources or assets that is required to transform an input to an output and guides describe when, why and how an activity occur (Long, 2012).

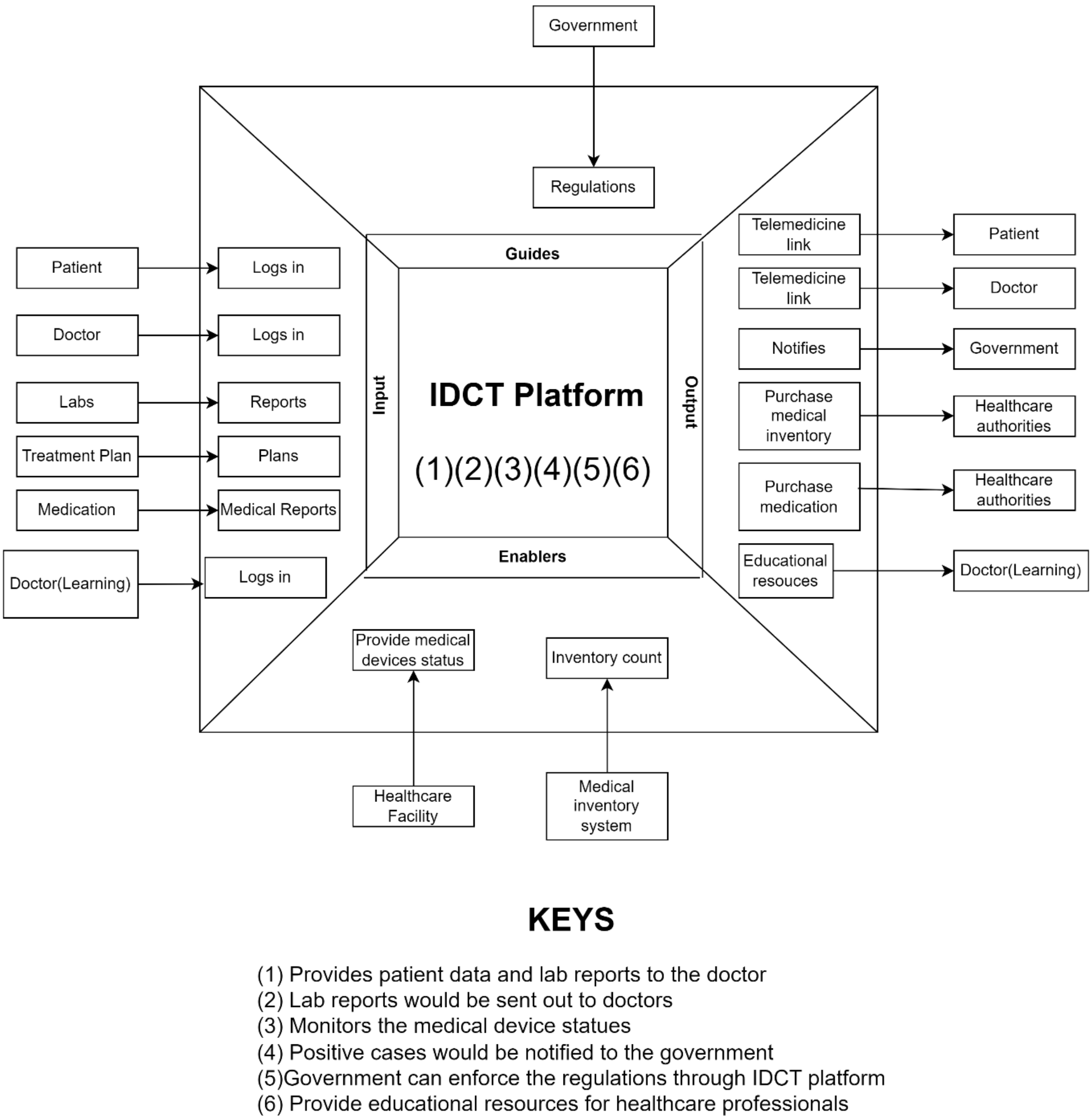

Figure 10: Context Diagram

For an example, patient logging in to the IDCT platform is shown in the input section of the context section diagram and patient receiving the telemedicine link is shown in the output section of the IDCT diagram. Government is an entity which guides the IDCT platform with regulations hence, it is an entity that guides the IDCT platform. Entities such as medical inventory system helps the platform to make informed decisions making, so it is added to the enabler section of the context diagram.

By creating the context diagram, it easy to understand the entities that are considered, the purpose of the entity and the purpose of relationships that are defined in the coming sections.

4.3.2 Conceptual Design

This sub section of the thesis is structured as follows, firstly in sub section 4.3.2.1 necessary entities are identified, in sub section 4.3.2.2 necessary relationships for the defined entities are identified, in subsection 4.3.2.3 possible attributes for the defined entities are identified and section 4.3.2.4 primary keys of the defined entities are identified.

Conceptual database design phase is the process of constructing a model of data used in an enterprise, independent of all physical considerations (Connolly & Begg, 2015). This would begin with the creation of the conceptual data models of the enterprise without considering the low level technical details such as target DBMS, programming language or any other physical considerations (Connolly & Begg, 2015).

The building of the conceptual data model would contain the identification of

- Entity types
- Relationship types
- Attributes and attribute domains
- Primary key and alternative key
- Integrity constraints (Multiplicity)

In this section of the thesis the identification of all the above would be done.

4.3.2.1 Identify entity types.

In database, design entity refers to a real-world object, concept or a defined object which can be distinctively identifiable. In relational databases these entities are typically would be defined as tables and each row would that is defined within these tables would be an instance of the defined entity. Columns within the defined tables would be attributes of the particular entity.

After considering the requirements of the architecture and the scoping diagram which was done section 4.3.1 below entities were identified as requirements for the architecture.

- Patient
- Doctor For Learning Purpose
- Hospital
- Metaverse Platform
- Virtual Laboratory
- Medication
- Knowledge base
- Healthcare Regulation
- Medical devices
- Telemedicine
- Doctor

4.3.2.2 Identify relationship types.

Having identified the entities the next step is to identify the relationships that exists between entity types.

The below table shows the entities, their description, alias names (if exists) and occurrences.

Table 3 :Identification of entities

Entity name	Description	Aliases	Occurrence
Patient	A patient who logs into the system	-	Each patient who are registered in the IDCT platform will log in to the platform
Doctor For Learning Purpose	The doctor who wants to access the knowledge database for learning purposes	-	Each doctor who is registered in the IDCT platform can log in to access the knowledge base
Hospital	Hospitals that are on the platform	Healthcare facility	Hospitals/Healthcare facilities which are registered in the platform will be able to allocate resource
Metaverse Platform	Chosen metaverse platform	IDCT Platform	Central hub to the platform which takes input from all the other defined entities
Virtual Laboratory	Digitally twinned laboratory	Virtual Lab	Lab reports would be shared to the doctors and patient
Medication	Medication prescribing	Medicine	Available medication would be shared to the doctors
Knowledge base	Stored knowledge regarding the spreading of infectious disease	Education Resource	Knowledge about the infectious disease would be stored in the database

Healthcare Regulation	Healthcare regulations imposed by the government and authorities	Regulations	Healthcare regulations which are imposed by the government would be stored
Telemedicine	Telemediation initiation	-	Telemedicine links would be generated and shared among the patients for remote consultation
Doctor	Doctors who are enrolled in the system	-	Doctors who are registered to the platform

The below table displays how each entity relate with other entities defined in the IDCT platform.

