MODELLING AND DEVELOPING VIRTUAL COLLABORATION

FOR HEALTHCARE

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Copyright Statement

Abstract

The demand for healthcare services are rising as the world's population is increasing, and on average, people are living longer. As a result, healthcare services are becoming more complex to organise and expensive to provide. Researchers in the field are arguing that the current centralised model of healthcare provision cannot address challenges relating to service cost, quality and availability and there is a need to decentralise it. To decentralise, virtual collaboration systems where healthcare organisers, providers and receivers can work together and share resources across time and space are seen as the future of healthcare.

Literatures suggest that a modelling framework specific to healthcare virtual collaboration is yet to be developed and there are unaddressed challenges relating to the organisation and management aspects of healthcare virtual collaboration. In this thesis, Virtual Breeding Environment (VBE) and Virtual Organisation (VO) concepts are used as theoretical bases to answer research questions relating to modelling, organising and managing virtual collaboration for healthcare. To contribute to the modelling aspect of virtual collaboration in healthcare and address organisational and managerial challenges of healthcare virtual collaboration the first objective of the thesis is to develop a modelling framework to enable system developers model healthcare virtual collaboration in terms of participants and services classification, representation and descriptions. The second objective is to develop a framework based on concepts developed in the modelling framework, to be used as guide to develop systems for organising and managing healthcare virtual collaborations.

To achieve the objectives, a deductive research approach is used to develop theoretical frameworks first, and later implement and evaluate the frameworks. For evaluation purpose, Technology Acceptance Model (TAM) is modified three times by adding new constructs. The extended TAMs are used as theoretical evaluation frameworks to test the acceptability of the technologies developed in this thesis. For each extension, a set of hypotheses are defined to be tested by prospective target users. Survey questionnaire is used as a data collection method, and Structural Equation Modelling (SEM) technique is used to analyse the collected data statistically in AMOS software.

The first contribution of this thesis is a Healthcare Virtual Breeding Environment Modelling Framework (HC-VBE-M-F) which consists of a service and participant classification mechanism, a domain specific modelling language and a service orchestration description language. The frame work is implemented as a Java application and has been tested for acceptance by system developers.

The second contribution is a Healthcare Virtual Breeding Environment Framework (HC-VBE-F) which is based on the first framework. The framework consists of a conceptual description, a member selection mechanism, a service level agreement creation and management mechanism and a provider verification and validation mechanism. The Framework is implemented as a mobile application and it is evaluated by healthcare requesters and providers for acceptance.

The evaluation results show that the frameworks are both acceptable by prospective users and their intensions to use systems developed based on the two developed frameworks are positive and validated empirically. The achievements of this thesis are the developed mechanisms and frameworks that together facilitate the modelling and development of healthcare virtual collaboration systems based on VBE and VO concepts.

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Acknowledgements and Dedications

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Finally, I am grateful to all the people who have assisted me, especially the Huddersfield Computing and Engineering School staffs, my friends, colleagues and students from the University of Human Development, Kurdistan.

List of Abbreviations

AMOS: Analysis of Moment Structures

AU: Atitude towards Using

BPEL: Business Process Execution Language

DSML: Domain Specific Modelling Language

HC-VBE: Healthcare Virtual Breeding Environment

HC-VBE-A: Healthcare Virtual Breeding Environment Actors

HC-VBE-E: Healthcare Virtual Breeding Environment Environement

HC-VBE-F: Healthcare Virtual Breeding Enviroment framewrok

HC-VBE-M-F: Healthcare Virtual Breeding Environment Modelling Framewrok

HC-VBE-MSM: Healthcare Virtual Breeding Environment Member Selection Mechanism

HC-VBE-ODL: Healthcare Virtual Breeding Environment Service Orchestration Description Lnaguge

HC-VBE-OM: Healthcare Virtual Breeding environemnt Orchestration Mechanism

HC-VBE-R: Healthcare Virtual Breeding Environment Relationships

HC-VBE-U: Healthcare Virtual Breeding Environement Use cases

HC-VO: Healthcare Virtual Organisation

HVCom: Healthcare Virtual Community

ICT: Information and Communication Technology

IU: Intension to Use

OCL: Object Constaint Language

OWL: Web Ontology Language

PAM: Percieved Ability to Model

PCE: Perceived Clinical Effectiveness

PEU: Percieved Ease of Use

PHA: Percived Healthcare Availability

PHG: Perceived Healthcare Globalisation

PHQ: Perceived Healthcare Quality

PU: Perceived Usefulness

SEM: Structural Equation Modelling

SLA: Service Level Agreement

SODL: Service Orchistration Description Language

SPCM: Service and Participant Classification Mechanism

TAM: Technology Acceptance Model

UML: Unified Modelling Language

VBE: Virtual Breeding Envirnment

VC: Virtual Collaboration

VCom: Virtual Community

VO: Virtual Organisation

Chapter 1 : Introduction

This chapter introduces the research topic and put it into context through providing research motivations and challenges in the Sections 1.2 and 1.3. The research aims and objectives are outlined in Section 1.4 and the target groups of the research are defined in Section 1.5. The contributions of the research are listed and described in Section 1.6 and the thesis structure is presented in Section 1.7. Finally, a summary of the chapter is provided in Section 1.8.

1.1 Research Introduction

Healthcare is a fundamental human right and the right was reaffirmed in the world leaders meeting in Alma-Ata [1]. To fulfil their obligations, governments around the world are investing a lot of time and resources in their healthcare systems with the aim to improve care availability, increase timely-care provision and make healthcare more affordable to provide and receive [2][3][4]. According to [5], healthcare spending takes up 17% of US Gross Domestic Product (GDP) and it is expected to rise from 17.4% to 19.6% by 2024. Developed countries such as the United Kingdom and France are also investing more than 10% of their GDP in their healthcare systems [6].

A major reason for the increase in spending is down to the fact that throughout the world the number of population is rising and the demand for healthcare services are growing [7]. For instance, in England, patients with long-term health conditions reached 15 million in 2014 and 70% of available beds and half of General Practitioners' visits went to this type of patients [8]. It is argued by the authors of [6] and [9] that the current centralised model of healthcare cannot answer the complex organisational and managerial questions arises during care provision; and cannot deal with today's healthcare challenges where more timely collaboration and resource sharing is required. In support of this claim, researches such as [10] and [11] indicate that despite the continuous efforts by governments around the world to improve healthcare, challenges such as cost and timely access to healthcare remain at large**.** These challenges, if left unaddressed, can lead to inefficiency and patient dissatisfaction as [12] states that access, availability and cost are essential patient satisfaction attributes in healthcare.

To address collaboration and resource sharing challenges in healthcare, the authors of [9] and [13] claim that healthcare provision has to be decentralised in order to increase opportunities to recruit providers and resources for a given care, when and where needed. To decentralise healthcare, cross stakeholder collaborations that can take place regardless of geographical boundaries is seen as the way to provide care in future [14][15][16]**.** To facilitate the decentralised collaborations, virtual healthcare is emerging as a strong option [17] [18] [19] [20] [21][22]. Virtual care is becoming a reality and it is "*no longer a futuristic idea"* claimed in a report published by the centre for health solution on virtual care programs (Deloitte) in 2018 [23]. The report also states that "*virtual care is a must-have*" for modern healthcare systems as it has the potential to diversify care delivery channels to patients, provide "*convenience and access"* and support *"patient-centricity*".

Virtual collaboration concept is important to healthcare because collaborating within virtual settings provide the platform for patients to seek support and information beyond the scope of healthcare institutions [24]**.** Virtual care is made possible by new information and communication technologies which has encouraged team-based collaborations to provide care and has transferred the traditional single care provider model to multi care provider model [25]. In virtual care, technologies such as online messaging, chat rooms and videoconferencing are used as a medium to connect healthcare requesters and providers. During a typical healthcare provision many stakeholders (e.g. healthcare professionals and government agencies) will have to collaborate and share resources which make healthcare provision a complex process. For example, in England, privately run GP practices, community trust, mental health trust and acute care trust are some of the organisations involved in providing care [8]. To cope with the complexity of bringing all required parties together to provide a given care, the authors in [26] suggest that efficient collaboration mechanisms that are capable of aligning stakeholders and resources are required.

Healthcare virtual collaboration presents many organisational and managerial challenges that requires an environment capable of regulating and formalising the collaboration process. To manage and organise virtual collaboration, researchers have developed the concepts of Virtual Breeding Environment (VBE) [27] and Virtual Organisation (VO) [28]. Researchers are becoming interested in the concepts as virtual collaboration among people are becoming the norm and communication technology advances [29][30][31][32]. VBE is a long-term alliance between a number of key stakeholders, supported by information and communication technologies that provide the environment for the formation and operation of short-term and goal-based collaborations known as VO [33]. To put the concepts into perspective for healthcare, VBE can serve as a virtual hospital where the need of a patient is addressed by recruiting healthcare professionals and resources on the fly and dedicate a virtual space (VO) for collaboration and service provision for a specific duration and to achieve a specific goal.

In this thesis, VBE and VO concepts have been used as theoretical bases to develop a Healthcare Virtual Collaboration Modelling Framework (HC-VBE-M-F) to enable healthcare system developers understand and model healthcare virtual collaboration scenarios. The concepts are also used to develop a Healthcare Virtual Collaboration Framework (HC-VBE-F) to address organisational and managerial challenges of healthcare virtual collaboration. The frameworks are described and empirically evaluated using Technology Acceptance Model (TAM) [34] in Chapters 5 and 6 respectively.

1.2 Research Motivations

The motivations behind modelling and developing virtual collaboration for healthcare are summarised in the following points:

1- In many fields of science such as engineering, models and visualisation techniques are used to simplify complex scenarios with the aim to facilitate better understandings and manage implementation risks. [35] States that a modelling framework to model the divergent aspect of virtual collaboration in a given community would be interesting. However, "*Visualisation of aspects of virtual collaboration has received relatively little research attention in the past*" [36], and a similar claim is also made by the authors of [37]. Researchers in the field of virtual collaboration are yet to offer a generic design modelling framework as claimed by authors of [38]. The prospect of providing a modelling framework capable of modelling virtual collaboration for healthcare in a simple, understandable and comprehensive manner is one of the motivations driving this research.

2- In healthcare, timely service provision is crucial for patients and could mean life if the service is provided on time or death if the service is not provided on time. The idea that virtual collaboration could provide services in a timely fashion and across borders, makes the concept very attractive and provide a motivation to research it for possible contributions that it can make to healthcare.

3- Cost plays a great role in the provision of every service, normally high cost of a service means it cannot be provided as often as necessary to those who are in need of the service. To reduce cost, healthcare virtual collaboration as an alternative to the current centralised model of healthcare has the potential to make a great contribution by providing a platform for healthcare services to be provided without the need for patients to travel and use local healthcare resources. The possibility of reducing cost of care and increasing healthcare availability though the utilisation of virtual collaboration, provides a motivation to research it.

4- Service quality attributes such as staff professionalism and service relevance are some of the service quality measuring factors that healthcare providers shoulder most of the responsibilities. In many occasions, time and energy is wasted and service quality is compromised by incompetent service providers which they claim to have a good track record. In virtual collaboration, during member recruitment, the profile of members could be screened and validated electronically before job assignments which can raise the quality of care.

5- For an effective healthcare provision, promptness is required, in a typical situation professional, family members, administrators, local authorities and many more have to work together to deal with the situation. Brining all these parties together is a highly complex and time-consuming venture with undesirable consequences if not managed properly. Virtual collaboration, through a described and guided framework, can cater for the management and promptness required especially for the services that can be provided virtually such as consultations and first aid guidance.

1.3 Research Challenges and Questions

The following points summarises the research challenges and questions.

1- Due to the complexity and broadness of the theoretical and practical use of virtual collaboration concept, it is yet to be fully researched. The majority of research literatures available such as [39] focus on the functional aspect of virtual collaboration. The authors of [38] claim that researches carried out so far on virtual collaboration " *do not yet provide a comprehensive view on its design*". Therefore, developing a model for virtual collaboration is a challenge as claimed by [20] and [40] which is also the case for healthcare virtual collaboration**.**

2- The authors of [41] state that, within a VO, it should be possible to determine roles and services that are going to be provided and [40] suggests for a virtual collaboration to fulfil its purpose the roles of its members should be coordinated. These researches point towards the need for a role and service coordination mechanism. This challenge is mentioned in [42] in a form of service orchestration. Therefore, developing a mechanism capable of classifying roles and services in healthcare virtual collaboration and a mechanism to describe the service provision coordination present challenges.

3- In virtual collaboration many parties have to collaborate to complete a task, these parties need to be organised and managed to have a productive result. Since virtual collaboration takes place in cyberspace the organisation and management of collaborators and resources offer real challenges in terms of member selections, member verification and validation and Service Level agreement (SLA). [43] Identifies a number of requirements that a typical VO should fulfil, for example a VO can have members that are participants of other VOs, resource could be shared between different VOs and in a given VO the same member can have different roles. Within this context, developing a member selection, a member verification and validation mechanism and an SLA mechanism for healthcare virtual collaboration present real challenges.

4- Developing concepts and frameworks for healthcare virtual collaboration requires proper evaluations to ensure that the developed concepts are sound and usable which is a research challenge.

From the challenges described, a number of research questions (RQ) are deduced to be answered in this thesis as follows:

RQ1: How to classify the main stakeholders and services in virtual collaboration for healthcare?

RQ2: How to model and describe service provision in virtual collaboration for healthcare?

RQ3: How to manage and organise virtual collaboration for healthcare?

RQ4: How to select, verify and validate participants for healthcare virtual collaboration?

RQ5: How to regulate virtual collaboration for healthcare?

1.4 Research Aims and Objectives

The General vision of this thesis is to initiate a new approach in healthcare provision based on VBE and VO concepts where there are many VBEs on global level competing to form VOs to provide real-time care. Figure 1.1 provides a diagrammatic view of the research vision in which the oval shape represents the world and the Healthcare Virtual Breeding Environment (HC-VBE) depicted as squares represent healthcare VBEs around the world. The square with more details in the middle represent the possible content of each HC-VBE which can create many Healthcare Virtual Organisation (HC-VO). A HC-VO is created for a specific purpose with the aim to achieve four goals (reduce cost, raise quality, increase availability and provide timely service) which are placed on the four corners of the diagram.

To realise the vision, the aim is to develop a modelling framework specific to healthcare, to help system developers model healthcare virtual collaboration scenarios more effectively. And based on the modelling framework, develop a virtual collaboration framework to guide the understanding and development of virtual healthcare systems.

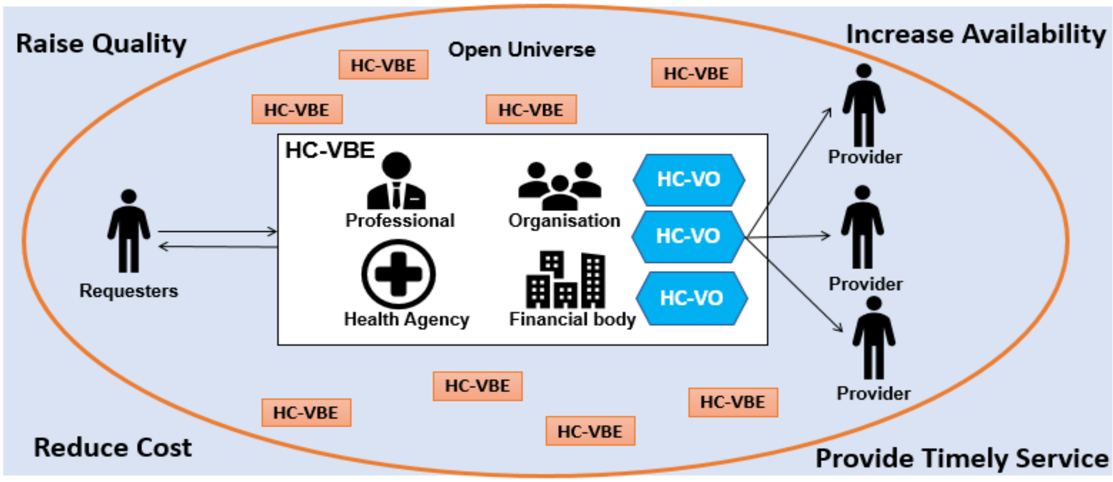


Figure 1.1: The healthcare virtual collaboration vision of the thesis which shows a number of rectangles representing VBEs with a possible content of a given VBE shown in the middle

1.4.1 Research Objectives

To achieve the aims and answer the research questions, Figure 2 shows the objectives and sub-objects of the thesis which are:

1- Develop and evaluate a generic modelling framework for healthcare virtual collaborations based on VBE and VO concepts that includes:

- A- A service and participant classification mechanism to enable the classification of roles and services of healthcare virtual collaboration scenarios.
- B- A domain specific modelling language to model participants and services in healthcare virtual collaboration scenarios.
- C- An orchestration description language to describe service orchestration in healthcare virtual collaboration scenarios.

2- Develop and evaluate a virtual collaboration framework for healthcare, based on the concepts and models developed in objective one that includes:

A- A conceptual architecture that outlines the main components and working steps for healthcare virtual collaborations.

B- A member selection mechanism for healthcare virtual collaborations.

C- A member verification and validation framework for healthcare virtual collaborations.

D- A set of SLA templates to frame contracts between participants of healthcare virtual collaborations.

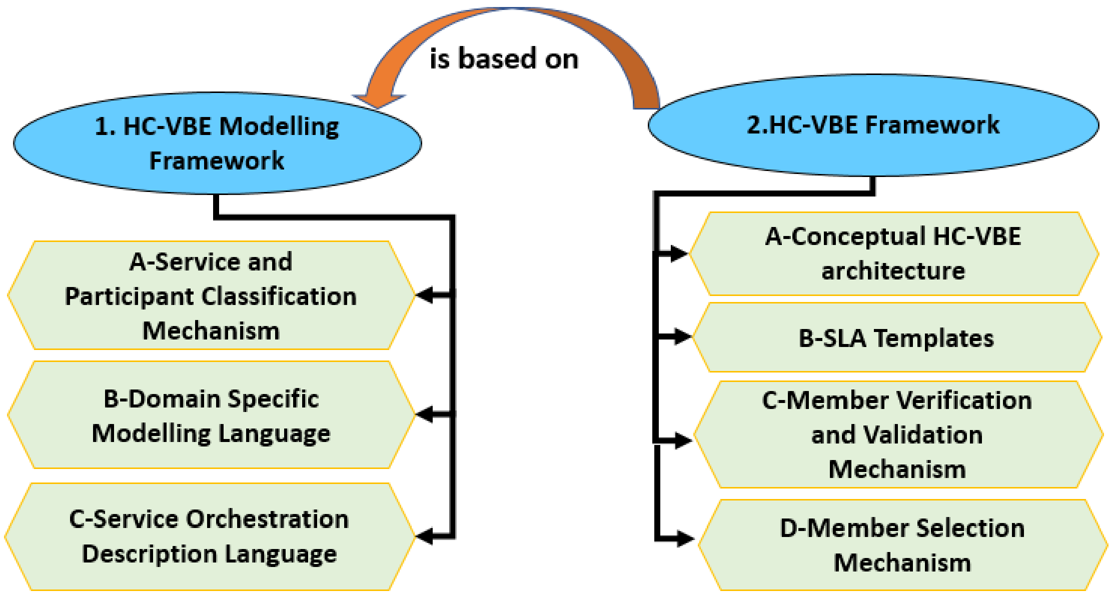


Figure 1.2: Research objectives, objective 2 is developed based on objective 1

1.5 Target Groups

The target groups of this research are healthcare stakeholders and system developers. Healthcare stakeholders can use the modelling framework (HC-VBE-M-F) described in Chapter 5 to visualise and plan ahead for possible virtual collaboration without technical expertise. The modelling framework is simple and text based which requires minimal effort to learn and use. Developers can use the modelling framework to model VBE and VO based healthcare virtual collaboration systems in terms of roles and use cases, and use the service orchestration mechanism to describe service provision coordination. System Developers can also use the HC-VBE-F described in Chapter 6 as an architectural base and a guide for healthcare virtual collaboration system developments.

1.6 Thesis Contributions

The contributions of this thesis are to frameworks for healthcare virtual collaboration which are both evaluated empirically. The first framework is a modelling framework which is called Healthcare Virtual Collaboration Modelling Framework (HC-VBE-M-F). Three specific contributions make up the overall contributions of the modelling framework which are listed below. Technology Acceptance Model (TAM) is extended with one new construct (Perceived Ability to Model) to evaluate the acceptance of system developers of the HC-VBE-M-F which is implemented as a Java application. The new construct has been validated by system developers as an acceptance factor for modelling languages. This is also a contribution that extends the applicability of TAM in examining users' acceptance of new modelling technologies. The extension is explained in Section 4.3.2 and validated in Section 5.5.

A. A unique conceptual Service and Participant Classification Mechanism (SPCM) for VBE and VO based healthcare virtual collaboration is developed as a result of addressing RQ1. The SPCM is a high-level classification of the main roles and services developed with the aim to simplify and help understanding the healthcare sector. On VBE level, the SPCM classifies roles (Human and non-human) into *Organisers* who participant in organising a VBE to provide healthcare virtually and *Support* which represents roles of information and communication support systems that facilitate virtual collaboration in healthcare VBEs. As for the service, all healthcare VBE management tasks are classed as *Task* which represent the use cases required for managing a healthcare VBE. On VO level, the SPCM classifies roles into *Provider* who represent all healthcare providers that participants in healthcare virtual collaboration and *Requester* which represents all who request healthcare virtual collaboration services such as patients. As for service, on VO level, the SPCM represents all types of healthcare virtual collaboration services as *Service.* The SPCM is described in Section 5.2.

B. A domain specific modelling language (DSML) to model the structural aspect of VBE and VO based healthcare virtual collaborations is developed to address the modelling part of RQ2. The DSML provides modelling notations to model the participants and services classified based on the SPCM. The DSML is extended from UML use case diagram notations using the UML profiling notation extension mechanism. The DSML provides five new graphical notations to model HC-VBE participants (Organiser, Requester, Provider and Support) which are all extensions of the UML actor notation modelled as a stickman. To model HC-VBE services (Task and Service), the DSML provides two new graphical notations which are extensions of UML use case notation modelled as an oval shape. The DSML provide a new relationship notation to model automatic relationship which is an extension of the UML relationship modelled as a straight line. The DSML is described in Section 5.3.

C. A unique Service Orchestration Description Language (SODL) for VBE and VO based healthcare virtual collaborations is developed as a result of addressing the service description part of RQ2**.** The SODL is comprised of two components; the first component is a mechanism that captures scope, attributes and process aspects of an orchestration. The second component is a textual description language developed for describing the sequence of actions during a service orchestration. The language has a specific and defined structure as well as a sentence grammar to ensure consistencies in all service orchestration descriptions. The SODL is described in Section 5.4.

The second contribution is a healthcare Virtual Collaboration framework (HC-VBE-F), developed based on the concepts and models outlined in the modelling framework described in Chapter 5, to address RQ3**.** The framework is described on conceptual, component and process levels which can be used by system developers as a guide to develop healthcare virtual collaboration systems. The framework contributes towards realising the implementation of VBE and VO concepts for healthcare. On conceptual level, the framework describes how HC-VBEs and HC-VOs can be formed and managed for healthcare virtual collaboration. The conceptual description is provided in Section 6.2.1. On component level, the HC-VBE-F specifies all the main components required for creation, operation and dissolution of HC-VBEs and HC-VOs. Each component is described and their main functions are outlined in Section 6.2.2. On process level, a detail step by step process is provided to show how the framework works, more details can be found in Section 6.2.3.

TAM is extended with four new constructs (Perceived Healthcare Globalisation, Perceived Healthcare Availability, Perceived Healthcare Quality and Perceived Clinical Effectiveness) to create two new TAMs (HC-VBE-TAM-Requester and HC-VBE-TAM-Provider). The new TAMs are used to evaluate healthcare providers and requesters acceptance of the HC-VBE-F which is implemented as a mobile application. The extensions contribute towards further validation of TAM in predicting the acceptance of new healthcare technologies. The extensions are detailed in Section 4.3.2. The collaboration framework is enhanced with three new mechanisms that are developed to address member selection, service level agreement and provider verification and validation challenges in healthcare virtual collaboration. The mechanisms are:

A. A conceptual Member Selection Mechanism (HC-VBE-MSM) for HC-VBE and HC-VO collaboration is developed as a result of addressing RQ4. The mechanism proposes to select members based on tasks which is different from reputation-based and predefined criterion-based mechanisms proposed by researchers in the field. The HC-VBE-MSM provides a seven steps guide to select the right member for HC-VOs. The mechanism contributes towards addressing the challenge of member selection for healthcare virtual collaboration. It is described in Section 6.3 in detail.