Table 4: Identification of Multiplicity between Relationships

Entity Name	Multiplicity	Relationship	Multiplicity	Entity name
Patient	0..*	Logs in	1..1	Metaverse Platform
Doctor For Learning Purpose	0..*	Logs in	1..1	Metaverse Platform
Hospital	1..1	allocate	1..*	Doctor
Metaverse Platform	1..1	assigns	1..*	Hospital
	1..1	Get status	1..*	Medical Devices
	1..1	Sends info	1..*	Knowledge base
Healthcare Regulation	1..*	Impose	1..1	Metaverse platform
Telemedicine	0..*	Sends link	0..*	Patient
Doctor	1..*	Create Session	1..*	Telemedicine
	1..*	Get plan	1..*	Treatment plan
	1..*	Get lab	1..*	Virtual laboratory
	1..*	Get Medication	1..*	Medication

After the identification of the entities and their Multiplication among entities an ER (Entity Relationship) diagram is created to visualize the IDCT platform. It is easier to visualize a complex system through an ER diagram rather than long textual description (Connolly & Begg, 2015).

Throughout the database design phase UML notation is carried out to design the ER diagrams. The following ER diagram is the first cut ER diagram with identified entities and the Multiplicity among entities.

Note that, creating separate ER diagrams for different user views were omitted as the there is a significant overlap between multiple users and the database system is not overly complex. With a centralized approach (One-shot approach) collecting the requirements of all the users' views into a single list of requirements is done and ER diagram is created (Connolly & Begg, 2015)

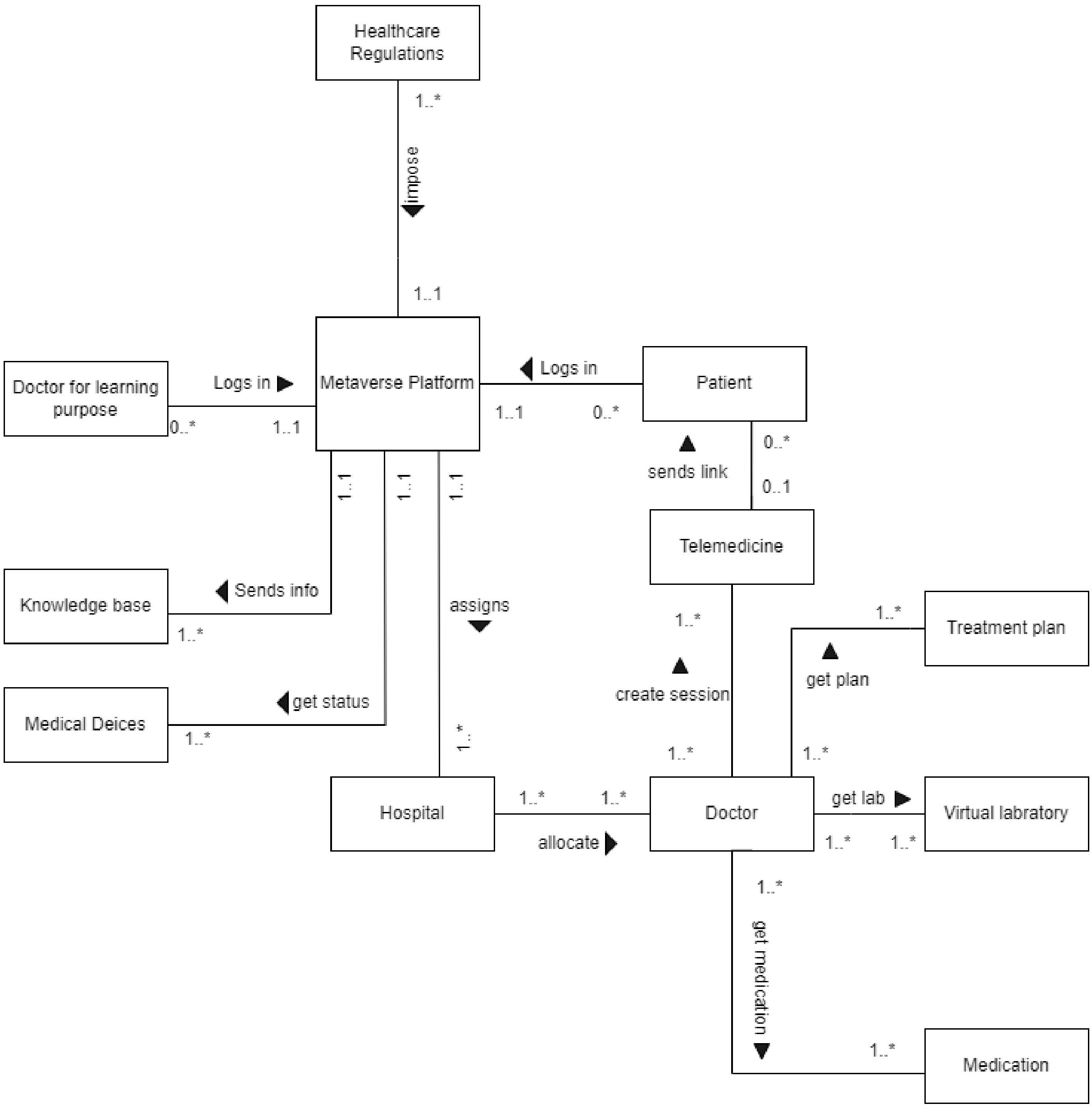

Figure 11: ER diagram with only the entities and relationships

4.3.2.3 Identify and associate attributes with entity or relationship types.

Attributes provide essential details about the entity and making it possible to store, query and manage formation effectively. Attributes of each entity defined is captured below with a brief description.

Table 5: Identified entites ,attributes and description

Entity	Attribute	Description
Patient	PatientID	Unique identifier for patient
	FirstName LastName	First Name of patient Last Name of patient
	insuranceInformation	Insurance number
	Age	Age of the patient
	Password	Password for login
Doctor For Learning Purpose	doctorID	Unique identifier for doctor
	FirstNameDoctor LastNameDoctor	First Name of doctor Last Name of doctor
	password	Password for login
Hospital	facilityID	Unique identifier for the hospital
	name	Name of the hospital
	type	Type of hospital
	address	Address of Hospital
Metaverse Platform	sessionID	A number created by the platform for each user login
Virtual Laboratory	testID	Unique identifier for the hospital
	FirstNameDoctor LastNameDoctor	First Name of doctor Last Name of doctor
	FirstName LastName	First Name of patient Last Name of patient
	description	Brief description of the report
Medication	medicationID	Unique identifier for the medication
	title	Name of the medication
	description	Brief description of the medication

Knowledge base	resourceID	Unique identifier for the case files and resources
Healthcare Regulation	regulationID	Unique identifier for the new regulation
	title	Title of the regulation
	description	Description about the regulation
	complianceAndEnforcemen	Enforcement towards the IDCT platform
Telemedicine	consultationID	Unique identifier for the consultation session
	FirstNameDoctor LastNameDoctor	First Name of doctor Last Name of doctor
	FirstName LastName	First Name of patient Last Name of patient
	startTime	Start time of the session
Doctor	doctorID	Unique identifier for the doctor
	FirstNameDoctor LastNameDoctor	First Name of doctor Last Name of doctor

4.3.2.4 Determining the primary key

Primary key is the minimal set of attributes of an entity that uniquely identifies each occurrence of an entity (Firouzi et al., 2021). The following diagram depicts the ER diagram with the primary key added.

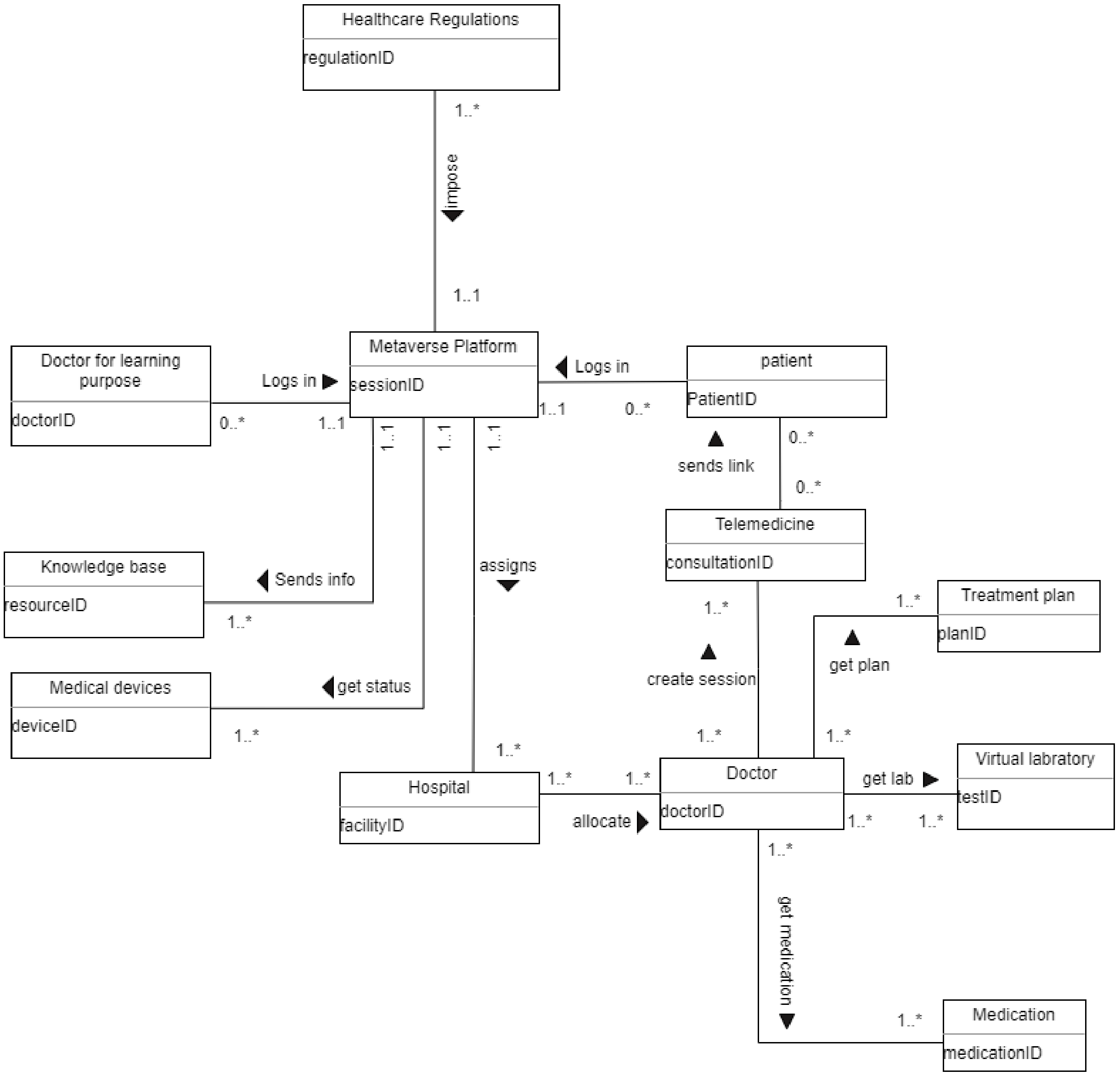

Figure 12:ER diagram with primary key added

4.3.3 Logical Design

In the logical design phase the conceptual data model is mapped into a logical data model (Connolly & Begg, 2015). Logical data model is a source of information for the database designer to step into the physical database design (Connolly & Begg, 2015).

Derivation of the relations to the logical data model to represent the entities, relationships and attributes is done in this section. The composition of each relation is done from DBDL (Database Designation Language) for relational databases (Connolly & Begg, 2015).

Relations are derived from the following structures that occurred in the conceptual data model.

1) Strong entities
2) one-to-one (1:1) binary relationship types
3) 0: * and 1:* relationship types

From referring to the previous conceptual data model following relationships have been derived.

Table 6: Relations for the IDCT Platform

Patient(PatientID,FirstName,LastName,InsuranceInformation,Age,Password,SessionID) **Primary Key** patientID **Foreign** key sessionID **references** MetaversePlatform(sessionID)
Doctor(doctorID, FirstNameDoctor,LastNameDoctor) **Primary Key** doctorID
Telemedicine(consultationID,FirstNameDoctor,LastNameDoctor, FirstName,LastName, startTime) **Primary Key** consultationID
VirtualLabratory (testID, doctorName, FirstNameDoctor,LastNameDoctor , ,FirstName,LastName,description) **Primary Key** testID
Medication(medicationID,title,description) **Primary Key** medicationID

Treatment Plan(planID, FirstNameDoctor,LastNameDoctor ,FirstName,LastName, description) **Primary Key** planID
Hospital(facilityID,name,type,address,sessionID) **Primary Key** facilityID **Foreign** key sessionID **references** MetaversePlatform(sessionID)
Metaverse platfoem(SessionID) **Primary Key** SessionID
HealthcareRegulation(regulationID,title,description,complianceAnd Enforcement) **Primary Key** regulationID **Foreign** key sessionID **references** MetaversePlatform(sessionID)
DoctorForLearningPurpose(doctorID,FirstNameDoctor,LastNameDoctor,password) **Primary Key** doctorID **Foreign** key sessionID **references** Metaverse Platform(sessionID)
Knowledge base(resourceID,sessionID) **Primary Key** resourceID **Foreign** key sessionID **references** Metaverse Platform(sessionID)
MedicalDevices(deviceID,manufacturere,name,status,sessionID) **Primary Key** deviceID **Foreign** key sessionID **references** Metaverse Platform(sessionID)
getPlan(doctorID,planID) **Primary Key** doctorID,planID **Foreign Key** doctorID **refenrences** doctor(doctorID) **Foreign Key** planID **refenrences** TreatmentPlan(planID)
getMedication(medicationID,doctorID) **Primary Key** medicationID,doctorID **Foreign Key** medicationID **refenrences** medication(medicationID) **Foreign Key** doctorID **refenrences** Doctor(doctorID)

getLab(doctorID,TestID) **Primary Key** doctorID,TestID **Foreign Key** doctorID **refenrences** doctor(doctorID) **Foreign Key** TestID **refenrences** VirtualLabratory(TestID)
CreateSession(ConsultationID,doctorID) **Primary Key** ConsultationID,doctorID **Foreign Key** ConsultationID **refenrences** Telemedicine(ConsultationID) **Foreign Key** doctorID **refenrences** Doctor(doctorID)
allocate(doctorID,facilityID) **Primary Key** doctorID,facilityID **Foreign Key** facilityID **refenrences** Hospital(facilityID) **Foreign Key** doctorID **refenrences** Doctor(doctorID)
sendLink(consultationID,patientID) **Primary Key** consultationID,patientID **Foreign Key** patientID **refenrences** patient(patientID) **Foreign Key** Telemedicine **refenrences Telemedicine**(consultationID)

After creation of the logical data models for the IDCT platform global ER / relation diagram is created. It contains new entities such as

1) getPlan
2) getMedication
3) getLab
4) CreateSession
5) Allocate
6) sendLink

These new entities were needed because the many to many relationships that was identified during the mapping stage of relationships to relations. After the addition of these entities global relational diagram for the platform is given below.