B. A Healthcare Provider Verification and Validation Mechanism (HC-VBE-PVVM) is developed for HC-VBE and HC-VO collaboration as a result of addressing the verification and validation part of RQ4. The HC-VBE-PVVM is a conceptual mechanism which utilises blockchain technology to verify and validate healthcare providers who offer to provide a virtual healthcare service. Unlike similar blockchain-based mechanisms proposed in literature, the mechanism provides a seven steps process which can be used as an implementation guide for the mechanism. The mechanism contributes towards addressing the challenge of user verification and validation in virtual healthcare. It is described in Section 6.4.

C. Two SLA templates have been developed to regulate and formalise contracts between HC-VBE and HC-VO participants as a result of addressing RQ5. The first template is a Master SLA template which works as an umbrella for all the SLAs approved between participants of a particular HC-VO. The second template is developed to regulate the terms and conditions of a healthcare service between two virtually collaborating participants. The templates are similar to the ones suggested in literature in terms of purpose and structure, but different in details and content presentation. They are text-based, simple to understand and contains the necessary clauses that depict a formal contract. The templates contribute towards the formalisation, standardisation and regulation of healthcare services provided in a given HC-VO. The templates are described in Section 6.5.

1.7 Thesis Structure

The thesis consists of seven chapters as follows:

Chapter 1: Introduces the research topic, motivations, challenges, aims and objectives and the main contributions of the thesis. At the end, a summary of the chapter is provided. The chapter consists of eight sections which are 1.1 Research Introduction, 1.2 Research Motivations, 1.3 Research Challenges and Questions, 1.4 Research Aims and Objectives, 1.5 Target Audience, 1.6 Thesis Contributions, 1.6 Thesis Structure and 1.8 Chapter 1 Summary.

Chapter 2: Provides the scientific background for the VBE and VO theories as well as technologies (e.g. blockchain) used in developing the modelling and collaboration frameworks in Chapters 5 and 6. A brief background of Technology Acceptance Model (TAM) is also provided which is used as a theoretical evaluation framework to evaluate the two frameworks developed. At the end, a summary of the chapter is provided. The chapter consist of eleven sections which are 2.1 Collaboration, 2.2 Virtual Collaboration, 2.3 Virtual Community, 2.4 Healthcare Virtual Community, 2.5 Virtual Breeding Environments and Virtual Organisation, 2.6 Modelling Virtual Collaboration, 2.7 Service Level Agreement, 2.8 Blockchain Technology, 2.9 Technology Acceptance Model, 2.10 Structural Equation Modelling and 2.11 Chapter 2 Summary.

Chapter 3: This chapter provides a brief review of related literatures and identify the gaps that this research is aiming to address. The chapter touches upon the state of the art in healthcare virtual collaboration modelling, healthcare virtual collaboration frameworks and healthcare SLA creation and management mechanisms. As a justification for choosing to use TAM as theoretical base for evaluation, a review of a number of related researches are provided. Finally, a summary of the chapter is provided at the end. The chapter consists of seven sections which are 3.1 Virtual Collaboration Models, 3.2 Virtual Collaboration Frameworks for Healthcare, 3.3 SLA Creation and Management, 3.4 Partner Selection Mechanism, 3.5 Service Orchestration, 3.6 TAM for Healthcare Applications and 3.7 Chapter 3 Summary.

Chapter 4: Describes the research design and methodology which are used to achieve the aims and objectives of the research. The chapter starts by explaining the main steps taken to conduct the research and end up with zooming into each step to provide fine details about how the step is executed. The chapter also provide implementation details of the frameworks. At the end, a summary of the chapter is provided. The chapter consists of four Sections which are 4.1 Research Methodology, 4.2 Research Design, 4.3 Evaluation Strategy and Methods and 4.4 Chapter 4 Summary.

Chapter 5: The chapter presents the HC-VBE-M-F as well as the framework evaluation results and discussions. The components of the modelling framework which consist of a service and participant classification mechanism, a domain specific modelling language and a service orchestration description language are described. The framework is demonstrated through developing simple healthcare virtual collaboration scenarios and modelling them using the framework components. At the end, a summary of the chapter is provided. The chapter consist of seven sections which are 5.1 Healthcare Virtual Collaboration Modelling Framework, 5.2 Service and Participant Classification Mechanism, 5.3 HC-VBE Domain Specific Modelling Language, 5.4 Service Orchestration Description Language, 5.5 HC-VBE-M-F Evaluation Results, 5.6 HC-VBE-M-F Discussions and 5.7 Chapter 5 Summary.

Chapter 6. The chapter presents the HC-VBE-F. The framework is described on conceptual, component and process levels. As part of the framework, a member selection mechanism for healthcare virtual collaboration is presented which provides a step by step guide as to how potential virtual collaboration members can be selected. The chapter also, provides a detail description of a healthcare virtual collaboration provider verification and validation mechanism. The final part of the framework is the description and explanation of two SLA templates that can be used to regulate and formalise contracts between healthcare virtual collaborators. The evaluation results of a mobile application prototype developed based on the HC-VBE-F are presented and discussed and a summary of the chapter is provided at the end. The chapter consists of eight sections which are 6.1 Healthcare Virtual Collaboration Framework, 6.2 The HC-VBE Framework Description, 6.3 HC-VBE Member Selection Mechanism, 6.4 HC-VBE Provider Verification and Validation Mechanism, 6.5 HC-VBE Service Level Agreement Templates, 6.6 HC-VBE-F Evaluation Results, 6.7 HC-VBE-F Discussions and 6.8 Chapter 6 Summary.

Chapter 7. The research is concluded in this chapter and a list of key achievements are presented. A number of future research ideas are introduced and a list of publications and future publication plans are provided at the end. The chapter consists of four sections which are 7.1 Conclusion, 7.2 Research Achievements, 7.3 Published and Planned Publications and Future Works. Figure 1.3 shows the structure of the thesis in detail.

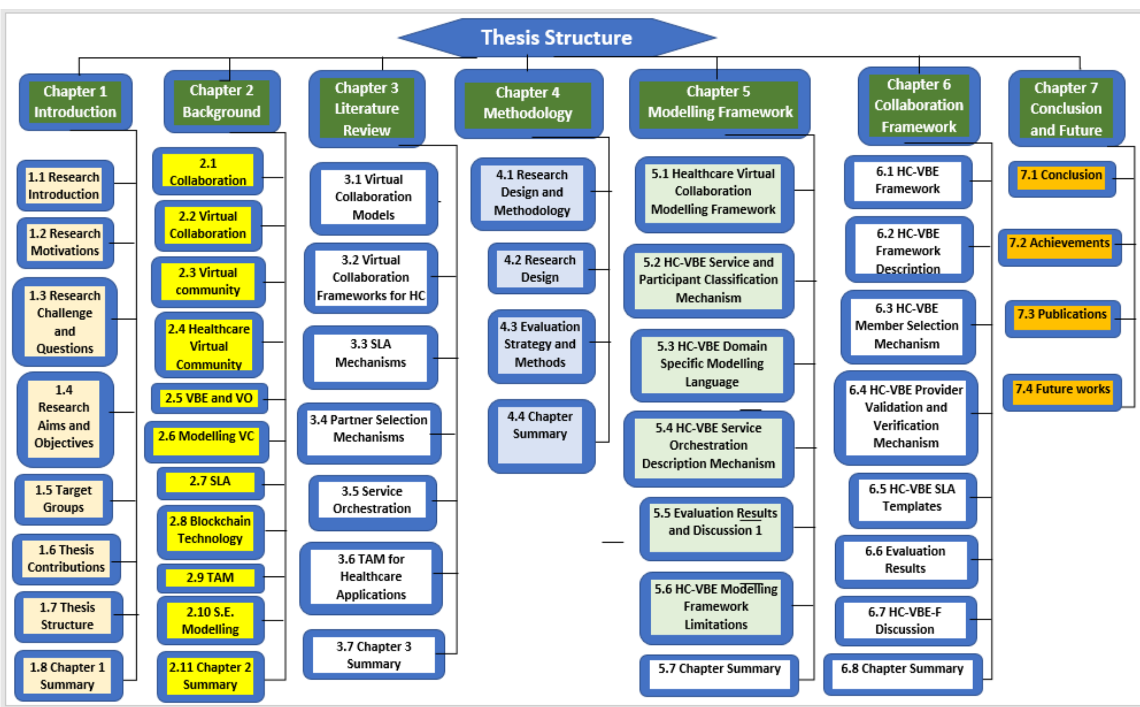


Figure 1.3:The thesis structure, showing the sections of each chapter

1.8 Chapter 1 Summary

This chapter introduced the research topic, the motivation and challenges for the research. The content of the chapter is summarised in the following points:

1- Healthcare is a complex multi-dimensional service where many stakeholders such as medical professionals, governmental agencies and organizations have to collaborate to organise, manage and provide. The demand for healthcare services is rising due to the rise in population numbers and population aging, the rise in demand has led to increase in cost and waiting time for patients.
2- The current centralised model of healthcare provision cannot cope with the rising demand for healthcare; therefore, a new decentralised model is required to facilitate collaboration and resource sharing across time and space in order to make healthcare more efficient.
3- Virtual collaboration where participants can come together regardless of whereabout they are, to collaborate and share resources to achieve a common goal, has the potential to facilitate a new model of healthcare provision.
4- The organisation and management aspect of virtual collaboration present challenges such as how to model healthcare virtual collaboration, how to recruit members for a given virtual collaboration and how to regulate the rights and responsibilities of each participant.
5- The aim of this thesis is to develop two frameworks for modelling, organising and managing healthcare virtual collaboration.
6- To develop the frameworks, the concepts of Virtual Breeding Environment (VBE) and Virtual Organisation (VO) are used as theoretical bases.
7- To evaluate the developed frameworks, Technology Acceptance Model (TAM) is used as a theoretical evaluation framework, survey questionnaire is used as a data collection instrument and Structural Equation Modelling (SEM) is used as a statistical calculation technique in AMOS software.
8- The contribution of this thesis is the development of two frameworks; the first framework is a modelling framework that consists of a service and participant classification mechanism, a domain specific modelling language and a service

orchestration language. The second framework is developed based on the first framework to address organisational and managerial challenges of healthcare virtual collaboration.

In Chapter 2, a brief background of the concepts and technologies used in this thesis is provided.

Chapter 2 : Background

This chapter provides background information about the concepts and technologies used in the research to formulate frameworks for modelling and facilitating virtual collaboration for healthcare. The chapter contains nine sections, Section 2.1 provides background on collaboration, and Section 2.2 introduces virtual collaboration. In Section 2.3, the concept of virtual community is introduced. In Section 2.4, background about healthcare virtual community is provided. Section 2.5 explains VBE and VO concepts. Section 2.6 explains the importance of modelling in virtual collaboration. Section 2.7 introduces SLA and Section 2.8 introduces blockchain technology. Technology Acceptance Model as a theoretical base for evaluation is introduced in Section 2.9 and Structural Equation Modelling as an empirical evaluation technique is introduced in Section 2.10. Finally, a summary of the chapter is provided in Section 2.11.

2.1 Collaboration

The term "collaboration" is frequently used to convey the joint actions between two or more parties towards achieving a common goal [44]. In a typical collaboration, all collaborating parties share responsibilities in accomplishing a task and get a joint credit for the outcome [45]. Working together and helping each other have always been part of human life from the days when joint efforts were needed to hunt to today's data driven world. Today, human with human, human with machine and machine with machine collaborations are the norm.

The human demand for a better life has led to a busier life style where the amount of time that people have for a face to face and direct collaboration has been reduced. In the absence of direct collaboration, a virtual one can serve as the alternative. It is for this reason that the concept is widely researched for possible facilitation in providing important services such as education and health [46] [47]. Virtual collaboration is a complex and multi-dimensional process that requires integration of various approaches, techniques and technologies to realise it. Hereafter, a brief background of the concepts and technologies that serve the base for the healthcare virtual collaboration frameworks developed in the thesis is provided.

2.2 Virtual Collaboration

Advances in the internet and telecommunications have transformed the traditional face to face collaboration; and have introduced a new type known as Virtual Collaboration (VC) where collaborating parties share resources and work together [48][49]. In VC, collaborating parties use modern technologies to connect with each other and share resources. According to [50], telecommunication, databases and multimedia are the three main technologies used in VC, where collectively, they provide means to create collaboration platforms such as websites, blogs, and discussion boards. Figure 2.1 shows a wholistic view of virtual collaboration where information and communication technology (ICT) brings Humans and machines together to create three VC settings (Human-Human, Human-Machine and Machine-Machine) regardless of geographical borders.

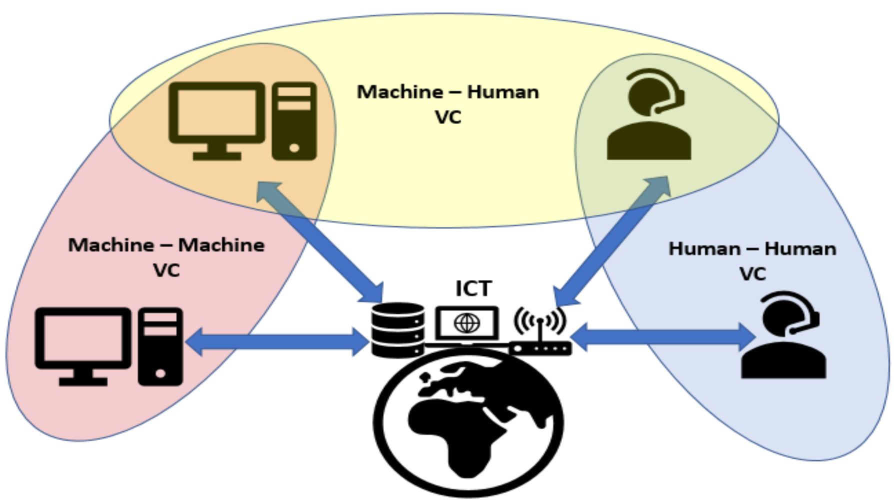


Figure 2.1: Virtual collaboration settings between human and machine participants

In Human-Human VC, ICT provides means such as telecommunications to connect two humans together, through which, they can collaborate and exchange information. In Human-Machine VC, humans and machines can communicate and collaborate with each other using specially designed interfaces that works as a translator between them. In

Machine-Machine VC, machines exchange electronic signals that can be interpreted to meaningful commands on both sides. The aim in all VC settings is to complete a common task.

VC is flexible and allow collaboration to happen when and where needed [51]. The flexible nature of VC has helped in reducing cost and improving quality in specialised fields such as manufacturing since collaborators can share information in real-time without the need for them to be at the same location [52]. Researches such as [53] claim that "*collaboration in virtual settings are occurring on a regular and increasing basis*" and according to [54], healthcare collaboration in virtual settings is going to increase due to globalisation and the rising demand for healthcare. This is because, in healthcare, complex considerations are required in diagnosing and treating a given case which imposes the need for collaboration between different healthcare specialists.

VC has also been considered for improving service quality by companies and organisations; for example, customers of Dell computers collaborate virtually with the company to request a specific computer by selecting the components that make up the computer [38]. In order for the services provided through VC to become reliable it requires a persistent environment with advanced ICT at its heart [55]. Technology dependency is one of disadvantages of virtual collaboration, which means, if the technology needed is not available collaboration cannot take place.

2.3 Virtual Community

Virtual Community (VCom) is the product of virtual collaboration, in which, a group of geographically spread individuals get together similar to the real world community to share ideas and exchange services facilitated by ICT [56][57]. The authors of [58] describe VCom as a community of agents (agents can be individual, organisation or machines) collaborating using ICT with the aim to provide services to each other. Howard Rheingold define VCom as ‘‘*social aggregations that emerge from the Net when enough people carry on those public discussions long enough, with sufficient human feeling, to form webs of personal relationships in cyberspace*’’ [59].

According to [60], shared goals such as solving a particular problem, collaborative participation, shared resource and shared social values such as being supportive are some of the attributes that virtual communities possess. Amazon, eBay and Gumtree are examples of such community. The communities are business oriented where members of the community buy, sell and advertise goods virtually. Health care virtual community is considered as one of target users of the virtual collaboration frameworks developed in this thesis. Figure 2.2 visualises three virtual communities C1, C2 and C3 in a virtual environment. Each community is created by a number of entities modelled as network of different sizes of circles that represents individuals and organisations. Each community is created for a specific purpose based on specific shared goals and values. The communities can also collaborate and share resources between each other (resource sharing is indicated by the blue three-way headed arrow) based on shared goals and values.

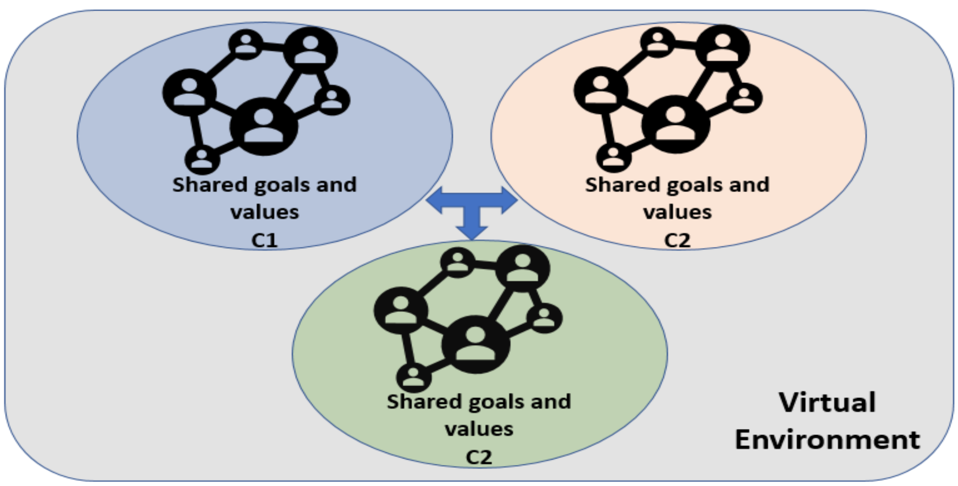


Figure 2.2: Virtual communities in a virtual environment

2.4 Healthcare Virtual Community

Healthcare virtual community (HVCom) is composed of patients, doctors, healthcare educators, providers and organisations collaborating and sharing health related information online [61] [62]. HVCom is becoming increasingly important as the number of people searching online for healthcare information is on the rise. Rentrop and Straton Marketing Research Company carried out an investigation in Romania and found 81.9% of 1300 survey responses received, went online in search of health information [35]. In a similar research, which was carried out in the early years of virtual community emergence, the authors of [63] found that, up to the time of their research, 33 million Americans have searched for health related information online. Individuals who search online for health information are referred to as e-patients. HVCom is known to *“ empower patients with knowledge, facilitate health information dissemination, and provide social and psychological support*” [40].

HVCom can facilitate the provision of some forms of healthcare such as consultation to patients even when the patients and care providers are at two different locations [64] [65]. Different types of HVComs exist and they can be formed between patients to share stories and obtain psychological support from each other which is known as Patient-Centred community, or, they can be formed between healthcare professionals to share ideas which is known as Professional-Centred community [20]. Communication in HVCom communities is normally asynchronous which is not suitable for real-time communication and collaboration. VO is a form of virtual community formed on a short-term base which is considered more suitable for the dynamic nature of healthcare as claimed by [66]. The reason is, members commit for a short period to provide a service in a VO and after the set goal is achieved, they are free to join other VOs. The flexible and temporary nature of VO is one of the determining factors considered in choosing it as a theoretical base for the purpose of concept development in this thesis.

2.5 Virtual Breeding Environment and Virtual Organization

Virtual collaboration comes with challenges such as regulation and organization to ensure that the collaborating parties meet their obligations. Collaboration is taking place between a number of collaborators to achieve a common goal; each collaborator is required to contribute to the process according to their level of obligations, however, this offer challenges in terms of defining the level of obligations and enforcing it. Researchers have been developing VBE and VO concepts to address the challenges [55][56][67][68][31][32].

VBEs are created by individuals, organisations and other relevant parties using ICT to provide a long-term environment for virtual collaboration. The main job of the environment is to recruit and connect collaborators and facilitate the process of resource sharing between them under some enforceable rules and regulations [69]. A possible collaborator recruitment method from a universal pool is suggested by authors in [70]. Theses environments can serve different collaboration purposes, for example, Virtual Research Environment (VRE) developed to help researchers connect and Open Science Grid (OSG) developed to facilitate scientific resource sharing [29][30]. Initiation, operation and dissolutions are the three main life-cycle stages of a VBE as described by authors in [27]. VBE is capable of overseeing the process of creation, operation and dissolutions of a number of parallel and temporary collaboration ensembles known as VOs.

VO is an independent container for a number of collaborating parties that wish to collaborate and share resources to achieve a goal, after which, it is dissolved and the collaborators are free to form or join a new VO. VO is defined by [33] as "*A loosely bound consortium of organisations that together address a specific demand that none of them can (at the given time) address alone and once the demand has been satisfied the VO might disband*". For the world of business, the authors of [71] define VO as a "*temporary network of independent companies, suppliers, customers, and even rivals - linked by information technology to share skills, costs, and access to one another's markets*".

Virtual collaboration presents many organisational and management challenges which researchers aim to tackle using the facilities offered by VBE and VO concepts. The concepts are believed to create a common organised virtual space where collaborators can share resources and work together [72]. To understand the management aspect of VBE and VO, the authors of [28] have developed a framework that models the structural and behavioural aspects of the concepts. The concepts are general and requires a different organisational and managerial approach in different sectors. For instance, a framework to manage VBE and VO in the business sectors is proposed by [27] which aims to describe roles and services and the authors clearly sate that the framework is not suitable for the healthcare sector.

In this thesis, a virtual collaboration framework specific to healthcare is developed with the aim to fill in the gap. Healthcare management and provision requires a dynamic mechanism that can adjust to different needs and circumstances, the idea that VO can be formed on goal bases with no long-term commitments from its collaborating members makes it appealing to healthcare.

The life cycle of a VO is similar to that of VBE according to [69] and [73], but with much shorter life-time for each stage. Figure 2.3 is a lifecycle diagram for VBE and VO. In the initiation stage of VBE, parties who are willing to commit to long-term base collaborations and resource sharing are recruited along with required resources (indicated by the arrows pointing to the VBE initiation stage) to provide the operational support needed for the life spam of the VBE. In the operation stage, VBEs accept requests based on which VOs are created (oval shapes inside the VBE operation indicate VO life-cycle stages). The main task of a VBE is to recruit collaborators and provide required resources to initiate the requested VO and oversee the operation and dissolution of the VO. Finally, the VBE is dissolved when its service is no longer needed in which case collaborators and resources are freed to be reused.

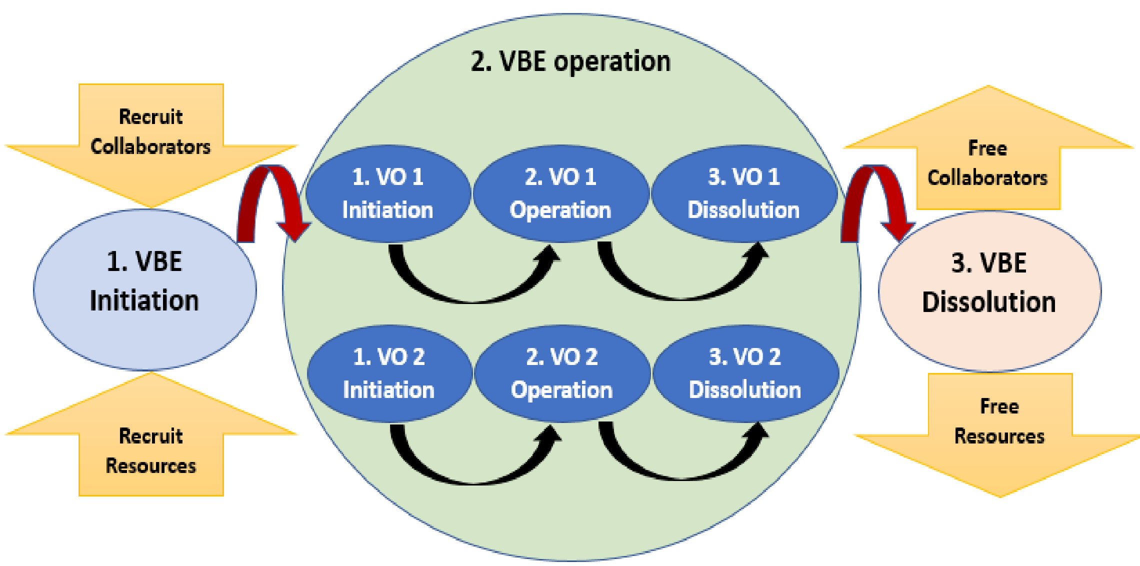


Figure 2.3: VBE and VO life-cycle showing the three stages (initiation, operation and dissolution)

2.6 Modelling Virtual Collaboration

To convey information, diagrams play an important role [74], they are created by human, for human, to offer conceptual solutions to problems using geometric and symbolic representation [75]. Diagrams are seen much like a natural language that use words and grammar of the language to form a meaningful sentence [76], since a diagrammatic or visual sentence is also made up of visual notations and grammars [77]. The structure of VBE and VO is important to be described as stated by [78] and to do so, there is a need for a formal modelling language. According to [79] modelling languages can be classified into two groups, general purpose and domain specific.

Due to advancement in technological solutions and the attempt to tackle ever more complex scenarios, domain specific modelling has gained importance recently [80][81][82]. Because of the diversity and complexity of virtual organisation structures, developing an inclusive model usable for VBEs and VOs in all sectors requires an intensive research. Therefore, developing a domain specific modelling language (DSML) can be more achievable for the obvious reason that every sector is different and requires different configurations in their design.

According to [83], DSML consists of a set of abstraction and notations that can be understood by experts in the field to which the DSML is created for. This means that the notations of DSML is more specific compared to general modelling languages such as UML. DSML provide solutions by "*raising the level of abstraction*" and the final products are generated from them. [84] Argues that diagrams created using DSML are formal descriptions of the domain and they are suitable for formal documentation. With this in mind, a DSML for VBE and VO based healthcare virtual collaboration is developed later in section 5.3.

2.7 Service Level Agreement

In virtual environments, SLA is a widely accepted mechanism to regulate collaborations and resource sharing. SLA is simply a contract that regulates service providers, receivers and expected service attributes. It also outlines the responsibilities of each party, expected rewards in case of full service delivery and expected penalties in case of contract violations [85]. SLA is defined by [86] as "*a contract that defines the level of services a service provider promises to a service consumer*". Formation, deployment, enforcement and termination are the life cycle stages of SLA [87]. [86] Identifies the main components of SLA as (1) expected service description, (2) the reliability level of the service, the monitoring and service reporting, (3) the service conditions. SLA is normally created based on a predefined template which is believed to speed up the process of SLA agreement between service requesters and providers [88][89][90]. SLA is important in a collaborative environment especially when collaborating parties expect services from each other. It provides a framework for working where the interest of all parties is protected and formalised. SLA in conceptual models can increase the level of understanding and service development according to [91]. In this thesis two SLA templates have been developed for healthcare virtual collaboration and their structure and content are presented in the Section.

2.8 Blockchain technology

In this research, blockchain technology is considered as a base to develop a mechanism for healthcare provider validation and verification in Section 6.4. Nakamoto in 2008 proposed the concept of Bitcoin [92], which removes the third-party authentication mechanism during transactions made online. Instead, authentication happens in a peer-to-peer network where all peers in the network hold a copy of the same information (Hash value in the Bitcoin context). In blockchain, transactions are recorded between peers in a network using cryptography and store the records in a digital ledger which is called a block. To verify and validate the content of blocks, each block is linked to the other and, during the verification and validation process the content of all blocks should match. Figure 2.4 shows the composition of blocks as block header, hash of previous block header and Merkle root.

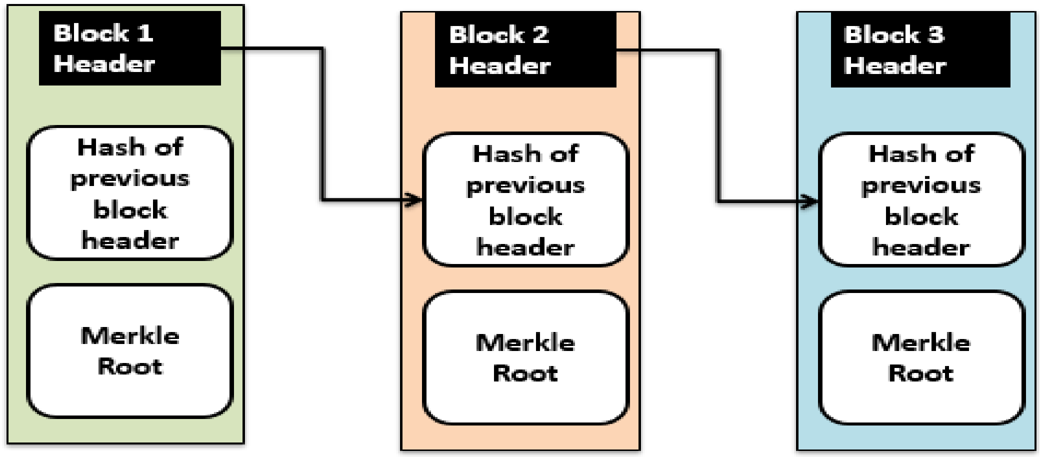


Figure 2.4: Blocks linked in a chain showing the concept of Blockchain technology

A unique hash value of the previous block is stored in each block in a chain, in case of requests to change a block all the hash values are compared, for the change to be recorded successfully, they all have to match. Any unconfirmed alteration to a block will render the block invalid as changes to the content of a block will alter the unique hash value which will not match with the hash values stored in other blocks. This mechanism safeguards the validity of the information contained in a block. Data security is an important requirement in healthcare systems, in blockchain, to ensure data security within a block, public key cryptography is used. This is where the information in a block is encrypted using a publicly available key, but to decrypted back to its original information, a private key which is held by the block owner is required [93]. This process verifies the identity of the block owner.

Permissionless and permissioned are the two main types of blockchain, the former allows free requests to change a block by the owner and in the later, requests to change a block is controlled by a central authority that requires the requester to provide identity verification credentials such as user name and password [94]. For the purpose of this research permissioned blockchain is chosen to be used later in the development of the healthcare provider verification and validation mechanism.

2.9 Technology Acceptance Model

The authors of [95] claim that most researches in the field of healthcare informatics have focused on technical aspects of developing and implementing healthcare systems and not enough attentions have been paid to the acceptability of such systems among prospective users. The acceptability level has been used as indicators by system developers to decide whether to continue developing a system or not [96][97][98]. Theory of reasoned action (TRA) and theory of planned behaviour (TPB) [99] are both used in the development of Technology Acceptance Model (TAM) [34].

The TAM pictured in Figure 2.5 was published by Davis in 1989 after a small refinement from the original one he developed in his PhD thesis in 1985 [100]. The TAM proposed by Davis consists of four constructs which are perceived ease of use, perceived usefulness, attitude towards using, and intention to use. Each construct tests an aspect of technology acceptance by prospective users of the technology in question.

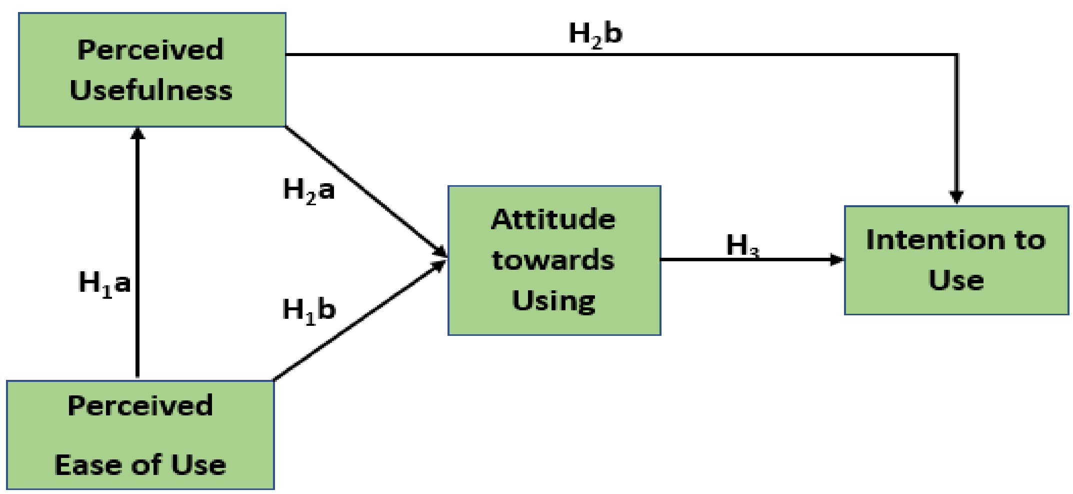


Figure 2.5: Original Technology Acceptance Model developed by Davis in 1989

Davis describes Perceived Usefulness (PU) as "*the degree to which an individual believes that using a particular system would enhance his or her job performance*" and perceived ease of use (PEU) is described as "*the degree to which an individual believes that using a particular system would be free of physical and mental effort*" [34]. Attitude towards Using (AU) is described as*" individuals positive or negative feeling about performing the* *target behaviour (e.g. using a system)* " and Intention to Use (IU) is described as " *the degree to which an individual has formulated a conscious plan to perform or not perform some specific future behaviour*" [101] [102].

The lines connecting the four constructs represent causal hypothesis used test the causal effect of the constructs on each other. Hypothesis is described as "*A proposition to be put to test to determine its validity*" [103]. Formulating and testing hypothesis has served as one of the fundamental pillars of research and it is popular among researchers. To evaluate the frameworks developed for healthcare virtual collaboration in this thesis, TAM is used as a theoretical base to develop evaluation models which includes extending the original TAM model with new constructs and formulating new hypotheses. TAM extensions are described in Section 4.3.2. [104] States that TAM has been successful in providing "*general explanation of the determinants of computer acceptance and explains computer usage behaviour in a wide range of computer user domains*".

According to [105], hypothesis "*can be formulated based on previous research and observation*", previously tested TAM hypotheses found in literatures such as [106],[107],[108] and [109] and the original TAM hypotheses were used as a base to formulate hypotheses for this research. The aim was to find out users' intention to use the developed healthcare virtual collaboration modelling framework implemented as Java Application and the virtual collaboration framework implemented as a mobile application. The hypotheses adopted and later modified from the original TAM published by Davis are the followings:

H_1a: "*Perceived ease of use will have a significant effect on perceived usefulness*".

H_1b: "*Perceived ease of use will have a significant effect on attitude towards using*".

H_2a: "*Perceived usefulness will have a significant effect on attitude towards using*".

H_2b: "*Perceived usefulness will have a significant effect on intention to use*".

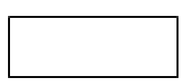
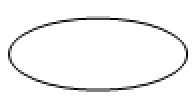
H_3: "*Attitude towards using will have a significant effect on intention to use*".

2.10 Structural Equation Modelling

To statistically analyse data obtained empirically during this research, Structural Equation Modelling (SEM) is used [110][111]. According to [112], SEM is the most frequently deployed method in analysing data collected from survey questionnaires. The technique utilises path analysis and regression testing to test the extend of relationships between surveyed items [110]. One of the attractive aspects of SEM is the graphical representation of measured and unmeasured constructs and the relationships between them, which has made it popular among researchers who prefer visual models over mathematical formulas. Table 2.1 shows the main graphical notations of SEM.

[110] States that SEM is more flexible than traditional statistical approach since it works based on a defined model, takes into account errors in variables and it is a multivariate estimation technique. Table 2.2 is a brief comparison between SEM and traditional statistical approach. In this research, TAM is modelled using the modelling symbols of SEM in AMOS to compute statistical values that can be interpreted for user acceptance testing purpose. Each construct in TAM is modelled as an oval (latent variable). To measure the latent variables, a number of questions are developed in a questionnaire, each question is represented as a rectangle (measured variable) in SEM. The symbols are linked using the causal effect (single headed arrow) and the circles of SEM are used to represent possible error values in the collected data.

Table 2.1: Structural Equation Model Notations

No.	Name	Symbol	Explanation
1	Measured Variable		A rectangle represents a variable that can be measured directly.
2	Latent Variable		An Oval represents unmeasurable latent variables which requires a number of measured variables to measure it.

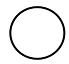
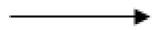
No.	Name	Symbol	Explanation
3	Error variable		Represents possible errors in a dataset of a variable.
4	Causal effect (Direct effect)		Represents the causal effect between variables in a path diagram.
5	Covariance (none-directional path)		Represents covariance relationship between variables.

Table 2.2: A comparison between Structural Equation Model and Traditional Statistical Method summarised from [146].

Structural Equation Modelling	**Traditional Statistical Method**
• Multivariate (measured and latent variables).	• Single-variate (measured variable only).
• Appropriate for testing a number of interlinked hypothesis in a wide range of areas such as economy, health, family, self-efficacy.	• Appropriate for testing a single hypothesis.
• A formal model is required to be estimated and tested.	• The default model is estimated and tested.
• A number of statistical estimation equations are solved in parallel.	• One estimation equation is solved at a time.
• Takes errors into account.	• Does not take errors into account.

Structural Equation Modelling	Traditional Statistical Method
• Model fit test is based on multiple tests. • To estimate a latent variable multiple measure are required. • Relationship between variables can be represented in a graphical model.	• Model fit is based on a single straightforward test. • Latent variables cannot be estimated. • No graphical modelling is available.

2.11 Chapter 2 Summary

This chapter provided a brief background of the concepts and technologies used to develop the healthcare virtual collaboration modelling and collaboration frameworks. The content of the chapter is summarised in the following points:

1- Virtual collaboration is where a number of parties come together to share resources and work on a common goal without meeting face to face. Virtual collaboration is facilitated by modern information and communication technologies such as the internet and telecommunication.

2- Virtual Breeding Environment is described as a permanent setting that is created by a number of collaborating parties with the aim to facilitate the management and creation of short-lived and goal-based virtual collaboration known as Virtual Organisation. The two concepts have been used as a theoretical base two develop the modelling and collaboration framework in this thesis.

3- Modelling is a method to simplify complex settings, the technique is used in many fields of science such as engineering and manufacturing. To facilitate the design of a healthcare virtual collaboration system, a domain specific modelling framework is considered necessary by researchers.

4- Service Level Agreement is a widely accepted mechanism to regulate the terms and conditions of a collaboration where the rights and responsibilities of each party is stipulated. The creation, deployment, enforcement and termination are considered the life cycle stages of SLA. In this thesis, two SLA templates are developed to be used for regulating the rights and responsibilities of healthcare virtual collaboration participants.
5- Blockchain technology is a peer to peer network that records transactions in a block and distribute a copy of the block to all peers in the network. The technology removes the need for a third party to verify and validate the content of a transaction by comparing all copies of a block held by participating peers in the network. This technology is considered to develop a healthcare virtual collaboration provider versification and validation mechanism in this thesis.
6- Technology Acceptance Model (TAM) is a widely used theoretical evaluation framework to examine the acceptance of a new technology by users. TAM examines the extend of the effect of *usefulness* and *ease of use* of a technology on the intention of a user to use the technology. The original TAM model is modified by adding new variables in order to adapt for the purpose of this thesis.
7- Structural Equation Modelling (SEM) is statistical data analysis technique which is frequently used to analysed data collected from survey questionnaires. The technique makes use of path analysis and regression testing and it is popular among researchers who prefer to use visual models instead of mathematical formulas. In this thesis the technique is used to analyse data collected to evaluate the two developed frameworks.

In Chapter 3, a brief literature review is provided to present the current state of the art in addressing virtual collaboration modelling, organising and managing for healthcare and identify the gaps that puts the need of this research into context.

Chapter 3 : Literature Review

This chapter reviews a number of the literatures available on developing models and mechanisms for virtual collaboration. The chapter also presents literature reviews on the use of TAM in evaluating healthcare systems. Section 3.1 presents some proposed modelling approaches for virtual collaboration and Section 3.2 presents reviews of virtual collaboration frameworks developed by researchers in the field. Section 3.3 presents a number of available SLA creation and management mechanisms and Section 3.4 provides some partner selection mechanisms proposed in literatures. A brief review of a number of service orchestration mechanisms are outlined in in Section 3.5. A review of literature on the use of TAM to test healthcare applications is provided in Section 3.6 and finally, a summary of the chapter is provided in Section 3.7. To put frameworks developed in this thesis into the context of current on-going research, more related work reviews will be provided in relevant sections in Chapters 5 and 6.

3.1 Virtual Collaboration Models

Enterprise related modelling approaches have been researched for some times and some of them are currently in use, for instances, Unified Modelling Language (UML) [75] [113], business Processing Modelling Notation [114], Integrated Definition Methods (IDEF) [115], Business Process Modelling Language (BPML) [116]. As for virtual collaboration, the authors of [117] propose the Vienna Development Method and the authors of [38] present a virtual organisation model that combines both “structure and process components”. The federation-agent-workflow (FAW) model is suggested by [70] to model collaborating federated agents that come together to accomplish a task. As for the elements of virtual organisation, the authors of [38] present a model as agents, behaviour and autonomous federation. [118] Offers a formal framework for modelling agent-based VOs. The purpose of the framework is to describe services provided by agents in grid applications and they focus on creating VOs automatically using intelligent agents. Providing explicit constructs of VOs is a feasible approach to define its structure, for this [119] suggests APPEL language for defining the policies of the construct.

The structure of VO is difficult to define due to its dynamic nature, therefore, finding a model capable of capturing important aspects of VO structure is a challenge [120]. To address this challenge the authors of [33] present a Virtual Organisation Modelling language that aims to model the structural and orchestration aspect of VO supported by a persistent breeding environment. The language consists of two sets of notations which are VO-S that define the structure of supported VOs and VO-R that defines the internal reconfiguration of VOs. This modelling language is developed for business environment and the language lacks graphical syntax; however, in developing the HC-VBE-M-F in this thesis, their direction is adapted for healthcare virtual collaboration with added graphical notations.

3.2 Virtual Collaboration Frameworks for Healthcare

Researchers have proposed a number of frameworks for virtual collaboration in healthcare for different purposes. A number of such researches are outlined here to provide a basic review of the different proposals. An image interpretation framework is outlined in [121] to allow healthcare professionals to share images provided by a patient with other healthcare professionals for diagnostic and treatment purpose. The authors of [122] suggest that team-based care is becoming the norm and to support the process, they propose a multi-agent framework where they describe a number of components which they call agents to manage different aspects of team work collaborations in healthcare. The framework is specific to teamwork management within a local healthcare system and dese not outline team creation mechanism.

The authors of [123] propose a Fog technology-based framework for healthcare collaboration which is specific to machines within a healthcare system. They call the collaborating entities “nodes” and the communication between them is powered by Internet of Things (IoT). Another similar framework to the Fog-based framework is proposed by [124] based on Cloud to connect healthcare Virtual Labs together. The framework is composed of seven components which they call agents, each managing different aspects of the collaboration. The frameworks mentioned are rather technical and do not consider human participants in the collaboration process.

A Smart Healthcare System Framework is proposed by [125] that uses cloud and mobile technologies to provide care. The framework aims to utilize a mix of technologies to enable healthcare providers to create, provide and reuse healthcare services in a virtual independent module. The framework is yet to be implemented and tested for acceptability which is an important stage to be passed by any new technology before its application. The review suggests that a comprehensive healthcare virtual collaboration framework is yet to be developed as the frameworks presented are developed to address specific aspects of virtual collaboration. It is one the objectives of this research to develop a general and comprehensive virtual collaboration framework for healthcare.

3.3 SLA Creation and Management

The importance of SLA as a mechanism to define and manage electronic resources in a virtual world is increasing and it is becoming more detail intensive. For example, the authors of [126] propose a SLA for defining Quality of Service (QoS) constrains and others propose it for service management [127]. In a virtual collaboration setting, automatic management of resource sharing, participant selection and goal achievement measures are required, for this, authors in [127] propose that SLA is the way to automate. A detail definition of roles and obligations for participants of a given VO is vital for achieving their set goals [128]. The importance of SLA management for virtual service provision is realised by many researchers, for instance, the authors of [136] propose SLAC management framework aimed at managing cloud services. They focus on the formal description of SLAs and manage the SLA once it has been agreed by all parties. A SLA framework for providing web services is proposed by [137] for regulating the agreements between clients and service providers. The authors of [89] propose a SLA management framework which deals with electronic contracts for distributed multimedia contents. The framework enables consumers to define the quality of services they require before they are delivered by service providers. TrustCoM proposed in [138] is an example of SLA management framework aimed at ensuring a trustworthy SLA creation. Others propose a logic based SLA management framework where they make use of knowledge representation to manage SLA [139]. As for creating SLA, there are a number of available mechanisms, Table 3.1 is a summary of a number of them.

Table 3.1: e-Contract Mechanism Examples

Years/decades	Reference	e- Contracting Creation Mechanisms
2000	[129]	WSDL, ebXML, UBL
2003	[130]	SLAng
2003	[131]	WSLA
2007	[132]	WS-Agreement
2007	[133]	Cc-pi
2010	[134]	C-Semiring
2010	[135]	SLA*
2014	[136]	SLAC

Not all services provided in healthcare can be provided electronically, human involvement therefore is inevitable. [135] Claims that popular SLA mechanisms such as WSLA [140], CC-Pi [133] and WS-Agreement suffer from flexibility and support for services that have human involvement. All available electronic SLAs mentioned are developed for machines to understand which can be difficult for human user to read and understand. Human and machine readability is an attribute that a SLA for healthcare virtual collaboration should possess to be deemed suitable. With this in mind, it is one of the objectives of this thesis to develop SLA templates that are text-based and support human readability.

On machine level, developing a language to describe SLA is another challenge. Due to the unique form of SLA in different domains, a generic SLA language capable of describing service provision in all domains is yet to be defined. It is for this reason that researchers in the field have defined a number of domain specific languages to express SLA. For instance researchers in [141] and [142] have developed SLAng specific to network services and the authors of [131] propose languages for web services. Object Constraint Language (OCL) is used in [143] to deal with service violation. WSaAgreement [132] and SLA* [135],are some other researches aimed at developing languages to write machine readable SLA and each is developed for a specific domain. It is not the intension of this research to develop a language for describing a machine-readable SLA, therefore any of the languages mentioned can be adapted if deemed suitable in future researches.

3.4 Partner Selection Mechanism

To achieve the dynamicity required in the formation of a healthcare VO, it is important to specify a mechanism for collaborators selection [69]. Recruiting the right partner into a VO setting is crucial for a successful collaboration. The authors in [144] claim that there is a gap in research on partner selection mechanism. To contribute to the body of literature, they propose a partner selection mechanism based on formal concept analysis. A criteria-based partner selection framework for virtual enterprise (which is similar to VO) is proposed by [145], in which, they survey literature for proposed partner selection criteria and filter the most important ones based on asset procedures. The framework is specific to business enterprises and may not be suitable for healthcare VO, however the method can be considered for possible adaption.

In a similar research, the authors of [146] propose a multi-agent model for partner selection, in which, they use price, quality, delivery time and past performance as selection criteria. The model uses an auction environment where potential partners can bid to offer a service and the criteria are used to select the best offer. Auction model in business could be a workable choice since the aim is to maximise profit, but in the context of healthcare, quality is more important. Moreover, the researchers have not outlined a clear mechanism for selecting partners within their model. Researchers in [70] suggest selecting partners from a universal pool of organisations based on short term objectives and long term objectives. The mechanism is rather ambiguous, it does not answer the partner selection question fully instead raises many more questions such as how do we classify members into short term and long term based? Literatures reviewed in this section show that there is a need for a clear partner selection mechanism that can be followed to select the right virtual collaborators for healthcare as none of the proposed mechanisms is healthcare specific. It is one of the sub-objectives of this thesis to develop a clear step by step healthcare virtual collaboration partner selection mechanism.