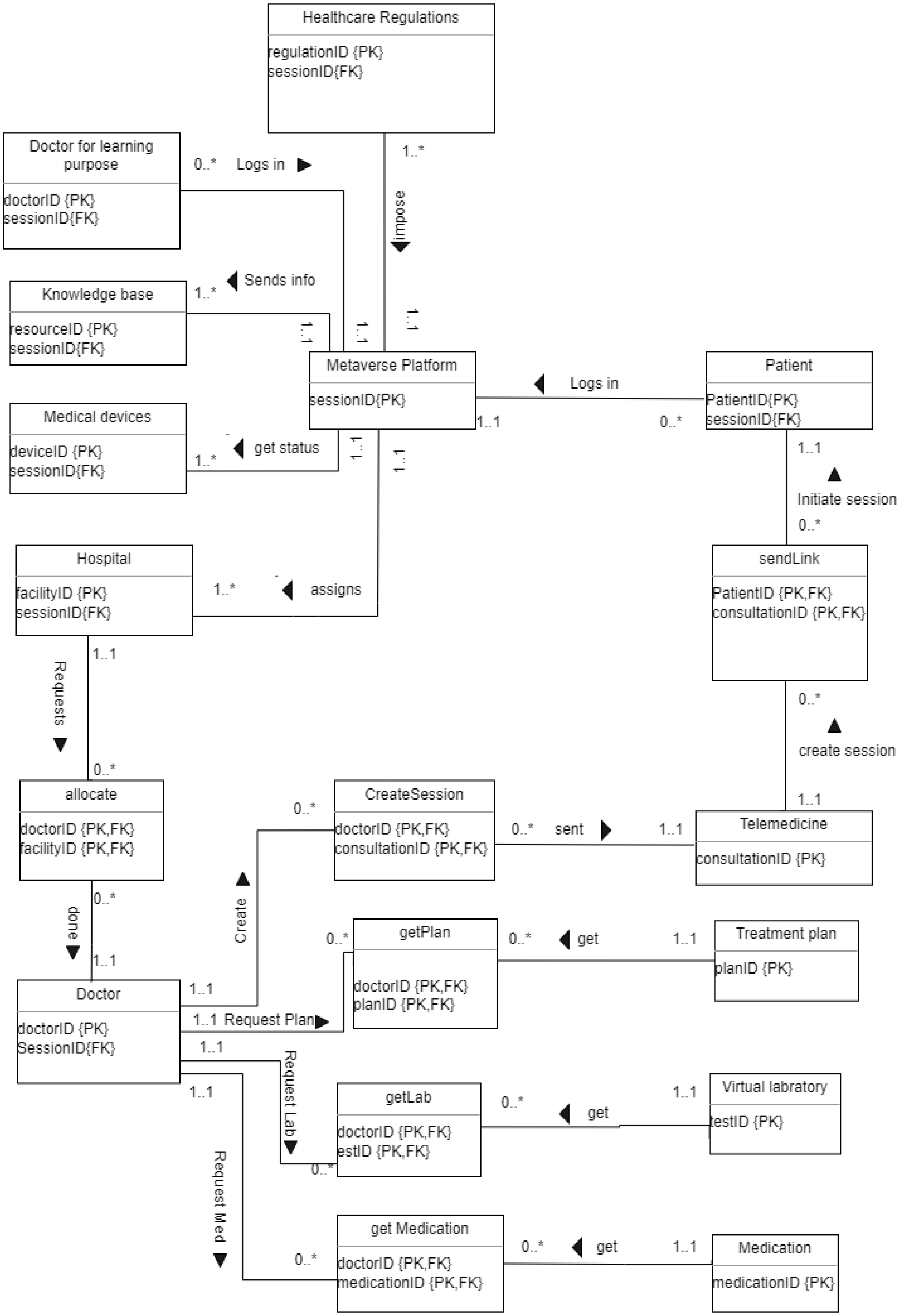

Figure 13: Global Relation diagram for the IDCT Platform

4.3.4 Physical Database Design

In database architecture physical database design phase holds a pivotal role in translating conceptual and logical designs into actual implementation. Physical database design in the context of digital twinning and the metaverse introduces unique set of challenges and opportunities compared to traditional database design. This chapter delves into the crucial aspects of physical database design, specifically concentrating on calculating the estimation of disk capacity.

It is a vital step of the design process to be able to estimate the disk requirements to store the database. The importance of the disk requirement is that the capacity of the database directly relates to the cost of the implementation of the database. Estimating the disk space requirement highly depends on the target DBMS and hardware used ,this is because factors such as data storage, compression techniques and indexing strategies come in to play (Connolly & Begg, 2015; Florescu & Kossmann, 2009).

In this section Oracle DBMS is used as the example database to calculate the disk capacity as it is a leading database vendor who is a leader in Gartner magic quadrant for DBMS (Adrian, 2022).

Estimation of the total disk space usage in non-clustered tables, whatever the DBMS is used in developing the system, the underlying equation that is used to calculate the total capacity is.

Total Disk Space= (Average Row Size) X (Number of Rows)

For the disk space estimation in this chapter, general equations and the general equation that is used to get the total disk space is derived from the oracles disk space equations for non-clustered tables.

The main reason behind using the oracle disk space estimations is that oracle is recognized as an industry standard and has been refined over the years. This section will contain technical equations but through this section of the thesis, the equation would be simplified and applied for the architecture proposed.

In the below table, it depicts the entities that were identified, attributes of the defined entities, variable types, and the arbitrary lengths of the variables. When the actual implementation is done the actual variable lengths will be finalized to get the actual disk space requirements.

But as for an example, doctor entity can have attributes such as,

$x_{10,1}$=12754851, $x_{10,2}$ = Adam , $x_{10,3}$ = James

Even though data within healthcare sector contain unstructured data there are methods to convert unstructured data into structured data, such as extraction based method, data model-based methods and query based methods (Yafooz et al., 2013). For an example a method proposed by Mansuri and Sarawagi (2006), problem of unstructured textual data is tackled as follows. First step involves looking at the textual unstructured data and identifying the specific entities within the unstructured data. After the entity identification, it should be checked with the already existing entities within the database to check whether they already exist within the database. When a match is found between a named entity and already existing entity, the connection can be created using a foreign key. By defining these named entities properly retrieving data from unstructured data is made easier.

Hence, the key takeaway is relational database could be used even in the presence of unstructured data and Analysis section will discuss in details pros and cons of having unstructured data within a database.