3.5 Service Orchestration

The authors in [42] claim that coordinating resource sharing is a real problem in dynamic and multi-participant grid collaboration; they stress the need for clear resource sharing rules between participants. The term that is most recognised with coordination process in virtual collaboration is "orchestration". [147] Describes orchestration as the activity sequences that takes place in a specific organisation, and the concept as a global coordinator for all elements involved in a virtual collaboration, is explained in [148]. For collaboration and orchestration mechanism, [70] proposes the use of communication languages such as KQML [149][150], as for the member selection and collaboration negotiation, they recommend the language outlined in [151]. The concept of orchestration is not widely researched for healthcare virtual collaboration, there are a few available researches such as [15] that aims to support the ''*dynamic creation, management and coordination of virtual medical teams for the continuous treatment*''. One of the sub-objectives of this research is to develop an orchestration mechanism for healthcare virtual collaboration.

3.6 TAM for Healthcare Applications

The use of Technology Acceptance Model (TAM) is extremely popular among researchers for testing the acceptability of newly developed ICT-based applications in healthcare [95][152] [153].In this section, the uses of TAM in a number of available researches are presented. A home telehealth service for people aged 50 and above was tested for acceptability by authors in [154] using TAM in Slovenia. [155] Uses and extends TAM to examine factors affecting users' intention to use mobile healthcare information system in

Jordan. A telemonitoring system was developed in Spain by the authors of [156] and to examine the factors that influence the intention to use the system by users, they used TAM. The acceptability of tablet computers by paediatricians was tested in [157] using an extended TAM and users attitude towards using electronic medical record systems was tested in a similar way in [158]. TAM has been used to study acceptability and implementation barriers of electronic health record systems by physicians in [159]. TAM was also used by the authors of [160] to examine nurses expected usefulness and ease of use with regard to healthcare information systems in Jordanian hospitals.

A mHealth application for elderly patients was developed by researchers in [161] and to research the factors affecting the intention to use the technology by target users, they used a modified version of TAM. The authors in [95] carried out a systematic review of the use of TAM in healthcare informatics up to the year 2017 and they found that mobile application for healthcare is one of the main technologies evaluated for acceptability using TAM. This survey supports the approach of this research to evaluate the developed virtual collaboration concepts through implementing it as a mobile application and use TAM to evaluate it.

3.7 Chapter 3 Summary

This chapter provided a brief literature review on frameworks, mechanisms and techniques developed for different purposes of virtual collaboration in healthcare. The following points summarise the content of the chapter:

1- Modelling virtual collaboration has been researched for business purposes and several modelling frameworks such as Unified Modelling Language (UML) and Business Process Modelling Language (BPML) are currently used. There is a gap in literature on modelling virtual collaboration for healthcare. To fill in the gap, a modelling framework for healthcare virtual collaboration is developed and evaluated in Chapter 5.

2- Several healthcare virtual collaborations have been presented in literature such as an Image Integration Framework for healthcare to facilitate image interpretation in a collaborative setting between healthcare providers. A Fog-based collaboration framework is developed to connect medical laboratories. The frameworks are task specific which reveals a gap in literature about a comprehensive collaboration framework for healthcare. To fill in this gap, a healthcare virtual collaboration framework is developed in Chapter 6.

3- There are a number of mechanisms presented in literatures for virtual collaboration. For the creation and management of SLA mechanisms such as SLAng and SLAC are developed, for partner selections, mechanisms such as criteria- based partner selection mechanism is developed and for service orchestration, mechanisms such as KQML is developed. None of the mechanisms is healthcare specific. in Chapters 5 and 6, similar mechanisms are developed specifically for healthcare virtual collaboration as part of the modelling and collaboration frameworks.

4- Technology acceptance Model (TAM) is widely used to test the acceptance of new healthcare technologies by prospective users. This chapter provides a brief literature review about a number of researches that have extend and used TAM as a theoretical evaluation framework. To evaluate the two developed frameworks in this thesis TAM is used.

The next chapter presents the methodology and evaluation strategy of the thesis.

Chapter 4 : Methodology

This chapter describes the research design and methodologies that are practised to achieve the aims and objectives of the study. It starts by providing a general idea about the research method used in this thesis in Section 4.1 and provide a comprehensive research design in Section 4.2. In order to evaluate the frameworks developed for healthcare virtual collaboration effectively, an evaluation strategy is outlined and described in Section 4.3. The strategy contains the concept implementations, testing, data collection and data analysis processes. Finally, a summary of the chapter is provided in Section 4.4.

4.1 Research Methodology

Research is described by [105] as a "*A logical and systematic search for new and useful information on a particular topic*". Basic research leading to theoretical discoveries as well as conceptual construction of knowledge regarding the use of virtual collaboration in healthcare sector was the focus of this study.

The overall aim of this research is to model and develop virtual collaboration for healthcare, and answer research questions that have been defined in Section 1.3. Modelling healthcare virtual collaboration requires an intense understanding of the sector in terms of healthcare stakeholders and services. To bring about the understanding required, in-depth literature review was conducted. To investigate how virtual collaboration can facilitate healthcare service provision, current virtual collaboration concepts needed to be studied and adapted. To ensure that the developed collaboration concepts are acceptable by healthcare providers and receivers, they had to be tested empirically. In light of these research needs, a mixed methods research approach consisting of literature reviews and survey questionnaire was performed.

4.2 Research Design

Success of a research partly depends on the research design used to carry out the research. Research design is defined as the overall plan to study and collect data [162]. In designing the research for this thesis a deductive research approach was adopted, which aims to develop theoretical concepts before testing it [163]. In this research, theoretical healthcare virtual collaboration frameworks have been developed first before carrying out empirical evaluations. Figure 4.1 shows the overall research design used in this study. The design consists of five major steps. In step one, the healthcare sector is researched from literatures found on the internet, books and published papers. In step 2, the concept of virtual collaboration is researched from literatures found on the internet, books and published papers. In step three, a HC-VBE modelling framework is developed which includes a service and participant classification framework, a domain specific modelling language and a service orchestration description language. In step four, HC-VBE collaboration framework is developed which includes a theoretical architecture, a member selection mechanism, a member validation mechanism and SLA templates. In step five, the developed frameworks are evaluated. The steps are described in Section 4.2.1.

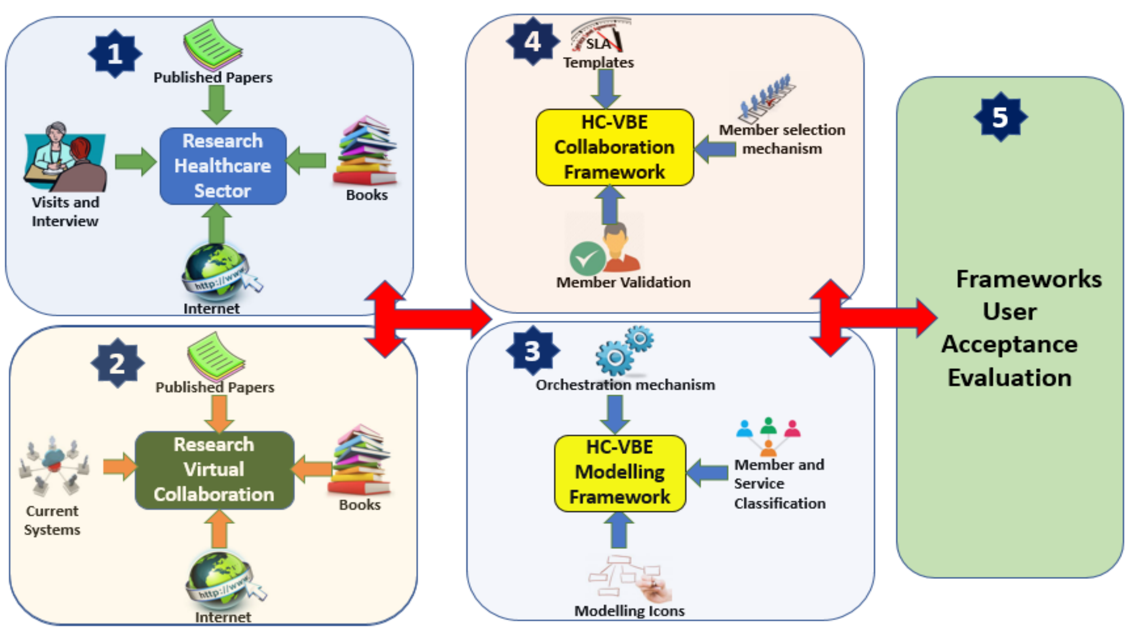


Figure 4.1: General search design used to carry out the research in this thesis

4.2.1 Research Design Steps Description

This section provides a brief description of each of the five steps in the research design.

Step 1: Research healthcare Sector

To understand the structure and elements that makes up the healthcare sector in terms of stakeholders and services available, literatures found on the internet is studied and analysed. It was decided that a deductive method is appropriate to identify healthcare services and stakeholders from the literatures found. To begin with, search words such as "healthcare, health care, and health-care" were used in different databases such as Google Scholar, Scopes and Science Direct to obtain references that could provide an overview of the sector.

As a result, more than a 100 books and articles such as the ones cited in this thesis were found and studied. From the result of the study, a summary chart for stakeholders and services of healthcare was drawn which can be found in Figure 5.2. The research outcome of this step was further processed and adapted to develop the service and participant classification mechanism described in Section 5.2.

Step 2: Research virtual collaboration

To understand the concept, purpose, technology and use of virtual collaboration, similar to the previous step, available literatures found in major research database on the internet were reviewed. As a result, relevant literatures found were studied and analysed to paint an overall picture of the current state of virtual collaboration. The main aim of this step was to understand the feasibility, mechanism, scope and applicability of virtual collaboration in healthcare sector.

Step 3: Develop healthcare virtual collaboration modelling framework

From the results of steps one and two, frameworks relating to modelling and applying the concept of virtual healthcare in healthcare were developed. The first framework developed is a generic modelling framework which can be used to model HC-VBE and HC-VO collaboration scenarios. The framework is developed for healthcare system developers as target audience with the aim to provide them with a tool to classify and model stakeholders and services for healthcare virtual collaboration. The modelling framework is described in Chapter 5. The framework consists of a service and participant classification mechanism described in Section 5.2, a set of modelling graphical notations developed by extending UML use case diagram graphical notations which are described in Section 5.3 and a service orchestration description language described in Section 5.4 that can be used to describe healthcare virtual collaboration service processes.

Step 4: Develop healthcare virtual collaboration frameworks

This is the second framework which provides a step by step VBE and VO based collaboration initiation, management and dissolution. It is developed based on the concepts developed in the modelling framework with the aim to facilitate healthcare provision remotely to those in need. The collaboration framework is described in Chapter 6. The framework consists of a general conceptual collaboration framework presented in Sections 6.1 and 6.2 which describes how a heartcare service is requested, processed and provided in a clear step by step process, a member selection mechanism that formalises the process of member selection for a particular healthcare service requested described in Section 6.3, a healthcare provider validation mechanism described in Section 6.4 and a number of general service level agreement templates that formalises contracts between participants of a healthcare virtual collaboration described in Section 6.5.

Step 5: Framework Evaluation

There are many organizations around the world working to develop healthcare information systems to improve the quality of care and reduce cost [164]. One of the most common ways to ensure that a system achieves its intended aims is to perform user acceptance evaluation. The authors of [165] claim that evaluation can aid advancing healthcare systems through identifying the strength and weakness of a system in terms of acceptability and intention to use by users. Healthcare system evaluation has many dimensions such as human, organizational, clinical and technological which makes it a challenging task that requires different approaches to address it [165].

Healthcare information systems have an unpredictable nature, evaluation is performed to ensure that an information system meets its intended purpose. [166] States that "*health information systems evaluation finds its roots in technology acceptance models*". To evaluate user' acceptance of the technologies developed in this research, TAM [108] was chosen as a theoretical evaluation framework. The authors of [160] state that TAM is widely used and its validity, reliability and robustness has been proven. Structural Equation Modelling (SEM) [111] was then used as a statistical data analysis tool to empirically show the acceptability of the virtual collaboration frameworks developed in this study.

4.3 Evaluation Strategy and Methods

According to [167], there are three types of strategies that can be considered when it comes to information system evaluation which are "*Goal-based evaluation, Goal-free evaluation and Criteria-based evaluation*". Goal-based evaluation is performed against a set of goals identified prior to the system development, Goal-free evaluation is performed without any prior goals, it is rather performed to discover the potential of a developed system, and finally Criteria-based evaluation is performed against a number of identified criterion that the system must adhere to in order to be deemed successful.

As for implementation strategies, "*IT-system as such*" and "*IT-system in use*" have been identified as two different strategies to perform information system evaluation. The first is concerned with having only evaluators of a system to collect data and carryout the evaluation. The second is concerned with involving users of a system to collect data and let evaluators perform the evaluation [167]. A mixture of Goal-based and IT-System in use evaluation was performed in this thesis. Other information system evaluation approaches such as summative, which evaluates a system at the end of development and formative, which evaluates a system during development are suggested by [166] and [168] with the aim to provide more guidance for evaluation. Evaluation is at the heart of research and to ensure that the evaluation for this research is carried out in a systematic way, an evaluation strategy was developed. The strategy consists of 8 steps that was used as a roadmap to ensure the quality and reliability of the end results. Figure 4.2 shows all the 8 steps and each step is described in detail in the following sections.

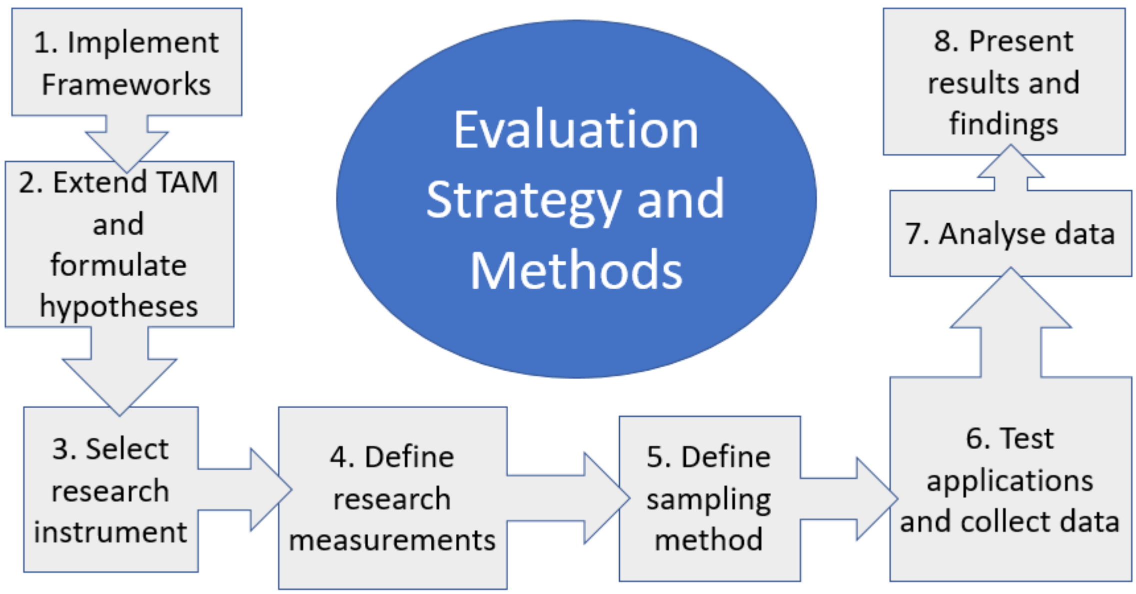


Figure 4.2: Evaluation strategy steps used to evaluate both the HC-VBE-M-F and the HC-VBE-F frameworks

4.3.1 Frameworks Implementations (Step 1)

To evaluate the acceptability of both frameworks developed, they were implemented as a prototype in order to make them available as tools to be used by the target audiences. The HC-VBE-M-F was implemented as a Java stand-alone application that could be down-loaded onto a computer and be used directly to model healthcare virtual collaboration scenarios. The HC-VBE-F was implemented as a mobile application that healthcare providers and requesters could install on their mobile phones and use it to provide and request healthcare services whenever and wherever, provided they have an internet connection. The two implementations are described in Sections 4.3.1.1 and 4.3.1.2.

4.3.1.1 Modelling Framework Implementation

UML is widely used by developers and system designers to model different aspects of a system, which means there are a wide range of tools available for UML modelling such as

UMLet, ArgoUML, and StarUML. Since the notations of the modelling language developed for healthcare virtual collaboration is an extension of UML use case diagram, it was natural to follow a similar deign of tools available to model UML. The layout of most UML modelling tools consists of three parts:

1- Graphical notation

Majority of UML tools, including the ones mentioned, have graphical notations ready for the user to drag and drop, after notation selection, editing capabilities such as resizing and moving are provided to edit the notation.

2- Canvas

Majority of UML tools provide a canvas for the users to draw their model on. Multi canvases can be opened each for a separate project.

3- Documentation

The common way to document models is to save them as images and print them. As for model modifications, the tools normally provide the capability to save projects and be reopened for later modifications.

To design and implement the modelling tool, the same design and layout of available tools was followed, but with less functionalities. The aim was to develop a prototype which can be used by healthcare virtual collaboration system developers to model scenarios and provide technology acceptance feedback later. Having this in mind, with the help of one of the author’s students, a simple Java-based application prototype was implemented with the aim to support the evaluation process. The prototype is simple and includes all the notations in the modelling framework that can be used to build a model without much efforts.

The tool is composed of two main parts, the first allow users to model healthcare virtual collaboration scenarios through using relevant notations that represent types of roles and services as described in Section 5.2.1. Figure 4.3 shows a few screenshots of the modelling part of the prototype and a few stages of model development. The second part of the prototype implemented the HC-VBE-SODL described in Section 5.4 that can be used to describe the service orchestration of a particular scenario.. Figure 4.4 shows a few screenshots of the second part with different stages of orchestration description process.

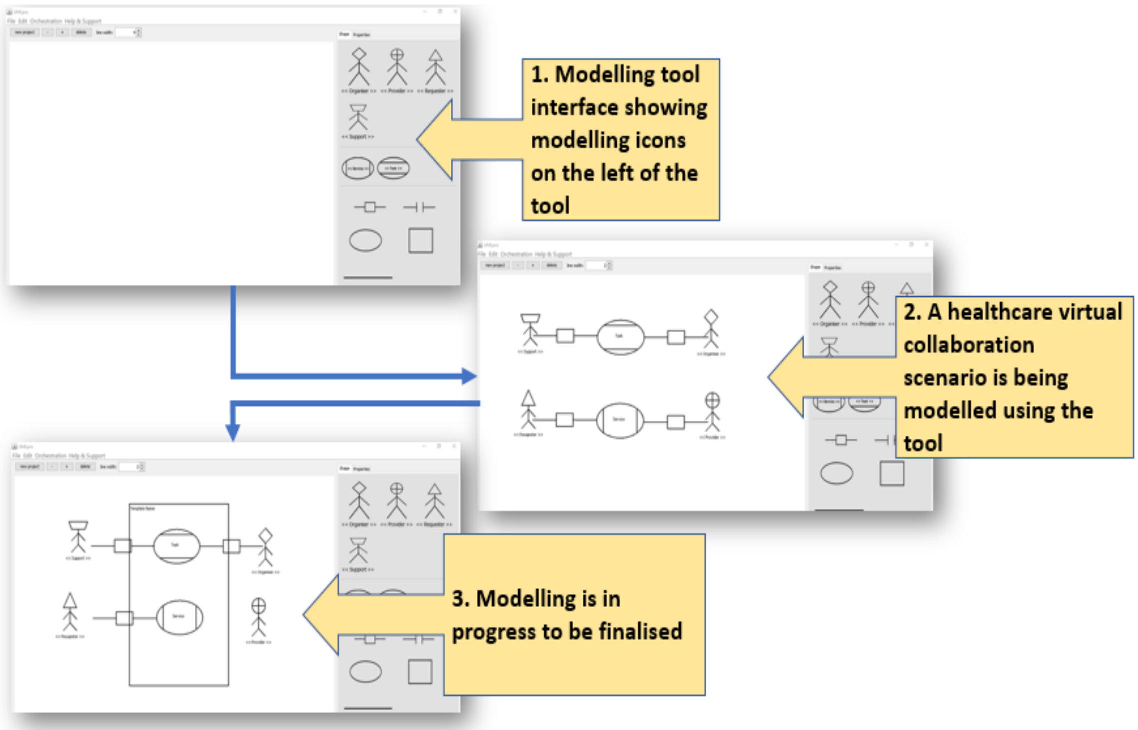


Figure 4.3: Implemented HC-VBE-M-F Java application screenshots showing framework notations and different stages of model development

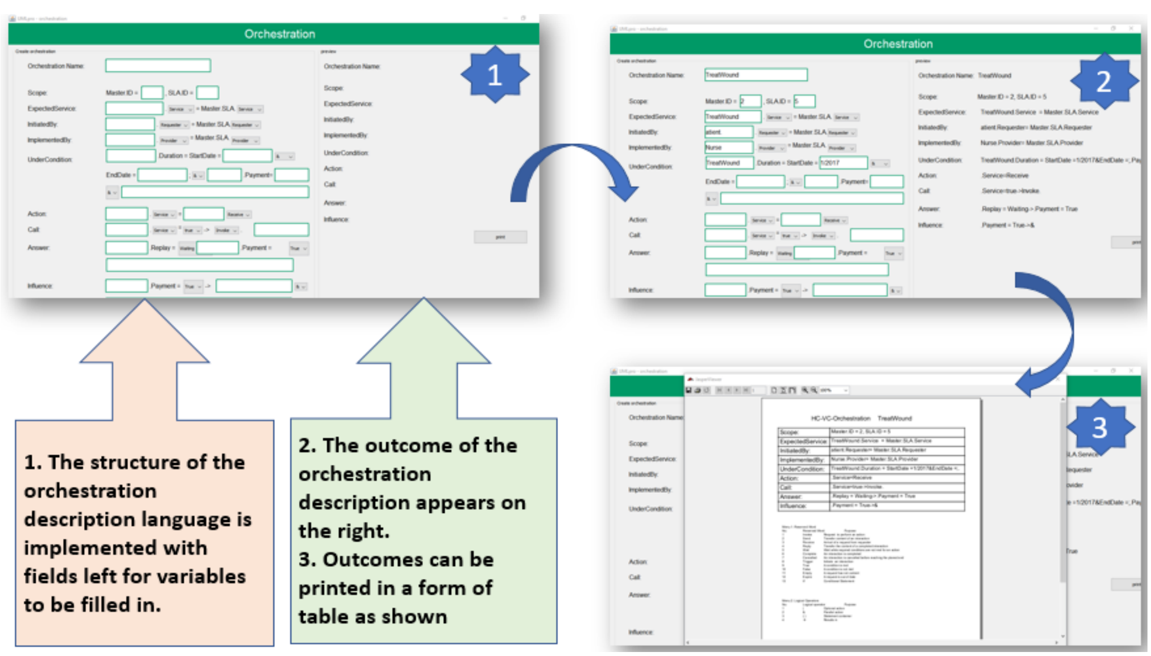


Figure 4.4: Implemented Orchestration Description Language screenshots and stages of the description

4.3.1.2 HC-VBE Framework Implementation

The virtual collaboration framework developed in Chapter 6 is complex with many features that require a lot of time and resources to implement fully, however, to evaluate the basic concepts of the framework, a mobile application prototype was developed with helps from two of the author's students. The use of mobile technology for providing access to healthcare has been promoted by researchers as an easy and affordable method that has the potential to save time and cost [169][161]. The application encompasses all the main stages of the framework such as virtual organisation initiation, creation and management and implements the main components of the framework. The prototype was developed to be tested by healthcare providers and requesters for acceptability using TAM as a theoretical evaluation framework.

The application is available on the author's personal website for users to download and use for feedback and data collection purposes. The mobile application serves as a virtual breeding environment where healthcare requesters and providers can register, negotiate and provide or receive a healthcare service. The application formalises the agreed service terms and conditions in a form of electronic SLA, based on which, the environment creates a dedicated VO for the agreed participants to collaborate and share resources for the duration they have agreed on. The Created VO will be dissolved as soon as the terms of the contract are fulfilled and the duration has expired. To elaborate more on the protype implementation the following steps were executed.

1- Identify prototype functionalities for implementation

To develop the prototype, its main functions had to be identified that covers the most basic but essential aspects of the developed framework. As a result, the following functionalities were identified before the protype development, as minimum requirements:

- Healthcare requesters should be able to:
  - **a) Register as a requester:** The prototype shall allow healthcare requesters to register their details in a registration form and submit it to the HC-VBE mobile application successfully.

b) **Request a healthcare service**: The prototype shall allow healthcare requesters to fill in a healthcare request form and submit it successfully.

c) **Negotiate a service**: The prototype shall allow healthcare requesters to negotiate a healthcare service with a healthcare provider.

d) **View SLA:** The prototype shall allow healthcare requesters to view a final agreed SLA**.**

e) **Approve SLA:** The prototype shall allow healthcare requesters to approve a SLA after agreement on the terms and conditions of the SLA with a healthcare provider.

f) **Virtual contact**: The prototype shall allow healthcare requesters to have a real-time virtual communication via audio or video or both with providers.

g) **Provide feedback**: The prototype shall allow healthcare requesters to provide feedback on services they received via the prototype and rate healthcare providers in terms of service satisfaction.

- Healthcare providers should be able to:

a) **Register as a provider:** The prototype shall allow healthcare providers to register their details in a registration form and submit it to the HC-VBE mobile application successfully.

b) **Offer a healthcare service**: The prototype shall allow healthcare providers to view all healthcare requests made by healthcare requesters and make an offer for a service successfully.

c) **Negotiate a service**: The prototype shall allow healthcare providers to negotiate a healthcare service with a healthcare requester.

d) **View SLA:** The prototype shall allow healthcare providers to view a final agreed SLA**.**

e) **Approve SLA:** The prototype shall allow healthcare providers to approve a SLA after agreement on the terms and conditions of the SLA with a healthcare requester.

f) **Virtual contact**: The prototype shall allow healthcare providers to have a real-time virtual communication via audio or video or both with a requester.

- Healthcare organisers should be able to:

a) **Register as an organiser:** The prototype shall allow healthcare organisers to register their details in a registration form and submit it to the HC-VBE system successfully.

b) **View all running VO:** The prototype shall allow organisers to view all running VOs for monitoring purposes.

c) **View all Master SLA**: The prototype shall allow organisers to view all master SLA created for a running VO for enforcement purposes.

d) **View SLA:** The prototype shall allow organisers to view all SLA within a VO for monitoring and enforcement purposes**.**

2- Implementation technologies

To develop the prototype, implementation technologies had to be selected and it was decided to use *React Native* technology for developing the mobile application. In developing the mobile application view layer, React Native [170], Android [171] and IOS [172] technologies were used. For the server side, Node.js [173], Express.js [174] and Socket.io [175] were used, and finally MySQL [176] was used to develop the database. To handle the video and audio calls between healthcare requesters and providers the multi-platform opensource video conferencing technology provided by (jitsi.org) was integrated into the mobile application. Figure 4.5 shows the main technology groups, their purpose and relationships used in developing the prototype.

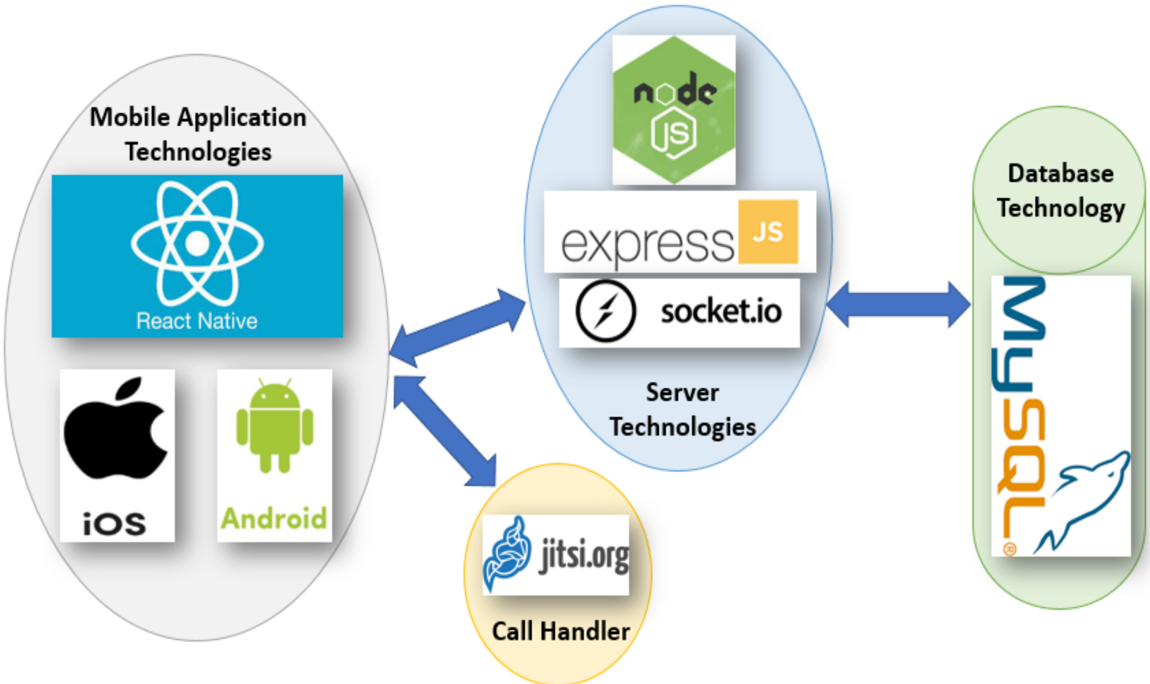


Figure 4.5: HC-VBE mobile application implementation technologies used to develop the view layer, the application layer and the database.

3- Application Architecture

A three-tier architecture was chosen for the mobile application, here a brief description of each layer is provided. The first the layer is the environment that organises and handles requests for registration and healthcare services. The environment creates a master SLA for each HC-VO which records some HC-VO-specific information such as creation date, expiry date, the participants of SLAs and a unique ID that will be used for future referencing. The master SLA acts as an umbrella for all the SLAs in the HC-VO and individual SLAs can be navigated to for modification purposes via the master SLA. Section 6.4.1 provides more detail about the concept of master SLA.

The second layer is a negotiation layer that service as the middle engine between the HC-VBE and the HC-VO management layer. It is responsible for handling negotiations between healthcare service providers and requesters and it will trigger the creation of HC-VOs once negotiations have ended. The third layer is where all HC-VOs are in operation and monitored for SLA enforcements and modifications. Each HC-VO is separate from the others and each is created under specific SLAs for specific purposes and they all run in parallel. Figure 4.6 shows the mobile application architecture described.

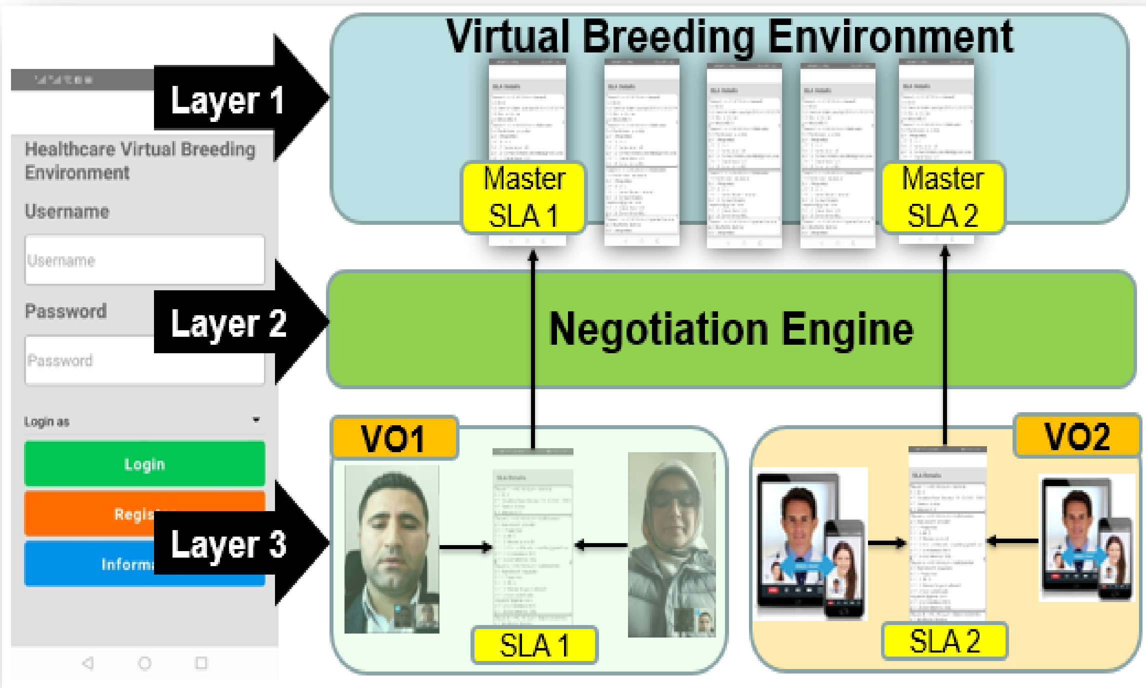


Figure 4.6: HC-VBE-F mobile application architecture showing the three layers

4. Prototype working steps

The framework functions in an eight-step process illustrated by the prototype screenshots in Figure 4.7. Initially, the HC-VBE mobile application accepts healthcare service requests from requesters, and then process the requests and announce them to registered providers for them to view. In step three, providers can either accept a request offer made by a requester or make a new offer based on some changes to the initial request. The HC-VBE mobile application will announce the offer to the requester in the same way, the requester can accept the offer or make a new offer to the healthcare provider in contact.

This process is handled by the negotiation engine and is aided by a decision support system in a complete system to speed up the negotiation process. The decision support system is not developed within the scope of this thesis and can be developed in the future.

When negotiation ended in step five, the HC-VBE mobile application generates a SLA based on the negotiation result for both parties to approve. In the subsequent steps, the HC-VBE mobile application creates a VO for the requester and provider to collaborate virtually for the duration they have agreed on in the approved SLA. Finally, in step 8, the HC-VBE end the particular HC-VO process with feedbacks and rewards for both requesters and providers after successful service provision or service termination for any reason.

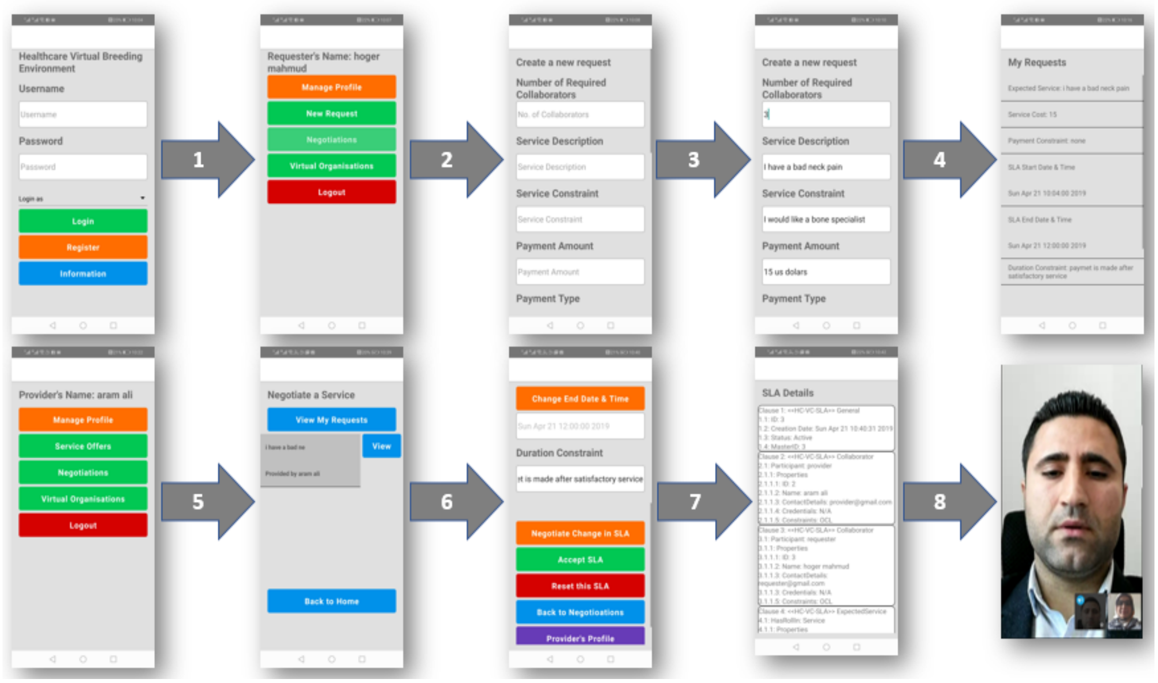


Figure 4.7: Mobile application screenshots for the prototype working steps developed based on the HC-VBE-F

4.3.2 TAM Extension and Hypotheses Formulation (Step 2)

The value of any healthcare system is in its effective use, [152] claims that a great number of information systems developed for healthcare are not in use due to user acceptability concerns. [177] States that there is a lack of information about the acceptability of collaboration systems in healthcare. The intention to use any new healthcare technology is important to be gaged before its full development and installation. To test user acceptance, the original TAM was extended through adding new constructs to develop mew TAMs specific for this research. Hypotheses for each extended TAM model were defined based on the original TAM hypotheses presented in Section 2.9.

It is recognised by Davis [34] that sometimes it is necessary to modify the TAM to accommodate new factors which might be influential in users' acceptance of a new technology. In their review paper, the authors of [178] claim that "*added variable approach*" is the most common approach to use TAM. This is where researchers add new constructs to the original TAM to adapt the model for their own study. The approach is used by many researchers such as [107], [109], [179] and [155]; following their directions, the same approach was used in this research. Depending on what technology is tested for acceptance, relevant factors have to be identified. Factor identification is a challenge and there are studies that concentrate on acceptance factor identification, for instance, [180] identifies factors for e-Government service acceptance test using the theory of planned behaviour.

To identify new acceptance factors to be added to the original TAM as new constructs, available literatures were studied and as a result five new constructs were defined and added to the original TAM to form three new TAMs and eight new hypotheses were formulated for the three sperate TAMs. In the case of the HC-VBE-M-F, one new construct (Perceived Ability to Model) was added to the TAM and two new hypotheses were formulated to be tested by healthcare system developers. For the HC-VBE-F, two new constructs (Perceived Healthcare Globalisation and Perceived Clinical effectiveness) were added to the TAM and three new hypotheses were defined to be tested by healthcare providers. Two new constructs (Perceived Healthcare Availability and Perceived Healthcare Quality) were added to the TAM and three new hypotheses were defined to be tested by healthcare requesters. The newly extended TAMs and hypotheses are described in Sections 4.3.2.1, 4.3.2.2 and 4.3.2.3.

4.3.2.1 TAM Extension for HC-VBE Modelling Framework

Researchers have used TAM to evaluate the acceptability of modelling languages previously, and their direction is followed to evaluate the developed HC-VBE-M-F implemented as a java application prototype. For examples, TAM has been used by [181] to evaluate System Modelling Language (SysML) and the authors in [182] have used TAM to evaluate the acceptance of UML diagrams by undergraduate students. A basic yet curtail feature of a modelling language is its ability to model the domain correctly. This feature has been mentioned in DSML related literatures. In [183] the authors suggest that DSML should demonstrate concepts that users in the domain are familiar with, represented by graphical notations that are suitable to model the domain. The concept of relevance is suggested by [184] as a criteria for developing DSML, which refers to how closely models developed using the DSML represent the domain. The ability of a DSML in providing a model solution that is fit for the purpose of the domain is indicated by [185] as a quality criteria, and the authors of [186] state that "*language-domain appropriateness*" is a quality measure which measures the extent to which a model represents a domain. Therefore, to evaluate the modelling ability of the HC-VBE-M-F, TAM was extended with one new construct which is Perceived Ability to Model (PAM) and it can be defined as the *degree to which an individual believes that models constructed using the modelling framework captures a healthcare virtual collaboration scenario correctly*. Figure 4.8 shows the added construct to the original TAM and the extended model has been used as a base for hypothesis development, questionnaire design and data collection.

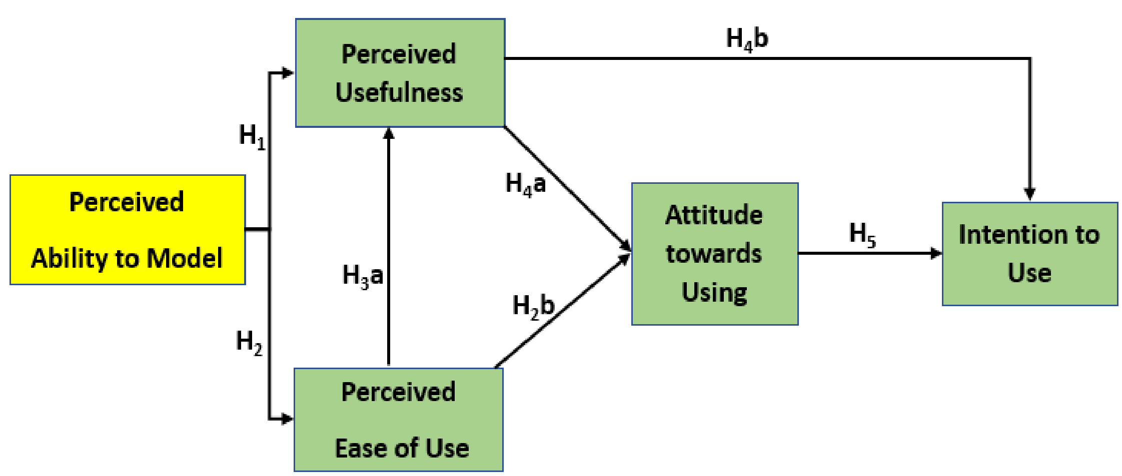


Figure 4.8: Extended TAM for HC-VBE-M-F showing the added PAM construct

Based on the extended TAM shown in Figure 4.8 and the original TAM hypotheses described in Section 2.9, the following hypotheses were defined to be tested in order to evaluate system developer's acceptance of the HC-VBE-M-F developed in Chapter 5.

i. **H_1**: Perceived ability to model has a significant effect on healthcare system developers' perceived usefulness of the HC-VBE modelling package.
ii. **H_2**: Perceived ability to model has a significant effect on healthcare system developers' perceived ease of use of the HC-VBE modelling package.
iii. **H_3a**: Perceived ease of use has a significant effect on healthcare system developers' perceived usefulness of the HC-VBE modelling package.
iv. **H_3b:** Perceived ease of use has a significant effect on healthcare system developers' attitude towards using the HC-VBE modelling package.
v. **H_4a:** Perceived usefulness has a significant effect on healthcare system developers' attitude towards using the HC-VBE modelling package.
vi. **H_4b**: Perceived usefulness has a significant effect on healthcare system developers' intention to use the HC-VBE modelling package.
vii. **H_5**: Attitude towards using has a significant effect on healthcare system developers' intention to use the HC-VBE modelling package

4.3.2.2 TAM Extension for HC-VBE-F Providers

Healthcare professionals look for functionalities in a healthcare system that improves their effectiveness and delivers value for them and their patients [187]. The authors of [166] state that beside technological concern, healthcare information system has "*clinical effectiveness*" concern that should be addressed. Clinical effectiveness has been defined as " *the application of the best knowledge, derived from research, clinical experience, and patient preferences to achieve optimum processes and outcomes of care for patients*" [188]. In this context, Perceived Clinical Effectiveness (PCE*)* was added to the original TAM as an important determinate of healthcare providers attitudes towards using a healthcare system developed based on the framework. PCE can be defined for the purpose of this research as *the degree to which an individual believes that the healthcare provided through systems developed based on the HC-VBE-F is clinically effective*.

Everyone is concerned about healthcare and due to globalization, options to receive healthcare has widen. The concept of medical tourism which refers to people traveling to a foreign country to receive healthcare services is researched in [189] and [190]. People who travel abroad will have to invest time, money and effort to receive the care they need. To address this issue, the HC-VBE-F in Chapter 6 is developed with healthcare globalisation in mind, which means, making virtual healthcare available and accessible globally to provide care over time and space to those in need. Through this, healthcare providers can reach as many healthcare requesters as possible without the need for them to travel.

Healthcare globalisation is also important for filling in healthcare professional shortages and increase collaboration between healthcare stakeholders. The HC-VBE-F developed can bring together healthcare professionals from different locations to provide care and provide the integrated platform needed for medical research. To evaluate this aspect of the framework and find out whether healthcare professionals who test the mobile application prototype believe that the HC-VBE-F has the potential to globalise healthcare, the second construct which is called Perceived Healthcare Globalisation (PHG) was added to the original TAM. PHG can be defined as *the degree to which an individual believes that using systems developed based on the HC-VBE-F would make healthcare service provision global*. The two new constructs are coloured yellow in the extended TAM pictured in Figure 4.9.

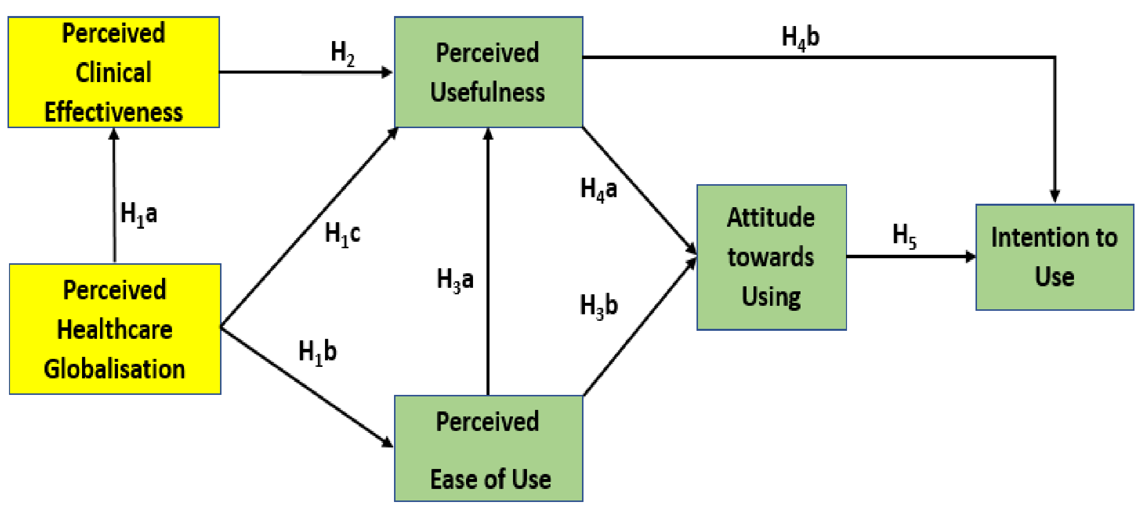


Figure 4.9: Extended TAM for HC-VBE-F for healthcare professionals showing the two newly added constructed (PCE and PHG)

Based on the extended TAM shown in Figure 4.9 and the original TAM hypotheses described in Section 2.9, the following hypotheses were defined to be tested in order to evaluate healthcare providers acceptance of the HC-VBE-F implemented as a mobile application prototype.

i. **H_1a:** Perceived healthcare globalization has a significant effect on healthcare providers perceived clinical effectiveness of the HC-VBE application.
ii. **H_1b:** Perceived healthcare globalization has a significant effect on healthcare providers perceived ease of use of the HC-VBE application.
iii. **H_1c:** Perceived healthcare globalization has a significant effect on healthcare providers perceived usefulness of the HC-VBE application.
iv. **H_2:** Perceived clinical effectiveness has a significant effect on healthcare providers perceived usefulness of the HC-VBE application.
v. **H_3a:** Perceived ease of use has a significant effect on healthcare providers perceived usefulness of the HC-VBE application.
vi. **H_3b**: Perceived ease of use has a significant effect on healthcare providers attitude towards using the HC-VBE application.
vii. **H_4a:** Perceived usefulness has a significant effect on healthcare providers attitude towards using the HC-VBE application.
viii. **H_4b:** Perceived usefulness has a significant effect on healthcare providers intention to use the HC-VBE application.
ix. **H_5:** Attitude towards using has a significant effect on healthcare providers intention to use the HC-VBE application.

4.3.2.3 TAM extension for HC-VBE-F Requester

To evaluate the HC-VBE-F acceptance from healthcare requesters perspective the original TAM was extended with two new constructs. The first is Perceived Healthcare Availability (PHA) and the second is Perceived Healthcare Quality (PHQ).

The availability of healthcare services where and when needed is an important attribute of an effective healthcare service. Service convenience, which refers to the availability of healthcare service at requesters' time and place of choice in the context of this research, is a determinant adopted form [191] and [109]. In the later study, convenience is described as the extent to which healthcare requesters believe that an IT-based healthcare system minimises "*the amount of physical and mental energy spent when in need of medical help and/or advice*". Therefore, PHA can be defined for the purpose of this study as the *degree to which a healthcare requester believes systems developed based on the HC-VBE framework increases healthcare availability*.