Table 7:Variable Length of the attributes

Entity	Attribute	Variable type	Length
Patient	PatientID	string	$x_{1,1}$
	Patient Name firstName lastName	string string	$x_{1,2}$ $x_{1,3}$
	insuranceInformation	string	$x_{1,4}$
	Age	integer	$x_{1,5}$
	Password	string	$x_{1,6}$
Doctor For Learning Purpose	doctorID	string	$x_{2,1}$
	FirstNameDoctor LastNameDoctor	string string	$x_{2,2}$ $x_{2,3}$
	password	string	$x_{2,4}$
Hospital	facilityID	string	$x_{3,1}$
	name	string	$x_{3,2}$

	type	string	$x_{3,3}$
	address	string	$x_{3,4}$ $x_{3,5}$
Metaverse Platform	sessionID	string	$x_{4,1}$
Virtual Laboratory	testID	string	$x_{5,1}$
	FirstNameDoctor LastNameDoctor	string string	$x_{5,2}$ $x_{5,3}$
	patient Name firstName lastName	string string	$x_{5,4}$ $x_{5,5}$
	description	string	$x_{5,6}$ $x_{5,7}$
Medication	medicationID	string	$x_{6,1}$
	title	string	$x_{6,2}$
	description	string	$x_{6,3}$
Knowledge base	resourceID	string	$x_{7,1}$
Healthcare Regulation	regulationID	string	$x_{8,1}$ $x_{8,2}$
	title	string	$x_{8,3}$
	description	string	$x_{8,4}$
	complianceAndEnforcemen	string	$x_{8,5}$
Telemedicine	consultationID	string	$x_{9,1}$
	FirstNameDoctor LastNameDoctor	string string	$x_{9,2}$ $x_{9,3}$
	Patient Name firstName lastName	string string	$x_{9,4}$ $x_{9,5}$
	startTime	string	$x_{9,6}$
Doctor	doctorID	string	$x_{10,1}$
	FirstNameDoctor LastNameDoctor	string string	$x_{10,2}$ $x_{10,3}$

The size of disk capacity depends on the size of each row and the number of rows in each table.

In Connolly and Begg (2015) the estimate disk process calculation method is shown and the main steps are as follows

(i) calculate the total block header size.

(ii) calculate the available space per data block.

(iii) calculate the space used per row.

(iv) calculate the total number of rows that will fit in a data blocks

(i) calculate the total block header size.

In DBMS block header refers to a block of data which is stored in the beginning of the block. This contains information such as block type information, address of the block on the disk, segment type etc.

Total block header can be calculated from the following equation:

totalBlockHeaderSize=fixedHeaderSize+fixedTransactionHeader+variableTransaction Header+dataHeader

fixedHeaderSize =KCBH +UB4

(This block contains information about blocks type and size which comprises, with 2 other blocks as KCBH (Block common header) and UB4(Unsigned byte 4))

fixedTransactionHeader =KTBBH

(This block contains information that is related to transactions)

variableTransactionHeader = KTBIT(INITTRANS-1)*

(This Block is used to ensure data consistency and integrity. It is calculated through two variables as KTBIT(Transaction variable header) and INITTRANS(Initial number of concurrent transactions))

data Header=KDBH(This block contain information such as row directory, row data, row length and Null values)

KCBH, UB4, KTTBH,KTBIT and KDBH are part of the oracle's database architecture and are not directly accessed or modified by users in regular database operations(Connolly & Begg, 2015).

These parameters defined above depend on the oracle database version.

(ii) calculate the available space per data block.

This step calculates the available space excluding the space that is necessary for header information which was calculated in the step 1 and space that is required for table directory entry.

availableDataSpace =ROUNDUP(blockSize -totalBlockHeaderSize)(1-PCTFREE/100)-KDBT*

(KDBT- Table directory entry, PCTFREE - percentage of space that is reserved in block for updates)

(iii) calculate the space used per row.

Space used per row depends on the number of columns in the table and the data types for each column.

Total column size is calculated as below.

totalColumnSize = columnSize + (1,if columnSize<250;else 3)

totalRowSize= rowHeaderSize +$SUM;totalColumnSize

In the patient entities case.

totalRowSize = rowHeaderSize + $\sum$*;(* $x_{1,1} + 1 + x_{1,2} + 1 + x_{1,3} + 1 + x_{1,4} + 1 + x_{1,5} + 1 + x_{1,6} + 1$*) ;* (Assuming each column size is less than 250 bytes)

totalRowSize= rowHeaderSize + $\sum_{i=1}^{i=6}(x_{1,i} + 1)$

totalRowSize= rowHeaderSize + $\sum_{i=1}^{i=6}(x_{1,i} + 1)$

(Size of the row header depends on the version of the oracle used)

(iv) calculate the total number of rows that will fit in a data block.

Number of rows that will fit into the data block can be calculated by dividing the calculated data space by total row size.

So,

noRowsPerBlock= ROUNDDOWN(availableDataSpace/totalRowSize)

$$noRowsPerBlock = ROUNDDOWN\left(\frac{availableDataSpace}{rowHeaderSize + \sum_{i=1}^{i=6}(x_{1,i}+1)}\right)$$

Assume that the number of rows in the table as = γ_1

$$Total\ space\ required\ for\ the\ table = ROUNDDOWN\left(\frac{availableDataSpace}{rowHeaderSize + \sum_{i=1}^{i=6}(x_{1,i}+1)}\right) * \gamma_i$$

Total space with the C% margin of error=

$$ROUNDDOWN\left(\frac{availableDataSpace}{rowHeaderSize + \sum_{i=1}^{i=6}(x_{1,i}+1)}\right) * \gamma_1 * (1+C\%)$$

Total disk space estimate would be the sum of the disk estimate of the defined entities in the IDCT platform.

$$Total\ disk\ capacity = \sum_{j=1}^{j=k} ROUNDDOWN\left(\frac{availableDataSpace}{rowHeaderSize + \sum_{i=1}^{i=n}(x_{j,i}+1)}\right) * \gamma_j * (1 + C\%)$$

(k is the number of entities in the ER diagram, n is the number of entities in the j th entity)

4.4 STEP 4-DEMONSTRATION:

Since this research is about developing an architecture, the demonstration step of the design science research could be done through transaction pathway which is used in Connolly and Begg (2015). The transaction pathways are depicted on the ER diagram, and it could be used to visualize the area of the model that are not required by the transaction (Connolly & Begg, 2015). Set of query transactions are listed below and they are annotated through arrows on the diagram. There could be more transactions that could be identified on the ER diagram, but these are the main transactions that is identified, which could enable the main functionalities of the architecture.

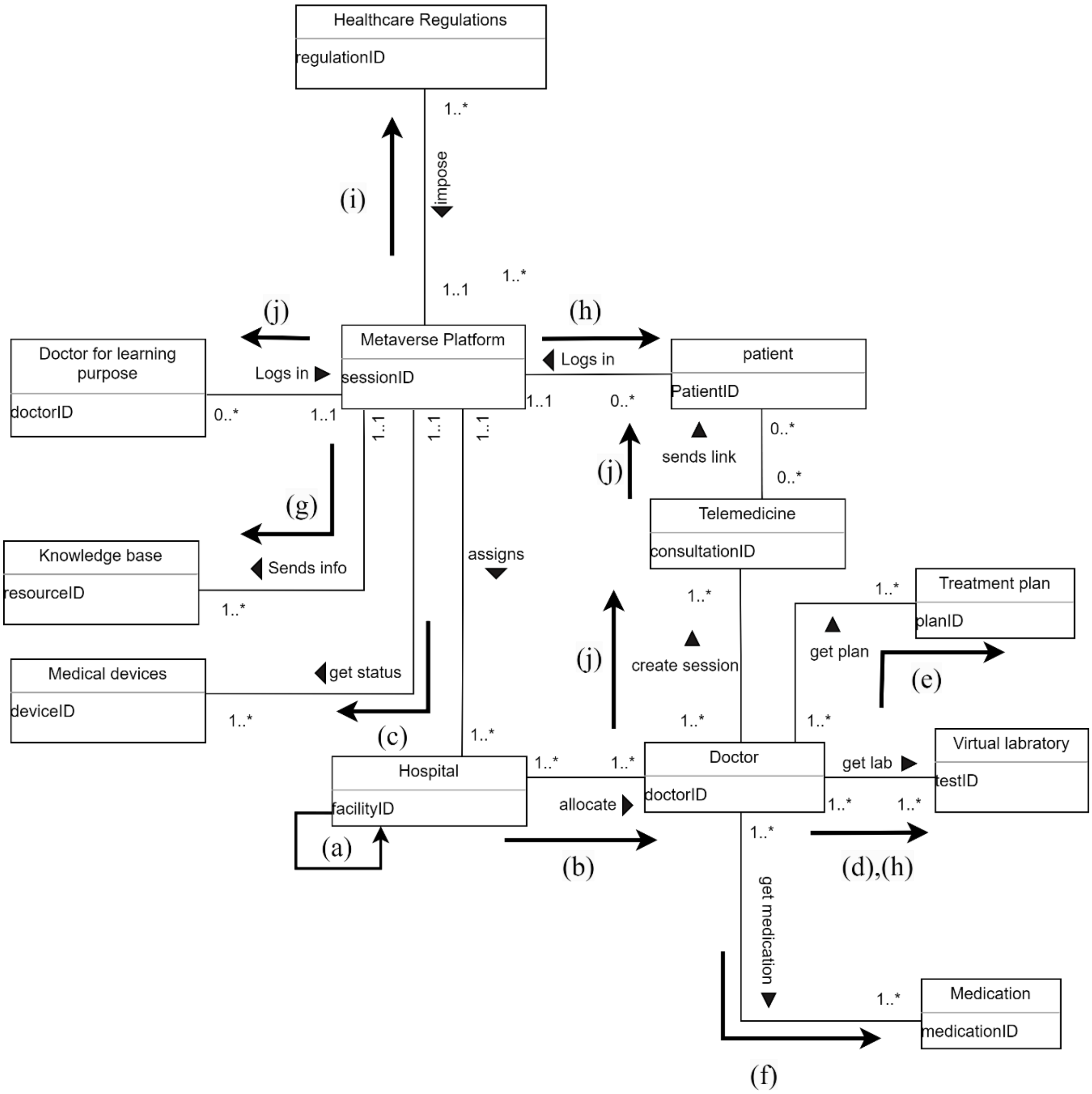

Figure 14: User trasaction pathways

(a) List facilities that are signed up with the platform.
(b) List doctors using the platform in a specific hospital.
(c) Get the medical status of devices.
(d) Provide the lab report for a particular patient for a specific doctor.
(e) Provide the treatment plan for a particular patient for a specific doctor.
(f) Provide medication details.
(g) Add new knowledge about the disease to the database.
(h) List the identified positive cases and their details.
(i) List the regulations imposed by the government.
(j) List the patient's name who has a consultation with a specific doctor and a consultation ID
(k) List of patients who are currently signed up with the platform.

4.5 STEP 5-EVALUATION

Hevner and Chatterjee (2010) mentions that a key elements of design science research is the evaluation of the design of the IT-Based artifact because the evaluation result can be used to further improve the artifact created. After the artifact is built, the completely next phase would be the evaluation of parameters such as efficiency, utility, or performance.

In the case of the artifact proposed is still in the conceptual stage, after the complete development is done evaluation of the information artifact could be done in form of a survey. Brooke (1996) has developed a simple usability scale which is simple, ten item scale giving the global view of the usability of the system. Usability means in term of the artefact created is the appropriateness to a purpose (Brooke, 1996; Hevner & Chatterjee, 2010). This simpleness of the survey is appropriate as it will make sure the person who is filling the survey has the concentration and would not need any assistance to understand the questions.

Survey should be distributed among following users:

- Doctors
- Hospital administration
- Doctors who used the system for learning
- Laboratory assistants
- Local government authorities
- Medical equipment manufacturers
- Patients

A structure of the survey is attached with Annex-B. The scoring of the SUS would yield as follows, Item number 1,3,5,7,9 would have the score contribution as scale position minus one and item number 2,4,6,8 and 10 would have the score contribution as five minus the scale position, then the final score will be calculated by adding the two scores and multiplying it by 2.5 scalar (Brooke, 1996). Received final score would be used to further improve the IDCT platform.

4.6 STEP 6-COMMUNICATION

According to Hevner et al. (2004) design science research must be communicated to both the technological oriented as well as management oriented personal. The key characteristics about this communication for these two separate audiences is, steps must be repeatable for the technical audience and for the management audience (Brooke, 1996; Peffers et al., 2007). The content for the technical audience is captured by the conceptual design. logical design and the physical design of the system. Details which are necessary for the management for decision making would be captured through the evaluation section of the design science research after the full implementation of the system.

Chapter 5: Analysis

In this section, it includes the full discussion of the analysis of the results that was developed in the results section. As per the methodology of the results, design science research was chosen as it covers the comprehensive development of the information system artifact (Hevner et al., 2004). In the design and development step of the artifact, conceptual data base, logical data base design and physical data base design was developed following from Connolly and Begg (2015).

In the conceptual and logical data base development phases the necessary entities and attributes for the proposed architecture were identified with data types, but the data lengths were not defined as it was left out to be finalized in the actual development phase.

But the attributes that was defined might contain unstructured data, for an example regulation description of the Healthcare regulation entity, description of the Medication entity, description of the Virtual Laboratory entity might contain unstructured data that does not have predefined structure and might contain various types of data. According to Adnan et al. (2020) most of the data in healthcare such as Electronic health records, Electronic medical records, patient health records, medical imaging are unstructured data. Even though unstructured data exists within the architecture a relational database could be used for the development and few of the methods were discussed in Physical Database Design section. But having unstructured data within an architecture would create few problems, following are some few points regarding problems with unstructured data.

- Most of the available data in healthcare are not fully usable due to noise, errors, missing values and quality issues (Adnan et al., 2020)
- Some unstructured data can fit into relational columns and some cannot (Blumberg & Atre, 2003).
- Challenge of integration of two different systems due to interoperability of the used data (Adnan et al., 2020)
- Most of the information such as surgery details and patient details are stored in form of a natural language (Adnan et al., 2020)

- Most sensor generated data are unstructured in healthcare (Adnan et al., 2020)

Regardless of whether the database is built on Relational database or a NoSQL database both of it would have advantages during the implementation.

Advantages of Relational database for this specific system is as follows.

- Data integrity: Ensuring accurate and consistent data in the proposed architecture is extremely important. A priority of a SQL database is to meet the ACID property requirements and it will ensure more reliability and integrity compared to NoSQL (Sahatqija et al., 2018).
- Query language: Relational databases have the capability to use query languages to handle complex queries and NoSQL databases does not have a standardised query language to manage data (Sahatqija et al., 2018).
- Security: Relational databases have very secure mechanisms compared to NoSQL databases because features such as sharding which distributes data across multiple databases will impact data security (Sahatqija et al., 2018)

Advantages of NoSQL database for this specific system is as follows.