The quality of healthcare service provided is another important factor in convincing healthcare requesters to use a system. Different scholars have interpreted service quality differently, for instance [192] sees service quality as "*on-time professional and personalised service*" and others have referred to quality in terms of response time and accessibility [193]. To assess the extent of users' belief with regard to the quality of healthcare services provided though systems developed based on the HC-VBE-F, the second construct which is called Perceived Healthcare Quality (PHQ) was added to the original TAM described in Section 2.9. For the purpose of this research PHQ can be defined as *the degree to which a healthcare requester believes that the quality of healthcare provided through systems developed based on the HC-VBE framework is acceptable"*. Figure 4.10 shows the extended TAM that is used to examine healthcare requesters acceptance of the HC-VBE-F implemented as a mobile application prototype.

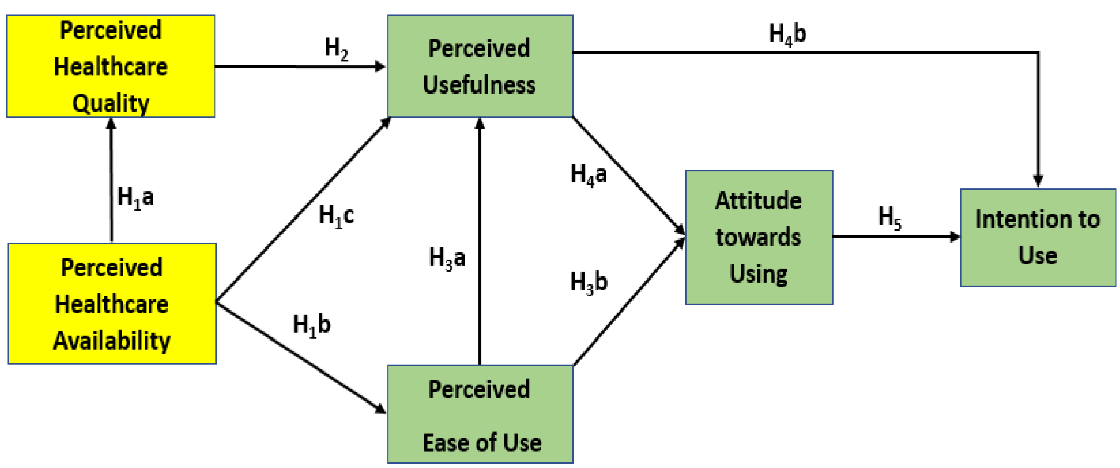


Figure 4.10: Extended TAM for HC-VBE Framework for prospective patients showing the two newly added constructs PHQ and PHA

Based on the extended TAM shown in figure 4.10 and the original TAM hypotheses described in Section 2.9, the following hypotheses were defined to be tested in order to evaluate healthcare requesters acceptance of the HC-VBE-F implemented as a mobile application prototype.

i. **H_1a:** Perceived healthcare availability has a significant effect on healthcare requesters perceived healthcare quality of the HC-VBE application.
ii. **H_1b:** Perceived healthcare availability has a significant effect on healthcare requesters perceived ease of use of the HC-VBE application.
iii. **H_1c:** Perceived healthcare availability has a significant effect on healthcare requesters perceived usefulness of the HC-VBE application.
iv. **H_2:** Perceived healthcare quality has a significant effect on healthcare requesters perceived usefulness of the HC-VBE application.
v. **H_3a:** Perceived ease of use has a significant effect on healthcare requesters perceived usefulness of the HC-VOBE application.
vi. **H_3b**: Perceived ease of use has a significant effect on healthcare requesters attitude towards using the HC-VBE application.
vii. **H_4a:** Perceived usefulness has a significant effect on healthcare requesters attitude towards using the HC-VBE application.
viii. **H_4b:** Perceived usefulness has a significant effect on healthcare requesters intention to use the HC-VBE application.
ix. **H_5:** Attitude towards using has a significant effect on healthcare requesters intention to use the HC-VBE application.

4.3.3 Research Instruments (Step 3)

Researchers have used various methods to examine new technology acceptance by users, for example authors in [194] have used open question and answer sessions to gage users thoughts and feedbacks on users satisfaction of a clinical system they have proposed. [193] Used one-to-one and one-to-many interviews to test nurses acceptance of their nursing care plan system and [195] used observations to collect data for their critical care information system acceptance evaluation. However, according to [107], survey questionnaire is the most widely used data collection method for user acceptance evaluation of a new healthcare information system. Therefore, survey questionnaire method was selected to be used in this research as a data collection instrument. Three sets of questionnaires based on measurement items for each construct in the given extended TAMs in Sections 4.3.2.1, 4.3.2.2 and 4.3.2.3 were designed and printed on A4 sheets. The questionnaires were then given to prospective users of the two developed frameworks to fill in.

The filled in questionnaires were collected straight after they were filled in by survey participants. The data were then transferred into SPSS datasheets to be processed further. A questionnaire set was composed of two separate forms, the first form was to obtain the participants consent to take part in the research and the second form was the questionnaire to be filled for the acceptance testing. The questionnaire sets were translated to the Kurdish language by a professional legal translator which is the local language were the data is collected. The translated version was given out alongside the English version to help those whose level of English was not adequate to understand the questions. The participants were asked to read the Kurdish version of the questionnaire items but fill in the English version as no scales were provided on the Kurdish version. Translating questionnaire items to the local language was similarly performed by authors in [159].

The filled in questionnaires were screened for completeness to ensure that there is no missing data. If any unfilled section spotted the relevant participant was asked to revise it. All filled in questionnaires are numbered and kept for future references and verifications along with the participant details. At the beginning of data collection sessions, survey participants were informed of their rights to withdraw from the process at any time they wished as participation was voluntary.

4.3.4 Research Measurements (Step 4)

The questionnaires were designed based on the TAMs extended in Section 4.3.2, each model consisted of 5-6 unobserved variables (latent variable). For each latent variable, 4-5 observed items were defined based on previously defined and validated questionnaire items from studies such as [196], [177], [197], [157] and [108]. Unobserved variables cannot be measured directly by survey participants as their scope is broad and flexible to answer, however, observed items are measurable directly by survey participants as they are formulated to capture a specific aspect of users' intention to use a system. Unobserved variables are measured as a result of analysing the collective answers for all its observed variables.

To measure each item and gage participants feeling, Linkert Scale measurement was used as it is one of the most popular measurement scales used by researchers [107]. Questionnaire items were measured on a seven-point Linkert-type scale and the measures were (1) strongly disagree (2) quite disagree, (3) disagree, (4) neutral, (5) slightly agree, (6) quite agree and (7) strongly agree. To ensure the appropriateness of the questionnaire items and make necessary changes to its structure and meanings, they were pilot tested by three small groups per the target users before their actual use. As a result, the wording and the structure of several questionnaire items were changed before their actual use.

4.3.5 Sampling Methods and Outcomes (Step 5)

The surveyed participants of this research were mainly from the Kurdistan Region of Iraq where the author currently works as a lecturer and some were from Finland where the author stayed for a month as a pedagogy student. The target audience for the first part of this study was system developers including software engineers, system designers, programmers, project managers and university lecturers who teach software developments. They were contacted though paying them a visit in their working places or acquiring their personal contact numbers. They were then given locations, dates and times for conducting the research. The original target number was 100 participants however, there aren't many system developers in the region and therefore only 28 participants turned up for this part of the research. In total 82% of the surveyed participants were male and 18% were female. Table 4.1 shows the demography of the surveyed participants.

Table 4.1: System developers' demographic data who participated in the survey after using the Java application developed based on the HC-VBE-M-F

Variable	Item	System Developer Frequency (N=28)	%
Sex	Male	23	82
	Female	5	18
Age	Age 15-20	0	0
	Age 20-30	9	32
	Age 30-40	15	54
	Age 40-50	4	14
	Age 50-60	0	0
	Age 60-above	0	0
Occupation	System developers	28	100

The target audiences for the second part of the study were healthcare providers and requesters. To recruit healthcare providers, hospitals and healthcare directorates were contacted in the region. Permissions such as the ones in Appendix E were requested to conduct the research inside hospitals during working hours or outside working hours in cultural centres. Incentives such as offering free dinners were one of the techniques used to recruit research participants. The concept of healthcare provider is a general one, therefore, all healthcare related professionals were invited such as doctors, nurses, pharmacist, first aiders etc. As for the healthcare requesters, lecturers and students from the University of Human development in the Kurdistan Region were recruited. The target number for both healthcare providers and requesters were 100 each, i.e. 200 in total. For this part of the research, the targets were met.

For healthcare providers, in total 56% of the surveyed participants were male and 44% were female. The highest age rang was 30-40 years with 32% and the highest healthcare provider participant were nurses with 53%. As for the requesters, in total 61% were male and 39% were female. The highest age range was 20-30 with 44% and the highest prospective healthcare requester participants were University lecturers with 57%. Table 4.2 shows the demography of the surveyed participants.

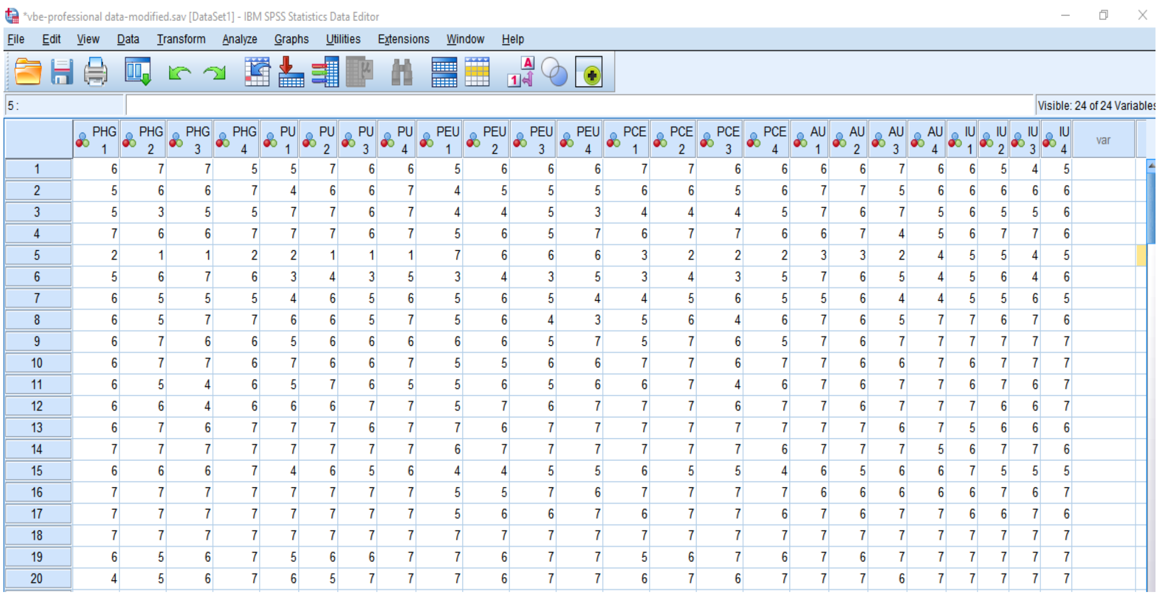
Table 4.2: Healthcare providers and requesters demographic data that tested the mobile application developed based on the HC-VBE-F

Variable	Item	Healthcare Provider Frequency (N=100)	%	Healthcare Requester Frequency (N=100)	%
Sex	Male	56	56	61	61
	Female	44	44	39	39
Age	Age 15-20	0	0	3	3
	Age 20-30	27	27	44	44
	Age 30-40	32	32	36	36
	Age 40-50	30	30	9	9
	Age 50-60	11	11	7	7
	Age 60-above	0	0	1	1
Occupation	Nurse	53	53	0	0
	Doctor	15	15	0	0
	Other medical staff	32	32	0	0
	Student	0	0	43	43
	Lecturer	0	0	57	57

4.3.6 Applications Testing and Data Collection (Step 6)

There were two applications developed for both the modelling and the virtual collaboration frameworks described in Chapters 5 and 6. The first application was implemented as a Java stand-alone application and the second application was a mobile application. They were both developed to be used by prospective users as part of user acceptance evaluation process which is designed based on TAM.

The application testing method for each of the applications were slightly different as described in the next two sections, however a direct face to face application testing method was chosen over an online one following the direction of others such as [161]. They noticed that the method has the advantage of addressing concerns and questions of participants which they may have during testing and filling in the questionnaire; the same advantage was noticed during the data collection process for this thesis. The data collected was documented in SPSS, Figure 4.11 shows some of the data documented after following the applications testing methods described in Sections 4.3.6.1 and 4.3.6.1. The first left column represents participants and the numbers on the rest of the columns represent answers given by the participants for each questionnaire item specified by each column header. The Column headers are abbreviations for questionnaire items which are described in Sections 2.9 and 4.3.2.



	PHG 1	PHG 2	PHG 3	PHG 4	PU 1	PU 2	PU 3	PU 4	PEU 1	PEU 2	PEU 3	PEU 4	PCE 1	PCE 2	PCE 3	PCE 4	AU 1	AU 2	AU 3	AU 4	IU 1	IU 2	IU 3	IU 4	var
1	6	7	7	5	5	7	6	6	5	6	6	6	7	7	6	6	6	6	7	6	6	5	4	5	
2	5	6	6	7	4	6	6	7	4	5	5	5	6	6	5	6	7	7	5	6	6	6	6	6	
3	5	3	5	5	7	7	6	7	4	4	5	3	4	4	4	5	7	6	7	5	6	5	5	6	
4	7	6	6	7	7	7	6	7	5	6	5	7	6	7	7	6	6	7	4	5	6	7	7	6	
5	2	1	1	2	2	1	1	1	7	6	6	6	3	2	2	2	3	3	2	4	5	5	4	5	
6	5	6	7	6	3	4	3	5	3	4	3	5	3	4	3	5	7	6	5	4	5	6	4	6	
7	6	5	5	5	4	6	5	6	5	6	5	4	4	5	6	5	5	6	4	4	5	5	6	5	
8	6	5	7	7	6	6	5	7	5	6	4	3	5	6	4	6	7	6	5	7	7	6	7	6	
9	6	7	6	6	5	6	6	6	6	6	5	7	5	7	6	5	7	6	7	7	7	7	7	7	
10	6	7	7	6	7	6	6	7	5	5	6	6	7	7	6	7	7	6	6	7	6	7	7	7	
11	6	5	4	6	5	7	6	5	5	6	5	6	6	7	4	6	7	6	7	7	6	7	6	7	
12	6	6	4	6	6	6	7	7	5	7	6	7	7	7	6	7	7	6	7	7	7	6	6	7	
13	6	7	6	7	7	7	6	7	7	6	7	7	7	7	7	7	7	7	6	7	5	6	6	6	
14	7	7	7	7	7	7	7	7	6	7	7	7	7	7	7	6	7	7	7	5	6	7	7	6	
15	6	6	6	7	4	6	5	6	4	4	5	5	6	5	5	4	6	5	6	6	7	5	5	5	
16	7	7	7	7	7	7	7	7	5	5	7	6	7	7	7	7	6	6	6	6	6	7	6	7	
17	7	7	7	7	7	7	7	7	5	6	6	7	6	7	7	6	7	6	7	7	6	6	7	6	
18	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	
19	6	5	6	7	5	6	6	7	7	6	7	7	5	6	7	6	7	6	7	7	7	7	7	7	
20	4	5	6	7	6	5	7	7	7	6	7	7	6	7	6	7	7	7	6	7	7	7	7	7	

Figure 4.11: A screenshot of sample data collected based on the surveyed questionnaires developed for testing both frameworks

4.3.6.1 HC-VBE-M-F Application Testing Method

The developed Java application was made available on a number of laptops for use, also perspective users (healthcare system developers) were given the option to put the application on their laptops and desktops if they wished. There were occasions that research participants thought a demonstration of the application was good enough for them to fill in the questionnaires. The testing process was given about an hour and it was performed in four steps explained below and pictured in Figure 4.12.

1- In short seminar style presentation, the modelling framework concepts and components were explained to participants. The aim was to familiarise participants with the concept behind the modelling framework as well as the components and modelling steps required to model a healthcare virtual collaboration scenario. During the presentation, concerns and questions of participants were answered which helped them to progress quickly during the testing stage.

2- As a second step, a healthcare virtual collaboration scenario was provided to the participants to model using the Java application.

3- In this step, the relevant questionnaire was handed out to the participants to fill in. They were asked to select a number that best represent their answer with regard to each questionnaire item on a 7-point Linkert Scale.

4- This step was the final step where completed questionnaires were collected and checked for completeness. The data was then transferred into SPSS data sheets to be processed later during data analysis.

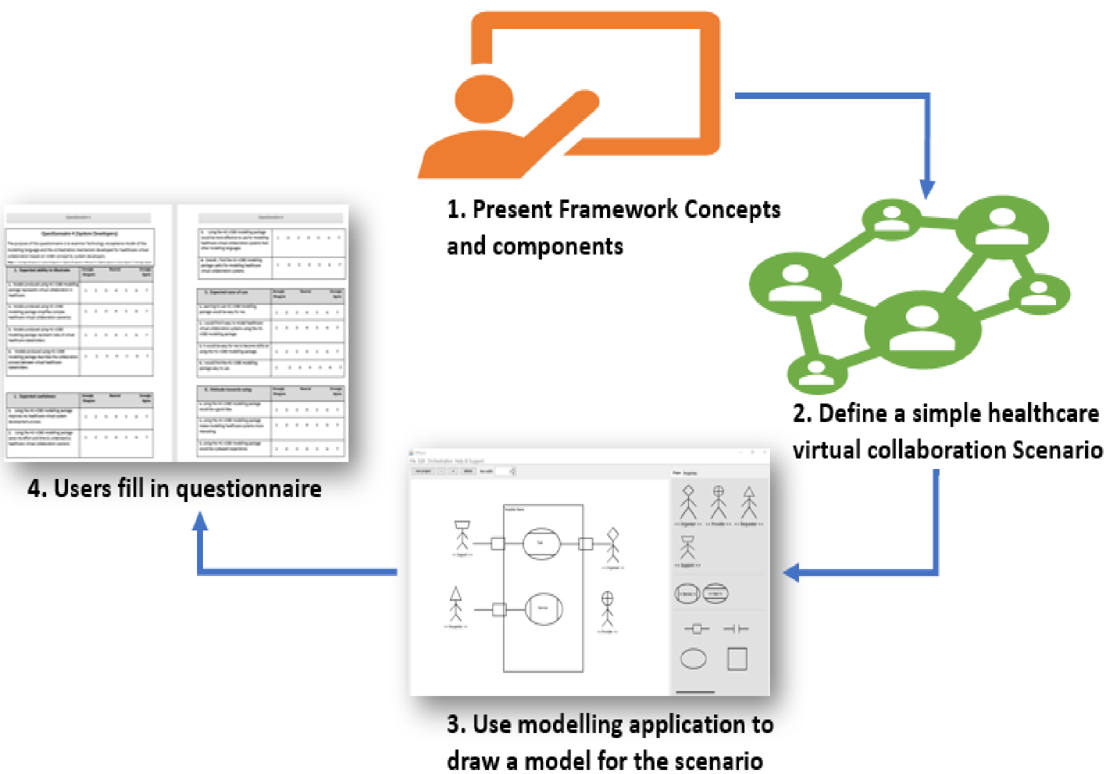


Figure 4.12: HC-VBE-M-F Application Evaluation and data collection Steps

4.3.6.2 HC-VBE-F Mobile Application Testing Method

To test the virtual collaboration framework developed in this study, the functionalities and working steps of the mobile application which is developed based on the framework were demonstrated to research participants. Demonstrating the working steps of the mobile application allowed users to experience the full working process of the prototype without the need for them to spend too much time on getting to know the different functionalities of the application before actual use.

Although the option to use the protype was given to participants but in most cases, users felt that the demonstration is good enough for them to understand the concept behind the application. Demonstrating the mobile application saved time for both the researcher and the users during the process of data collection. This method has also been used by other researchers, for example the authors of [198] showed patients the way that their developed online posting for Emergency Department waiting time worked rather than letting users use the website; and the authors of [199] used a similar method to test a home telemedicine system.

To demonstrate the working process of the prototype the following five steps were taken which are pictured in Figure 4.13.

1- Two or three prospective users (requester and providers) from the recruited research participants were invited to download the application onto their smart phones if they wanted, if not, readily set up mobile devices were provided.

2- They were instructed to register as either a healthcare provider or healthcare requester.

3- Once they registered, they were guided step by step regarding how to make a healthcare service request in the case of requesters, and how to make a service offer in the case of providers.

4- The HC-VO creation and operation by the HC-VBE mobile application was demonstrated from start to finish, each step of the process was announced to the attended audience and the outcome was shown around. Internet was needed for each smart phone in the demonstration process as the mobile application had to connect to a database hosted externally which was developed as a part of the application.

5- After allowing some times for questions and answers from the participants, the printed questionnaires were distributed to be filled in by the participants. The filled in questionnaires were then collected and the data from them were documented using SPSS software.

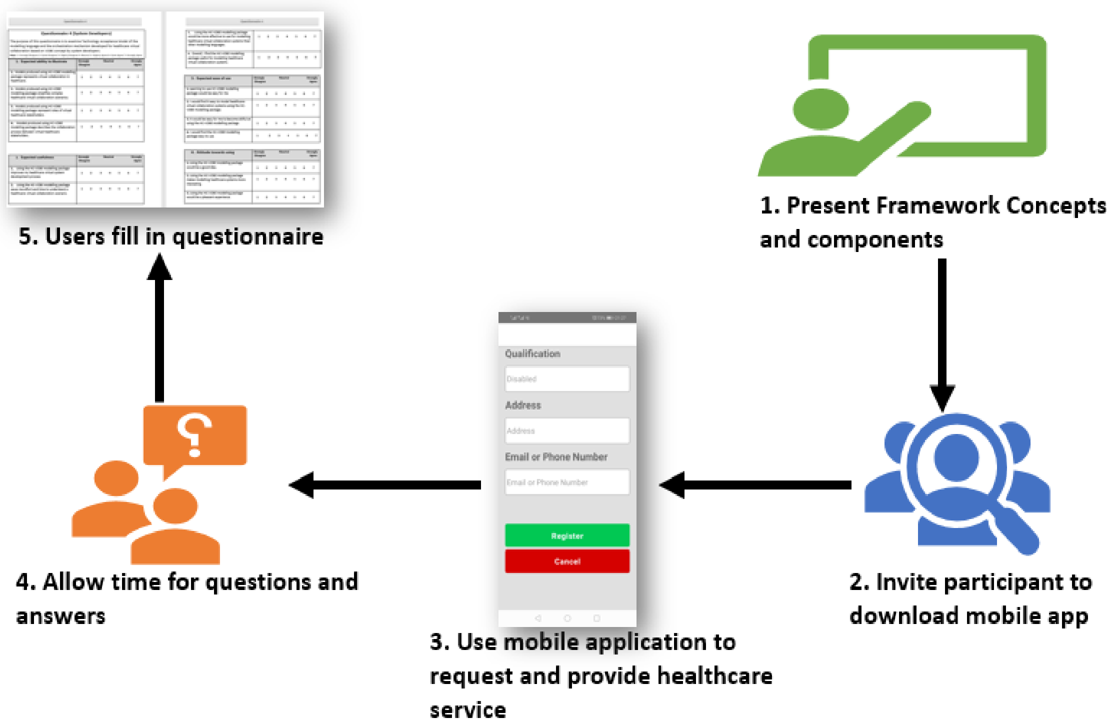


Figure 4.13: HC-VBE mobile application evaluation and data collection steps

4.3.7 Data Analysis (Step 7)

Structural Equation Modelling (SEM) was utilised to analyse the data obtained from the survey questionnaires filled in as a result of testing the applications. SEM is one of the most widely used techniques to statistically analyse collected data for the constructs of a TAM [112]. SEM uses path analysis, regression testing and other methods to statistically estimate and examine the extent of relationships between unobserved variables and their observed items in a specific model [110]. To draw the extended TAMs for this study and perform the SEM analysis, AMOS version 23, SPSS version 25 and Microsoft excel 2019 were used. AMOS is a tool that utilizes structural model to compute several different statistical results for acceptance testing such as standardised estimates for each test path [180]. Figure 4.14 is screenshots of the AMOS program and outcomes of some of the analysed data, such as factor loading between observed items and their related unobserved variable.

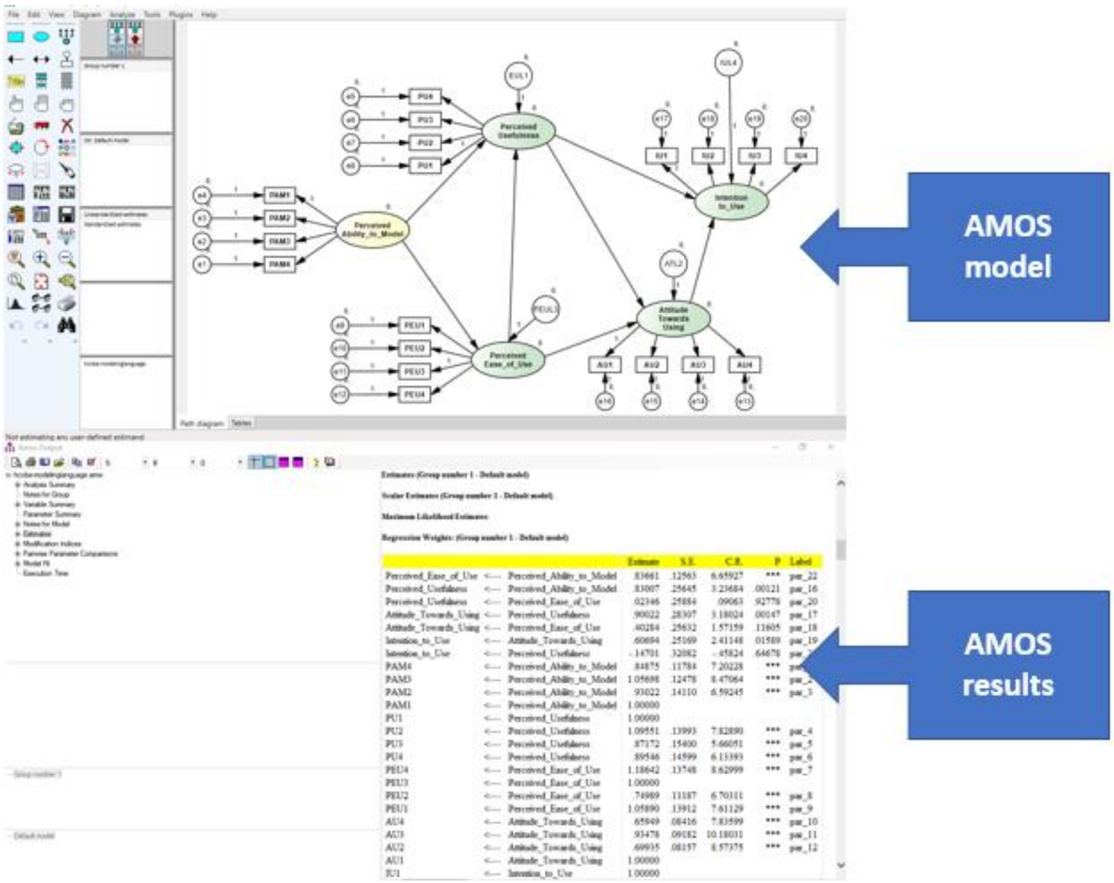


Figure 4.14: A screenshot of AMOS model created based on one of the extended TAM and some computed statistical results for the model

To understand how to use AMOS, IBM provides and updates AMOS user manual regularly [200]. The AMOS models developed for the three extended TAMs are similar to the one in Figure 4.14 and they are presented and explained in Section 4.3.7.1, 4.3.7.2 and 4.3.7.3. The arrows between the latent variables indicate the causal effects between them. The arrows between the latent variables and the observed items indicate the item loading on each latent variable. The strength of the loading is indicated by a number on each loading which is between 0 and 1. The closer the value to 1 the stronger the item loading on the latent variable. The circles pointing to the latent variables and observed items represent error values in the item loading. The generation of such values on a SEM diagram indicates that the model has been run by AMOS successfully without any error.

4.3.7.1 HC-VBE-Modelling Framework AMOS Model

Figure 4.15 is the SEM model developed in AMOS based on the extended TAM explained in Section 4.3.2.1. The figure shows all the latent (unobserved variable) with their related measured items (observed variable). Each latent variable is a construct in the corresponding TAM. In this case, there are five latent variables represented by the oval shapes, namely Perceived Ability to Model (PAM), Perceived Ease of Use (PEU), Perceived Usefulness (PU), Attitude towards Using (AU) and Intention to Use (IU). In total, there are 20 observed items, 4 for each latent variable represented by the squares.

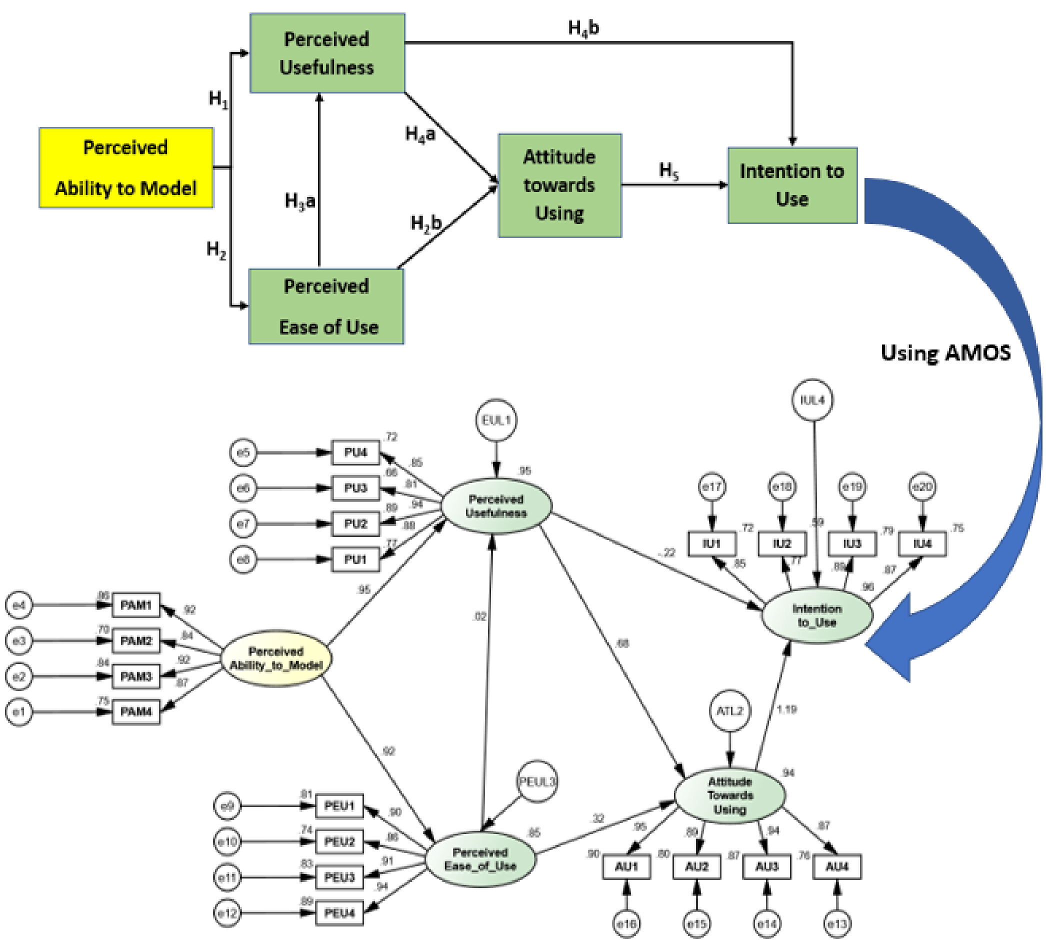


Figure 4.15: HC-VBE-M-F-TAM Structural Equation Model developed in AMOS

4.3.7.2 HC-VBE-F-Provider AMOS Model

Figure 4.16 is the SEM model developed in AMOS based on the extended TAM explained in Section4.3.2.2. The model consists of six latent (unobserved) variables represented by the oval shapes, namely Perceived Clinical Effectiveness (PCE), Perceived Healthcare Globalisation (PHG), Perceived Ease of Use (PEU), Perceived Usefulness (EU), Attitude towards Using (AU) and Intention to Use (IU). In total there are 24 observed items, 4 items for each latent variable denoted by the squares.

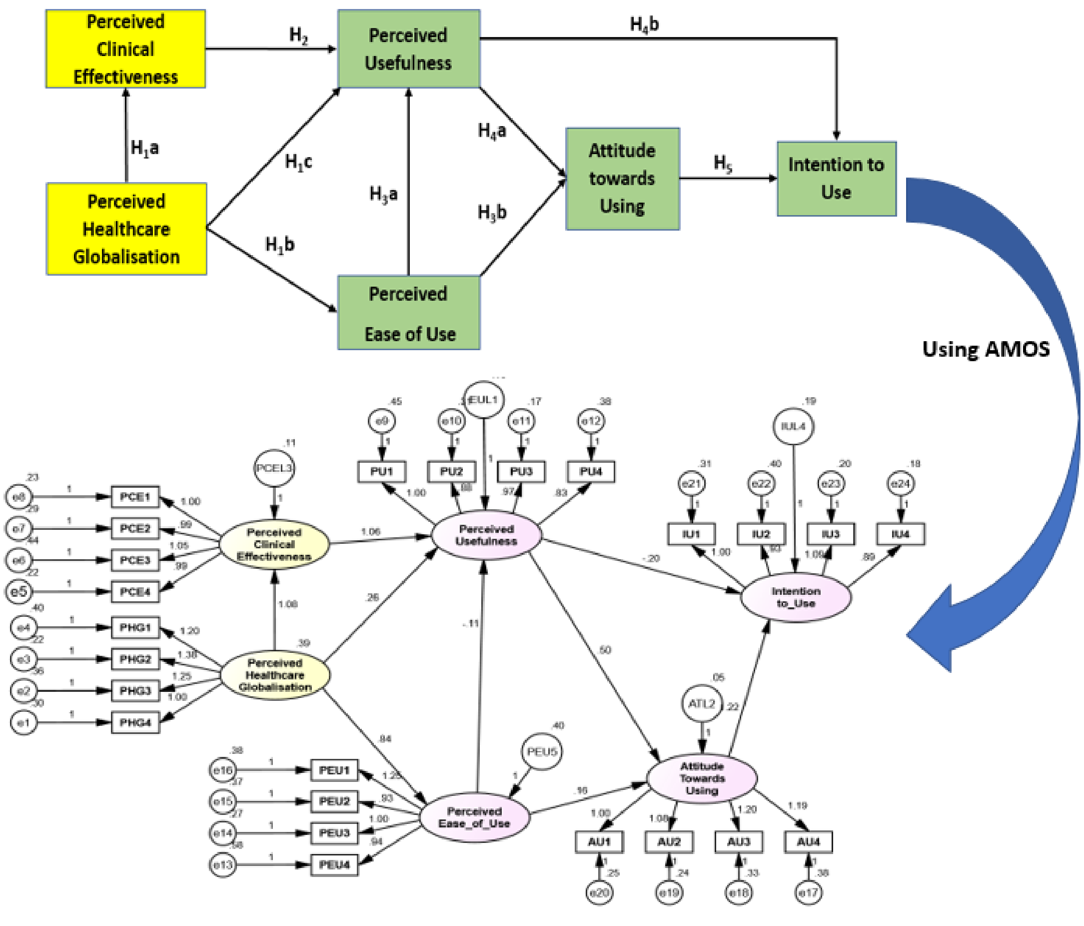


Figure 4.16: HC-VBE-F-TAM-Provider Structural Equation Model developed in AMOS

4.3.7.3 HC-VBE-F-Requester AMOS Model

Figure 4.17 is the SEM model developed in AMOS based on the extended TAM explained in Section 4.3.2.3. It shows all the latent (unobserved constructs) with their related measured items (observed variable). The model consists of five latent variables represented by the oval shapes, namely Perceived Healthcare Quality (PHQ), Perceived

Healthcare Availability (PHA), Perceived Ease of Use (PEU), Perceived Usefulness (PU), Attitude towards Using (AU) and Intention to Use (IU). In total there are 25 observed items, 4 for each latent variable except PHQ which has 5 items.

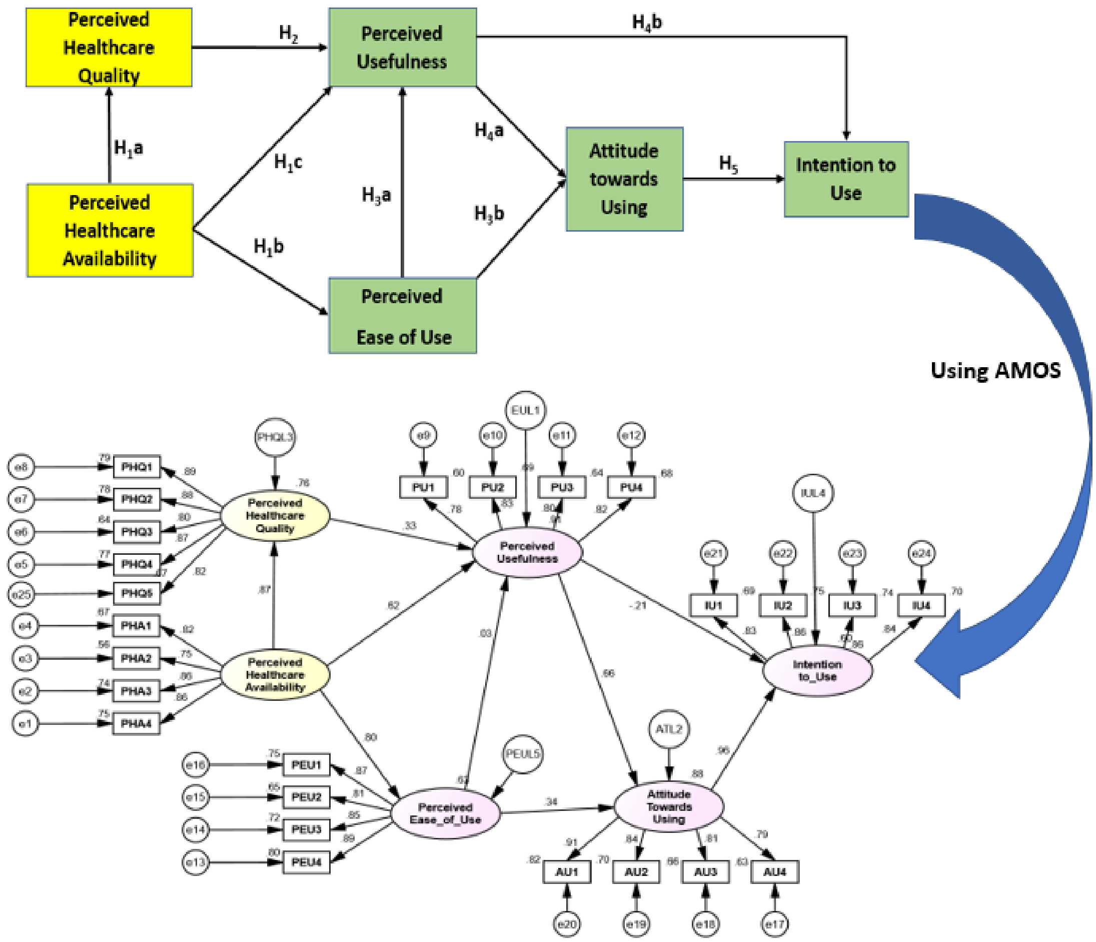


Figure 4.17: HC-VBE-M-TAM-Requester Structural Equation Model developed in AMOS

4.3.8 Statistical Results Selection (Step 8)

Many different statistical results can be computed for data analysed in AMOS and SPSS, in this section, a brief introduction is provided for each of the statistical values selected to be computed to support the evaluation process and show users acceptance of the developed healthcare virtual collaboration modelling and provision frameworks. The selected statistical results are Mean, Standard Deviation, Factor Loading, Significant *p* Value, Correlations Coefficient Matrix, Average Variance Extracted, Construct Reliability, Cronbach's Alfa, Kaiser-Meyer-Olkin and Model Fit Indices.

4.3.8.1 Mean

Mean is defined as the sum of all observations in a distribution divided by the total number of all observations [201]. It is calculated to show the average of all values in a specific distribution; in the context of this research two different mean (average) values are computed. The first one is the average of all values given to a particular observed item, which means, if we have 24 observed items in a TAM then we have calculated 24 different means. The second one is the average value of all the observed item for a particular unobserved variable, which means, if we have 6 unobserved variables in a TAM then we have 6 different average values. Mean present researchers with a single value that is representative of all the answers given to a particular questionnaire item and it is a powerful tool that enable researchers to easily draw conclusions. Equation 4.1 is used to calculate Mean (average).

$$A = \frac{1}{n} * \sum_{i=1}^{n} X_i$$

Equation 4.1: The equation for calculating "Mean"

where:

- A = average (or arithmetic mean)
- n = the number of participants in a research
- x = the values given to a particular questionnaire item.

4.3.8.2 Standard Deviation

Standard deviation measures how far the values in a particular distribution are from the average value [202]. Big standard deviation value indicates widely spread values from the mean; the bigger the standard deviation value the more widely spread are the values in a given set of values. In the context of this research small standard deviation value is preferred since it indicates that participants' perception towards a particular item in a questionnaire are close to each other. It provides support to conclude whether answers given to a specific item by perspective users are consistent or not. Equation 4.2 is the mathematical formula for standard deviation.:

$$s = \sqrt{\frac{\sum_{i=1}^{n}(X_i - A)^2}{n-1}}$$

Equation 4.2: The equation for calculating standard deviation

Where:

- S = standard deviation
- x = the value of each data item
- A = average values
- n = number of data items

4.3.8.3 Factor Loading

Factor loading is the indication of relationship strength between an unobserved variable and it's observed variable the higher the loading value the stronger the relationship [203]. In SEM the latent variable is indicated by an oval shape, the observed item is indicated by a square and the error variance for each observed item is indicated by a circle [204]. Figure 4.18 shows a SEM diagram and Equation 4.3 is the general formula for factor loading calculation.

$$X_m = \lambda_m F_m + e_m$$

Equation 4.3: The equation for calculating factor loading

Where:

X is the observed item, *F* is the unobserved variable, *λ* is the factor loading of *X* on *F*, *e* is the measurement error of *X* and *m* is the observed item number.

For instance, if we have a latent variable (*F*) that has four observed items ($X_1 ... X_4$) then the formula for each factor loading (λ) is:

$X_1 = \lambda_1 F + e_1$
$X_2 = \lambda_2 F + e_2$
$X_3 = \lambda_3 F + e_3$
$X_4 = \lambda_4 F + e_4$

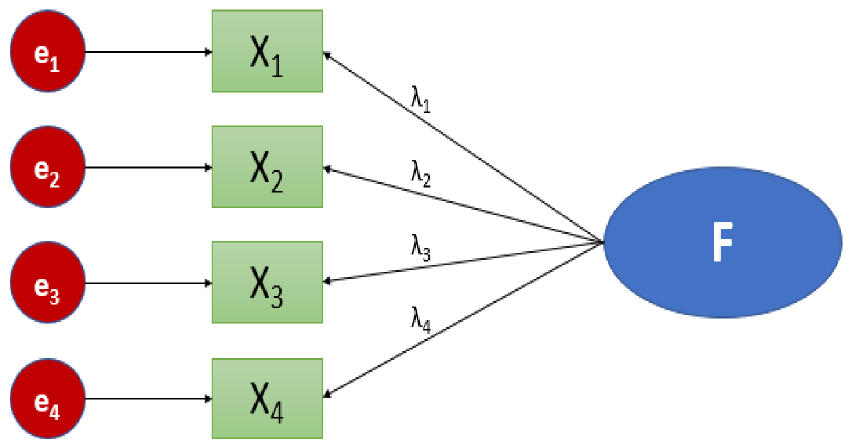


Figure 4.18: Structural Equation Model components

4.3.8.4 Significant *p* value

To accept or reject a hypothesis, researchers use "*significant p value*" which is a number between 0 and 1 and the acceptable level of significance is set as 0.05 [205]. A hypothesis is accepted if the significance value calculated is less than the set value. *p* value is calculated using Equation 4.4.

$$z = \frac{\hat{p} - p0}{\sqrt{\frac{p0(1 - p0)}{n}}}$$

Equation 4.4: The equation for calculating significant *p* value

where:

- z is a value to be looked up in significance value table
- $\hat{p}$ is the sample proportion
- $p0$ is the assumed population proportion in the null hypothesis
- n is the sample size

4.3.8.5 Correlation Coefficient Matrix

Correlation coefficient is also known as Pearson Product-Moment Correlation, measures the covariance of two variables [206]. Usually a collection of variables together provides an overview of a goal, for example in this research more than 20 questionnaire items (observed variables) are used together with the aim to show whether users accept the proposed technologies for healthcare virtual collaboration or not. Correlation coefficient matrix is a method to summarise data where values above 0.3 is considered acceptable according to [207]. Figure 4.19 shows the structure of a correlation coefficient results table.

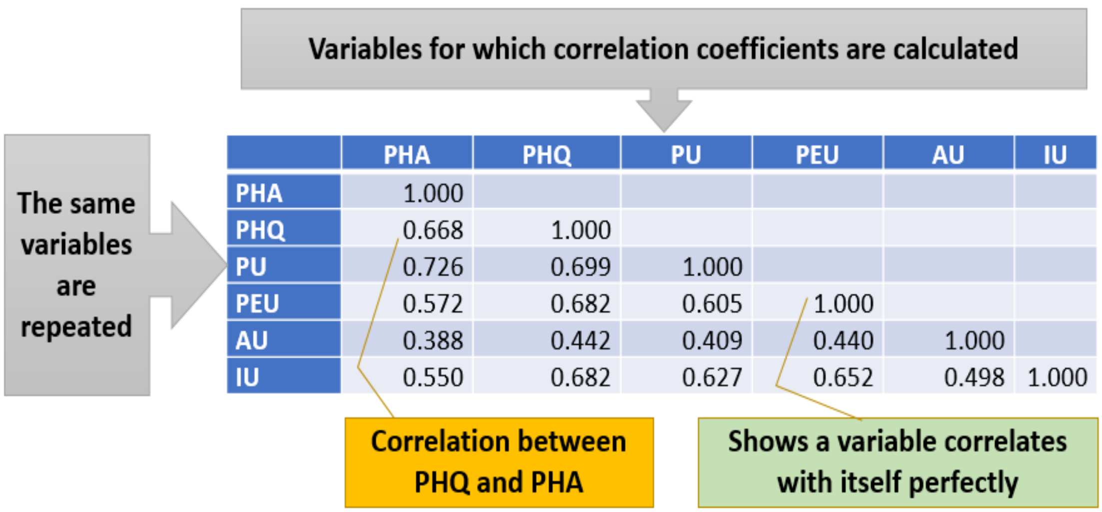


Figure 4.19: Structure of correlation coefficient results table

4.3.8.6 *AVE* (Average Variance Extracted)

AVE measures the convergent validity that is used to examine measurements, and the calculated value indicates the internal consistency of answers for a set of related questionnaire items [208]. Values above 0.5 is considered acceptable and Equation 4.5 is used to calculate *AVE*.

$$AVE = \frac{\sum \lambda^2}{n}$$

Equation 4.5: The equation for calculating Average Variance Extracted

Where:

- *AVE* is the average variance extracted
- λ^2 is the square of factor loading
- *n* is the number of indicators

4.3.8.7 *CR* (Construct Reliability)

CR measures internal consistency of measurements similar to Cronbach Alpha [209]. *CR* values above 0.7 is considered to represent acceptable reliability. Equation 4.6 is used to calculate *CR*.

$$CR = \frac{(\sum \lambda)^2}{(\sum \lambda)^2 + (\sum \delta)}$$

Equation 4.6: The equation for calculating composite reliability

Where:

- *CR* is the composite reliability
- λ is factor loading
- δ is measurement error

4.3.8.8 Cronbach's Alpha

Lee Cronbach developed the statistical model which is known as "Cronbach alpha" to help researchers calculate the reliability of measures of a test [210]. Cronbach alpha is the statistical measure used for internal research variable reliability and validity which is a value between 0 and 1 and measures ranging above 0.6 is considered a good reliability and validity indicator [211].