- Scalability: Infectious disease outbreak could generate large amount of data in short time frame. Hence compared with Relational databases scalability of NoSQL is advantageous for the system (Sahatqija et al., 2018).
- Unstructured data: The architecture might generate structured and unstructured data. NoSQL databases can be used efficiently used to store the unstructured data generated by the architecture (Sahatqija et al., 2018).

Because of the advantages in both the relational databases and NoSQL databases the best approach is to develop the system in a hybrid approach which combines both the relational and NoSQL databases.

Multi model data is data which encompasses multiple types of information within the dataset. According to Lu and Holubová (2019) there are two approaches to represent multi-model data, they are through polyglot persistence and multi-model databases. In polyglot persistence different vendor databases would be used to manage different models of data and used a mediator integrate them together (Lu & Holubová, 2019). For an example the designer would use relational databases to store structured data, NoSQL database for unstructured data and graph database for data that has complex data. Using this method have the advantage of having the best database for each data type.

Second type of database approach that could be used is to use multi-model database which is a one single database that manage multiple databases. This database could handle various data types such as relational, unstructured, graph etc. If the development is done in multi-model approach the entire database would be in a unified platform with a consolidated architecture.

Hence, it is recommended to use a multi-model database for the proposed infectious disease treatment and control architecture. Few of the recommended multi-model databases are as follows.

- ArangoDB
- OrientDB
- MarkLogic
- Azure Cosmos DB
- FoundationDB
- Apache Ignite Compare

Chapter 6: Discussion

This chapter will discuss the summary of key findings, interpretation of the results, discussion on how the literature found related with the results, possible limitations of the results and recommendations for the future research.

Purpose of this thesis was to propose an architecture where it can minimize the infectious disease spread, protection of healthcare workers, reduce the chance of healthcare resources being depleted, training functionality for healthcare professional to prepare for an infectious disease outbreak and a platform where multiple sectors who are necessary for infectious outbreak could collaborate. Refer the Purpose section for defined purposes in depth. To achieve this objective the conceptual design, logical design and the physical design of the thesis was built following a systematic database development process. No past literature was found, which was built to achieve these purposes, hence these designs are a key finding of this thesis. Minimizing the infectious disease spread can be achieved through several features from the proposed architecture such as telemedicine capability of the architecture. The ability to consult the patients from the platform itself would drastically reduce the probability of healthcare workers being infected. Resource monitoring capability of the system was used to monitor the status of medical equipment and medication as these resources are vital to successfully manage a pandemic outbreak. Trained healthcare professionals are a vital human resource to manage an infectious disease outbreak. Hence a training functionality for healthcare professionals is also added to the architecture. To face an infectious disease outbreak successfully many entities must collaborate. So, during this period, regulations and decisions imposed by the government would impact how a region or an area successfully face an outbreak scenario. Not only that, but government entities also lack a one single platform which provides dashboard view of the outbreak status. Hence, government is a vital entity that is added to the architecture as it would ensure the regulation and the management is done effectively. In the physical design section of the thesis a generalized equation for the disk estimation is provided for the deployment of this architecture. Since estimated disk capacity is a vital piece of information that is needed for the implementation disk space estimation equation which is mentioned in Physical Database

Design is a significant finding. Furthermore, in the Analysis section considering the types of data being gathered, potential type of database and recommended vendors are provided.

After following the database design methodology in Connolly and Begg (2015), possible entities, attributes, data types and relationships were identified. Further to these identified entities additional entities could be added to add further functionality to the platform. For an example if the platform requires the capability of monitoring the vitals of the remote patients through wearables devices or sensors this functionality could be added as well. In addition to that the if the location of the infected patient is needed to be monitored, it can be taken as an input for the platform and check for the contact points of the infected patients. So, further functionality can be added according to the requirement of the region or the country the architecture being deployed.

As discussed in the Literature Review section when it comes to proposing an architecture for infectious disease control and treatment there was no proposed architecture which addressed it from the database point of view. In other words, no architectural view was proposed through the conceptual design, logical design, or physical design. Even though literature suggested the importance of having a one single pane view of the status of infectious disease outbreak, none of the literature has though about the database aspect of it. The potential target DBMS for the actual implementation which was provided in the Analysis section of the thesis is a significant result, as no such literature was found suggesting databases for the actual implementations. In addition, not literature was found regarding the disk estimation of a similar architecture proposed. Generalized disk estimation calculation is a calculation which is modified specifically for this proposed architecture. It can be tweaked according to the finalized entities and attributes to get the disk space estimation.

The database that was proposed in this thesis was built using a relational database. Even though the architecture proposed contain unstructured data it could be converted into structured format and still be used in a relational database. But there are certain disadvantages in the conversion of the unstructured data to structured and they were discussed in the Analysis section of the thesis. Hence, in the next iteration of the design should be done not purely on relational database. For each specific data type that is used in the architecture would have a database type which performs well. This aspect of the design should also be considered to fully optimize the performance of the database. Further to that the generalized disk estimation equation which was mentioned in the Physical Database Design section should be changed according to the new design in the next phase. In a future phase of this design, security aspect of using data such as patient records, medical records, staff information for digital twinning and Metaverse technologies must be analysed and take appropriate measures to ensure critical data is secure. Further to that, the compliance, and regulatory requirements of deploying region for using these sensitive data in digital twinning and metaverse environment must be analysed and make suitable amendments to comply for these requirements.

To summarize, the thesis was able to achieve the original purposes which was mentioned following design science research methodology. They are many future research avenues in this domain such as security aspect of metaverse and digital twinning, hybrid design of the database considering the data types used, compliance and regulatory requirements for using sensitive data with these technologies.

Chapter 7: Conclusions

The conclusion chapter contains the following.

Firstly, the purpose of the thesis is presented then, the key points of the work carried out is briefly described. Afterwards, summary of results is presented then, the significant of the work carried out is discussed and finally potential future research in this domain is mentioned.

The absence of a well-defined methodology for addressing an infectious disease outbreak can result in dire consequences, including increased mortality and severe economic repercussions. Multiple personals and entities such as patients, doctors, doctors for learning purpose, hospitals, virtual laboratories, medication, healthcare regulation, medical devices, tele medication platform should work synchronously to successfully face a pandemic and for this to happen a one single platform specialising the management of pandemics is needed. Architecture proposed will use digital twinning and metaverse technologies to treat and control the pandemic. This thesis proposed the architecture of such a platform from the perspective of database design.

Design science research methodology was used as a structured approach to develop the architecture. This methodology ensured the actual real-world need is achieved by the developed information system artifact. The largest chunk of content in this thesis came from the development section of design science research. Under this step a structured approach on developing the database design of the proposed architecture has been undertaken, encompassing conceptual database design, logical database design and physical database design aspects of the proposed architecture.

After following the database design methodology, the thesis recommended suitable target DBMS to do the actual implementation. Further to that, a generalized equation for disk space estimation is provided for the proposed architecture which would be helpful when the actual implementation occurs. Comparing the past literature regarding an architecture for infectious disease and control, there was none which discussed the database aspect of it. Through this thesis the initial level database design was introduced as well as target DBMS which would be helpful for the future researchers in this domain.

Through the analysis of past literature, it was identified that there were discussions about proposing a single architecture for infectious disease treatment and control, but these literatures were extremely high level, and no in-depth discussion was carried out. Through this thesis, a platform for infectious disease and control is proposed through a database aspect which would be useful when the actual development occurs. There are many more further research avenues in the domain of development of an architecture for infectious disease treatment and control, and these developments could be done as multiple iterations of design science research. For an example, area such as the security aspect of digital twinning and metaverse, regulatory and compliance requirements and a hybrid approach of database development of the platform would have promising research prospect in the future.

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Appendices

Appendix A

Systematic Literature Search Planner

My research question/subject is:

Infectious Disease Control and Treatment using Healthcare Metaverse and Digital Twinning

Hypothesis:

-Not Applicable

Step 1: Use PICO or PICo to determine your **main concepts**. Be really specific.

PICO	PICo (Qualitative Studies)
Population/ Problem:	Population:
Intervention(s):	Phenomenon of interest: **Infectious Disease Control and Treatment** Hypothesis: **Not applicable**
Comparison(s):	Context:
Outcome(s):	

Step 2: Write your mains concepts in the table below (Logic Grid). Under each concept list the synonyms, acronyms, alternative spellings for your concept. You can do a scoping search in large databases, for example, Google Scholar to find other terms you may like to use.

Logic Grid

	Infectious	Healthcare	Metaverse	Treatment
	Pandemic	Health system	Digital Twins	Control
	Covid			

OR

AND

Step 3: Choosing the appropriate database:

Qualitative based question chooses databases like Proquest or Scopus
Clinical focus question: choose databases like Medline, CINAHL, Emcare, PsychINFO, Cochrane Library, Web of Science, Scopus
Interested in statistics: AIHW, ABS, Social Atlas
Indigenous Health: Health Infonet

Step 4: Drafting a search.

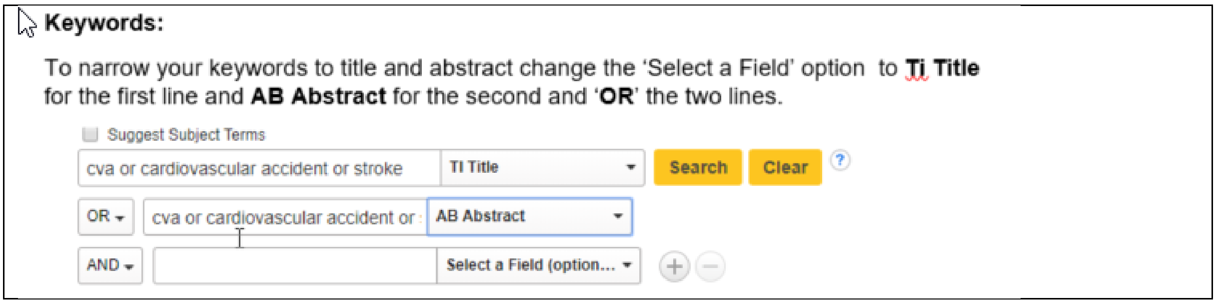
Command	Action
OR	Finds articles containing either of specified words.
AND	Finds articles containing both specified words.
" "	Double quotes required in some databases for phrase terms to be kept adjacent, **"public health".**
( )	Use parentheses to group words. Eg: (education) AND (cigarette OR tobacco)
Truncation	Help you find all words with the same word stem E.g. educat* = **education , educating, educational** Database specific, ***** or **?**
Limits	Database specific. Allow you to restrict search in different ways, e.g. date, language, age, gender, study design

Two types of databases Subject heading or Textword searching

For Subject based databases (Medline,Emcare, Psycinfo, CINAHL)
First look for **Subject headings** for your each of your concepts. Then do a search using textwords.

**To find textwords in only the *Title, Abstract* and *Author* keywords:
In **Medline & Emcare** use .tw,kw at the end of your search string , for example, (CVA OR Stroke).tw,kw
In **Psycinfo** use .ti,ab,id at the end of the search string (CVA OR Stroke).ti,ab,id

In CINAHL



For Textword searching databases (Web of Science, Scopus, Proquest) to find textwords in title, abstract, author textwords

Web of Science choose: Topic
Scopus choose: Article title, abstract, keywords
Proquest choose: Anywhere except full text

*Remember to save your search- all of the above databases you can create an account for free.

Step 5. Apply any limits applicable to your topic.

These may include:

- Age groups: Students are tertiary education
- Geographic regions or country groupings (e.g. developing countries or all OECD countries): All countries
- Study designs (e.g. RCTs, qualitative): Scoping review
- Language: English
- Gender: All
- Publication types (e.g. peer reviewed journals): Journal only both peer reviewed and non per-reviewed
- Date range (use only where justifiable): last 10 years.

Step 6: Document your searches:
Using one sheet per database or resource record:

- **Name of resource searched**
  Record all detail e.g. not just *Cochrane* but *Cochrane Central Register of Controlled Trials, Issue 12 of 12, December 2017.* Include database platforms too, e.g., not just *Medline* but *Medline (Ovid).*
- **Date search was executed**
  Important as databases/web resources are dynamic.

- **Search strategy**
  This should incorporate terms used *and how they were combined* (e.g. AND, OR, ADJ). Copying and pasting the search history into a Word document is the easiest way to do this.
- **Number of results retrieved by the search**
  Record the numbers of citations retrieved for each database, before and after deduplication. (See PRISMA flow chart.)

Search Query	Date Of search	Data base	Citations	5 Year refinement	Only Considering Research and Review articles	Title, abstract or author-specified keywords	Final article count	Comment
("Infectious" OR "Covid") AND ("Healthcare" OR "Medical" OR "Health") AND ("Metaverse" OR "Digital Twins")	2023.03.12	Sciencdirect	777	774	587	("Metaverse" OR "Digital Twin") AND "Health"	20	
		Pubmed	27	26	26		26	
		Google scholar	11800					Too many articles
		IEEE	25	25	22	-	22	

Search Query	Date Of search	Data base	Citations	5 Year refinement	Only Considering Research and Review articles	Title, abstract or author-specified keywords	Final article count	Comment
("Pandemic" OR "Infectious" OR "Covid") AND ("Healthcare" OR "Health System") AND ("Metaverse" OR "Digital Twins") AND("Treatment" OR "Control")	2023.03.18	Sciencdirect	374	372	291	("Metaverse" OR "Digital Twin") AND ("Health" OR "Pandemic" OR "Covid" OR "Infectious")	19	
						("Metaverse" OR "Digital Twin") AND ("Health")	13	
		Pubmed	7	7	7		7	
		IEEE	6	6	22	-	6	

Appendix B

System Usability Scale (SUS) (Brooke, 1996)

This is a survey which evaluates the usability of the Infectious disease treatment and control platform (IDCT). After the usage of the IDCT platform please choose the best response that captures the experience while using the IDCT.

	Strongly Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Strongly Agree
1. I think I would like to use this tool frequently.	☐	☐	☐	☐	☐
2. I found the tool unnecessarily complex.	☐	☐	☐	☐	☐
3. I thought the tool was easy to use.	☐	☐	☐	☐	☐
4. I think that I would need the support of a technical person to be able to use this system.	☐	☐	☐	☐	☐
5. I found the various functions in this tool were well integrated.	☐	☐	☐	☐	☐
6. I thought there was too much inconsistency in this tool.	☐	☐	☐	☐	☐
7. I would imagine that most people would learn to use this tool very quickly.	☐	☐	☐	☐	☐
8. I found the tool very cumbersome to use.	☐	☐	☐	☐	☐
9. I felt very confident using the tool.	☐	☐	☐	☐	☐
10. I needed to learn a lot of things before I could get going with this tool.	☐	☐	☐	☐	☐