In the context of this research Cronbach alpha helps to decide whether the observed items (questions in a questionnaire defined for a particular unobserved variable) correctly measures the unobserved variables such as Perceived Usefulness. Equation 4.7 is used to calculate Cronbach alpha.

$$\alpha = \frac{n * \overline{A}}{\overline{V} + (n-1) * \overline{C}}$$

Equation 4.7: The equation for calculating Cronbach Alpha

Where:

- *n* = the number of items.
- $\overline{A}$ = average covariance between two observed items.
- $\bar{v}$ = average variance.
- α = calculated Cronbach's Alpha value

4.3.8.9 Kaiser-Meyer-Olkin

Kaiser-Meyer-Olkin test is carried out on data sets to assess the adequacy of the data sample to carry out factor analysis [212]. A sample values above 0.5 is considered adequate for factor analysis. Equation 4.8 is used to calculate the value.

$$KMO_j = \frac{\sum_{i \neq j} r_{ij}^2}{\sum_{i \neq j} r_{ij}^2 + \sum_{i \neq j} u_{ij}^2}$$

Equation 4.8: The equation for calculating KMO

Where:

- *KMO* is the sample adequacy measurement value
- *r* is the correlation matrix
- *u* is the partial covariance matrix
- the calculation will be performed under the assumption that $j \neq i$

4.3.8.10 Model Fit Indices

Model fit statistical values are calculated to show how best a model represents theories presented in a research and there are many different fit indices which have made it difficult to bring about consensus among researchers regarding their use [213]. According to [214], the most used fit indices are chi-square (χ2), GFI, TLI, CFI, RMSEA and SRMR for which they provide a table where the definition and recommended values of the indices are outlined. Kline in his famous book [215] (p.221) suggests that as a minimum, Chi-Square, RMSEA, CFI and SRMR should be reported for model fit analysis. According to [213] absolute fit indices such as Chi-Squared test, RMSEA, GFI and SRMR "*provide the most fundamental indication of how well the proposed theory fits the data*". Based on their suggestions fit indices listed in Table 4.3 were used to evaluate the fitness of the extended TAMs in this study.

Table 4.3: Recommended model fit indices and recommended values

Model fit index	Description	Recommended Value
CMIN/DF	Chi Square in AMOS	Between 1 and 3
CFI	Comparative fit index (baseline comparison)	CFI ≥ 0.90
TLI	Tucker Lewis Index (baseline comparison)	TLI ≥ 0.90
IFI	Incremental fit index (base line comparison)	IFI ≥ 0.90
RMSEA	Root Mean Square Error of Approximation (Absolute fit indices)	RMSEA ≤ 0.08
SRMR	(Standardized) Root Mean Square Residual	SRMR ≤ 0.08

4.4 Chapter 4 Summary

This chapter provided a detail account of the methodology and evaluation strategy used to achieve the aims and objectives of this thesis. The following points summaries the main content of the chapter:

1- A deductive research approach is followed to complete this research. This is where theoretical frameworks are developed first and then evaluated empirically. The research design consists of 5 stages which care research the healthcare sector, research virtual collaboration, develop virtual collaboration modelling framework, develop virtual collaboration framework and finally implement and evaluate the frameworks.

2- An eight steps evaluation strategy is followed to implement and evaluate the two developed frameworks. The first step is to implement the frameworks; the modelling framework is implemented as a Java stand-alone application and the collaboration framework is implemented as a mobile application. In step two, TAM is extended three times to adapt it for this research. The first TAM is extended with one new construct (Perceived Ability to Model) for evaluating the healthcare virtual collaboration model. The second TAM is extended with two new constructs (Perceived Healthcare Globalisation and Perceived Clinical Effectiveness) to examine the acceptance of the collaboration framework from healthcare providers perspective. The third TAM is extended with two new constructs (Perceived Healthcare Quality and Perceived Healthcare availability) to examine the collaboration framework from healthcare requesters perspective. New hypotheses are defined for each extended TAMs to be tested by relevant target audience.

3- Survey questionnaire is used as a data collection instrument and research measurements are developed based on 7 points Likert-Scale measurements.

4- Survey participants from the Kurdistan Region of Iraq, where the author currently works as a lecturer, are invited to participant in the research. In total, 28 system developers participated in evaluating the healthcare virtual collaboration modelling framework presented in Chapter 5, 100 healthcare requesters and 100 healthcare providers participated in evaluating the healthcare virtual collaboration framework presented in Chapter6.

5- Structural Equation Modelling (SEM) is used to model the three extended TAM using AMOS software. The SEM models are used to analyse collected data and compute statistical results such as mean, standard deviation, factor loading and model fit indices.

The next chapter presents the Healthcare Virtual Collaboration Modelling Framework (HC-VBE-M-F).

Chapter 5 : Modelling Framework

This chapter presents a modelling framework specific to healthcare virtual collaboration, developed based on VBE and VO concepts. Section 5.1 provides a brief opening about the characteristics and components of the modelling framework. The framework consists of three parts which are: A Service and Participant Classification Mechanism (SPCM) described in Section 5.2, a Domain Specific Modelling Language (DSML) described in Section 5.3 and a Service Orchestration Description Language (SODL) described in Section 5.4. The framework is implemented as a Java application and evaluated by users' (System designers and software developers) for acceptance using TAM. Section 5.5 presents the evaluation results and in Section 5.6 the results are discussed. Finally, a summary of the chapter is provided in Section 5.7

5.1 Healthcare Virtual Collaboration Modelling Framework

Developing a modelling framework that is understandable by stakeholders is a research challenge [216]. Modelling VO for healthcare allow healthcare stakeholders to understand virtual collaboration at a level of abstraction that doesn't require technological expertise. Modelling also allow picturing a VO structure independent from its operational aspect [216]. In this study, a modelling framework for healthcare virtual collaboration is developed with following attributes in mind:

1- Be able to model VBE and VO based collaboration scenarios for the healthcare domain.

2- Be simple, understandable and usable by healthcare stakeholders.

3- Be platform and technology independent.

Developing a modelling framework for a complex sector as healthcare, and be able to capture an aspect of collaboration (virtual collaboration in this case) between its stakeholders to provide a healthcare service, is a challenging task. Some backgrounds and literature reviews in this regard are provided in Sections 2.6 and 3.1. The aim here is to answer the two specific research questions relating to the modelling aspect of this research which are:

1- How to classify the main stakeholders and services in virtual collaboration for healthcare?
2- How to model and describe service provision in virtual collaboration for healthcare?

To answer the research questions relating to the modelling aspect of this research, the direction of [28] is followed to model healthcare virtual collaboration structure and behaviour. The modelling framework developed for VBE and VO based healthcare virtual collaboration consists of three parts which are Service and Member Classification Mechanism, Domain Specific Modelling Language and Service Orchestration Description Language. The framework components are pictured in Figure 5.1.

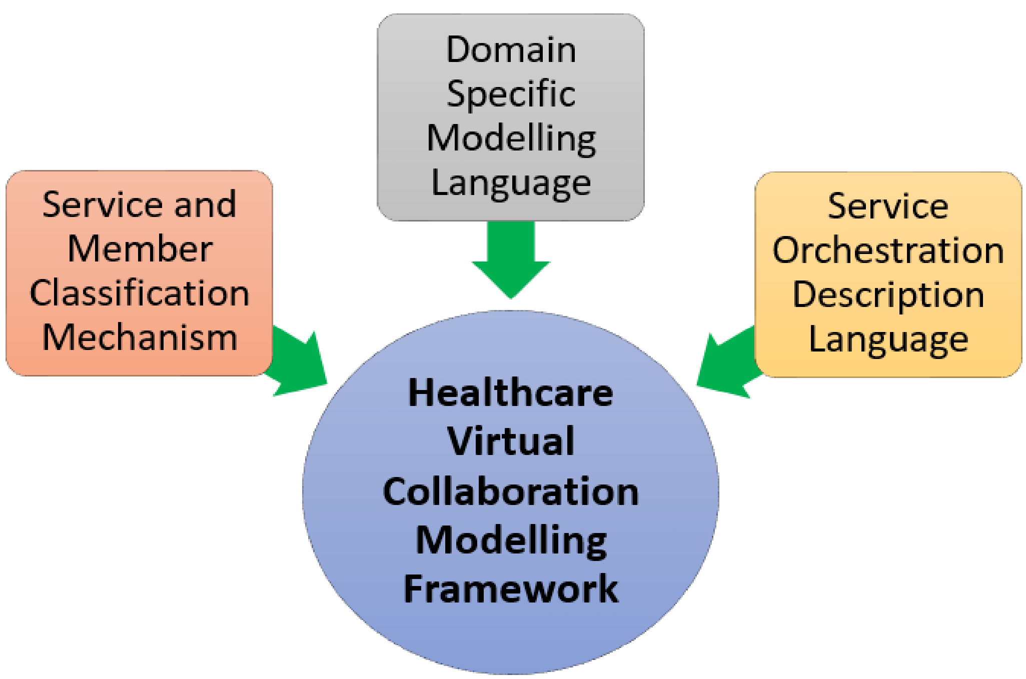


Figure 5.1: HC-VBE Modelling framework components (SPCM, DSML and SODL)

5.2 Service and Participant Classification Mechanism

Developing a classification mechanism that is representative of all stakeholders and services in a sector is a research challenge [216]. To classify services and participants in healthcare on an abstract level, one must identify the main components in terms of environments, stakeholders and services first, for this purpose, research articles such as [217] and [218] as well as online sources such as websites about healthcare is studied . Figure 5.2 presents the findings of the study in terms of different types of roles and services that exists in healthcare sector.

In general, 6 classes of roles and services are identified, which are, care providers, executives, consumers, care environments, electronic devices and healthcare services. Care providers can be broken down to a number of sub-categories such as healthcare equipment manufacturer, healthcare communities and agencies, academic institutions, financial agencies, governmental agencies, pharmaceutical companies and medical professionals. Each of the sub-categories is composed of a number of sub-sub-categories, for instance medical professionals include doctors, nurses and pharmacists.

The executive class represents all individuals and organisations who oversee and manage healthcare environments. Consumers represent patients and people around patients who are affected during a healthcare service provision. Care environments represent places where healthcare is provided such as hospitals and patient homes. Electronic devices represent all electronic equipment that support the process of healthcare provision used by both patients and doctors. Finally, the service can be divided over healthcare related administrative services and care related services.

In a typical virtual collaboration scenario, many of the identified stakeholders will have to collaborate to provide a service. This clearly presents a complex collaboration setting that requires a simplification mechanism to understand. Abstract models can simplify the complexity, this where a modelling language that is simple and understand by stakeholders play a vital role.

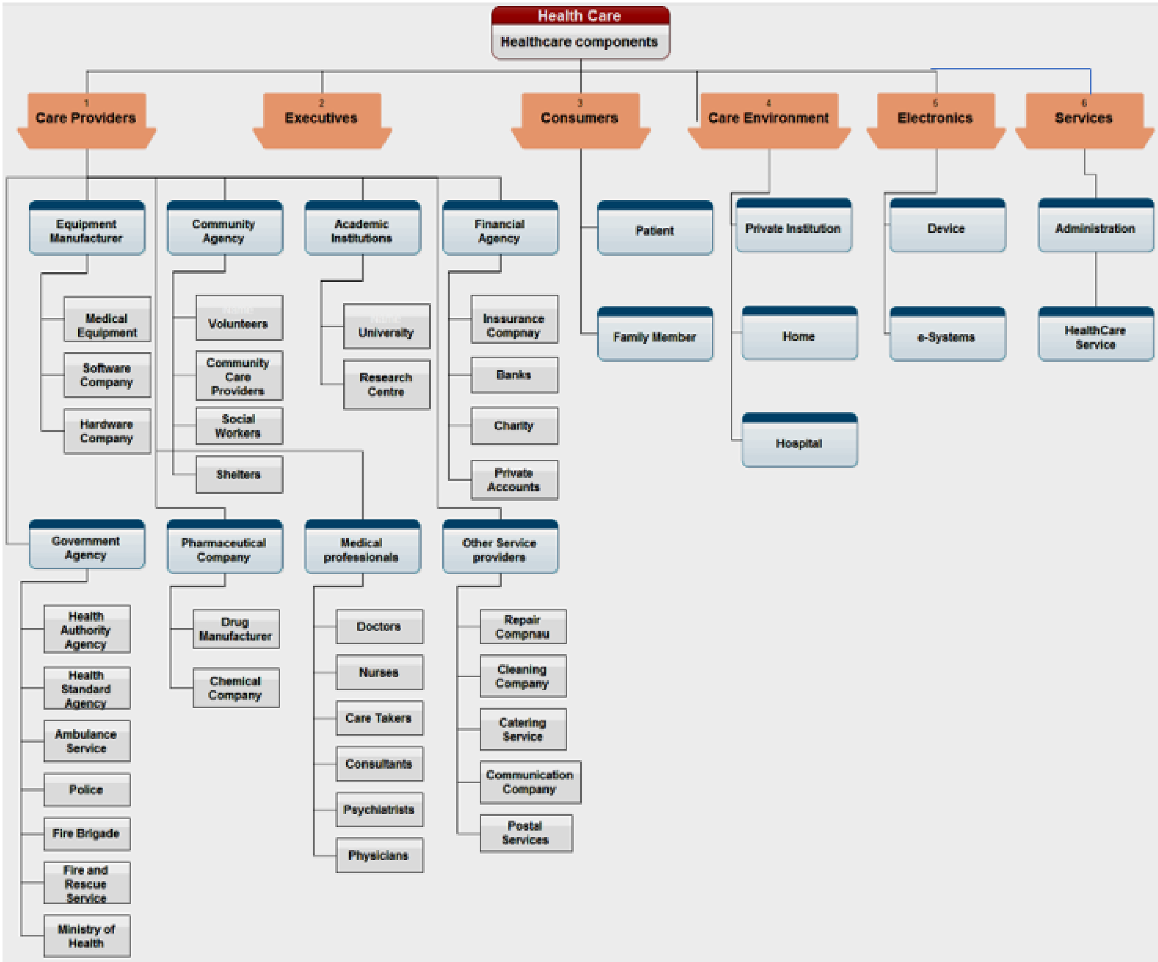


Figure 5.2: Summary of healthcare roles and services identified as a result of studying resources in the form of articles and websites

The findings presented in Figure 5.2 have served as the base for developing the service and participant classification framework which is outlined in Section 5.2.1. In order to develop an abstract and generic classification that is simple and inclusive, the categories are further refined into three main classes which are stakeholders, environment and services as shown in Figure 5.3. Here, a brief description of each refined category is provided:

1- **Stakeholder:** The class represents all individuals, organisations, governmental and none governmental agencies who participant in providing, consuming and managing healthcare. They can be classified into three sperate sub-classes:

   a- *Care providers*: These are healthcare professionals and organisations that provide care.

b- *Executives:* These are healthcare organisers and managers who ensure the smooth running of healthcare related operations.

c- *Care consumers*: These are patients and family members who receive healthcare services.

2- **Environment**: This is the environment where healthcare is provided. Generally, they consist of two types:

a- *Physical environment:* This type of environment is the traditional healthcare environments where healthcare is provided such as hospitals, clinics and institutions.

b- *Electronic environment*: This type includes all the electronic systems where care is provided using information and communication technologies.

3- **Services**: This class is concerned with all the services required to provide, run and maintain healthcare services; they can be classified into two types:

a- *Care related service*: This type includes all the services that are concerned with providing care to consumers.

b- *Management related service*: This type of service is concerned with managing the healthcare environments to ensure the orderly operation of care provision.

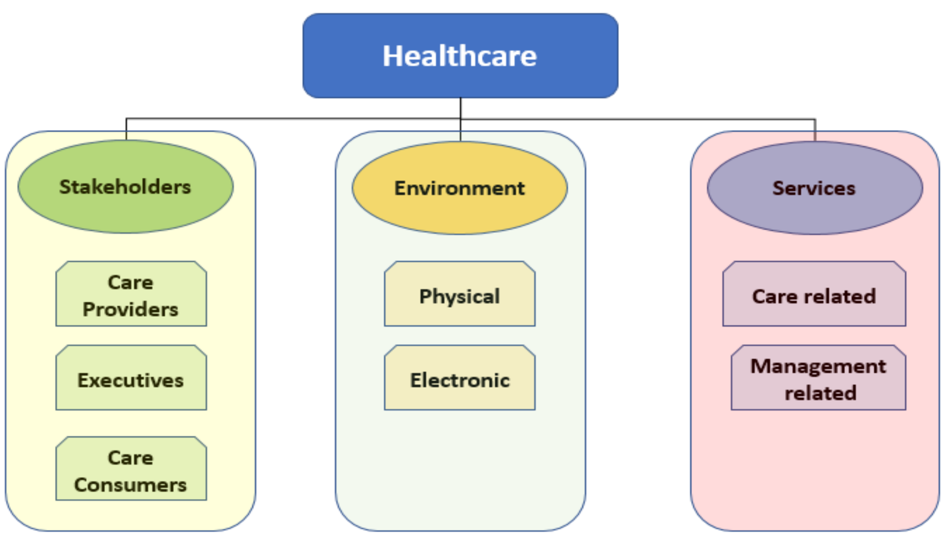


Figure 5.3: Refined healthcare roles, services and environment classifications

5.2.1 SPCM Description

To describe virtual collaboration scenarios in healthcare in a manner that both healthcare system developers and stakeholders understand, a simple service and participant classification mechanism would contribute to the process positively. In developing the SPCM, the author has followed the direction of other researchers who have suggested classification frameworks similar to what is outline in this section. For instance the authors in [28] have proposed a general business-oriented actor and resource classification framework to model VBEs and VOs at abstract levels. Grid technology has been used by the authors in [219] to define resources and assign roles and services in managing healthcare virtual organisation.

The authors of [27] propose a framework by which general roles and service relating to VBE and VO in business can be defined, however, they state that "*Clearly neither Competencies nor resources of the organizations in the VBE for Healthcare (e.g. Doctors practice office, insurance company, ambulance services, etc.) can be defined by the same ontology*". A framework that uses the concept of service-based agents to classify virtual organisation participants is outlined by the authors of [118]. To define the SPCM for VBE and VO based healthcare virtual collaborations, the direction of [15] is followed. In this thesis, a role-based classification method is used to develop the mechanism using the roles and services summarised in Section 5.2. The mechanism is aimed to achieve two objectives, first to be general and wholistic in classifying services and participants in healthcare virtual collaboration and second, be simple and understandable by healthcare stake holders.

Figure 5.4 shows the SPCM classes and their mapping with the healthcare classes identified in Section 5.2. The mechanism is developed to classify participants and services for VBE and VO-based healthcare virtual collaboration. It is comprised of six classes which is can be applied to all healthcare virtual collaboration scenarios. The mechanism addresses the structural organisation of VBE and VO-based healthcare collaboration on an abstract level. It is designed with healthcare system developers in mind to provide them with a mechanism that they can use to breakdown complex scenarios for system design purposes.

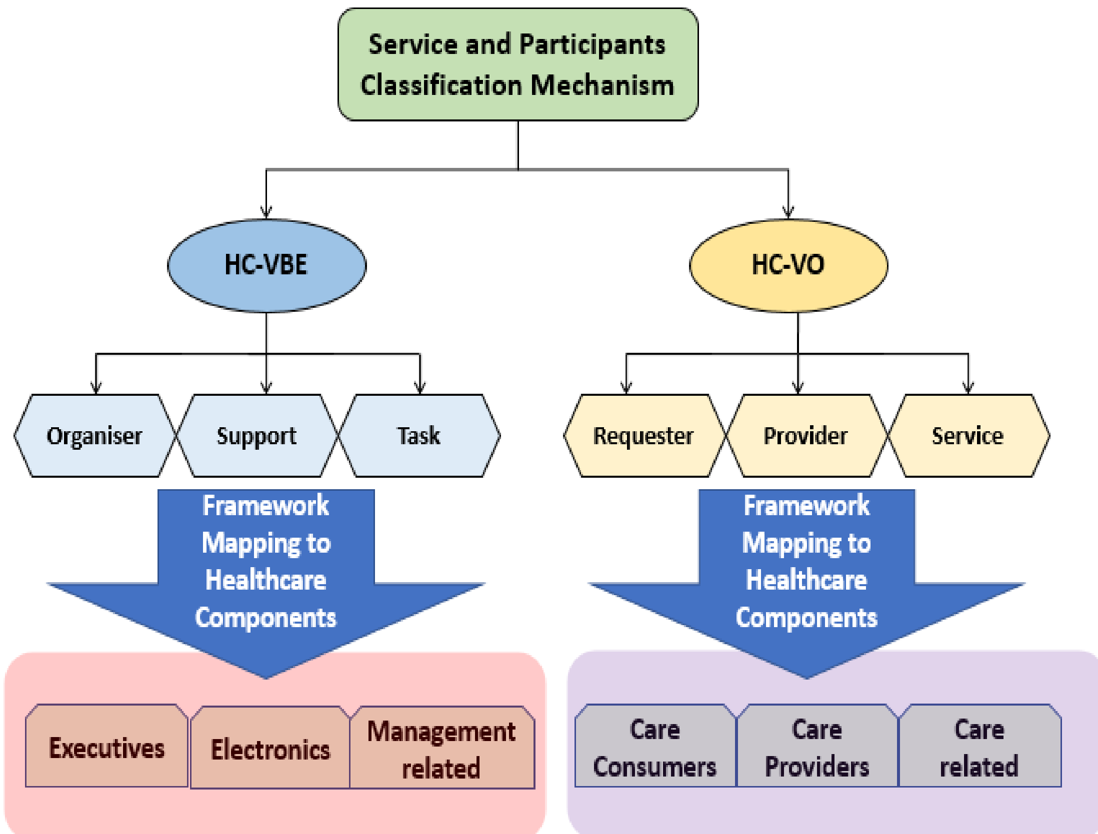


Figure 5.4: Healthcare service and participants classification mechanism mapped to the six classes of stakeholders and services

As illustrated in Figure 5.4, the mechanism classifies roles and services on VBE and VO levels as below:

1. HC-VBE level: Participants are classified into two distinct classes of participants, the first is **Organiser** and the second is **Support**. Service is classified as one class which is **Task**.

a) **Organiser*:*** Roles that participant in the establishment of a HC-VBE are called *Organiser* which can be individuals and organisations. This class is denoted by *<<Organiser>> Name* and has the following responsibilities:

- Create HC-VBE to provide an environment for healthcare service provision virtually.

- Oversee and manage a HC-VBE environment and operations.
- Recruit other participants who wish to contribute to the creation and management aspect of HC-VBE.
- Ensure resource availability and accessibility as required for operating a HC-VBE and HC-VO.
- Ensure all necessary facilities are available for timely HC-VO creation.

b) **Support:** Represent electronic resources such as decision support systems and databases which provide operational support to HC-VBE or HC-VO. It is denoted by *<<Support>> Name* and has following responsibilities:

- Data storage.
- Organise communications between healthcare service provider and requester.
- Collaboration and sharing facilitation.
- SLA creation and management.
- Provide electronic Input mechanisms for resources as required from HC-VBE internal and external sources.
- Provide output mechanisms for managers, care providers and receivers.

c) **Task:** All HC-VBE management activities that are carried out by *Organisers* are classed as *Task,* which is denoted by *<<Task>> Name* and has the following responsibilities:

- Provide a common interface for *Organiser* collaborations.
- Administer resource allocations.
- Define and manage resource access privileges.
- Define *Organiser* rights and responsibilities within a HC-VBE.

2. HC-VO level: Participants are classified into two distinct classes of participants, the first is **Requester** and the second is **Provider**. Service is classified as one class which is **Service**.

a) **Requester**: This class represents virtual collaboration participants who request a healthcare service from a HC-VBE; it is documented as *<<Requestor>> Name* and has the following responsibilities:

- Request virtual healthcare services.

- Respond to queries that are sent by HC-VBE participants (Organiser and provider).
- Negotiate a healthcare service to be received.
- Approve SLA after negotiation.
- Pay for healthcare services provided.
- Rate Providers and services provided.

b) **Provider**: Healthcare professionals who are recruited by a HC-VBE to provide services in HC-VOs are classed as *Provider*. For example, a psychologist can be recruited to provide a consultation service to a patient. It is documented as *<<Provider>> name* and has the following responsibilities:

- Provide a healthcare service.
- Negotiate a healthcare service to be provided.
- Approve SLA after negotiation.
- Expect to be rewarded after complete service provision.

c) **Service**: The class represents short-lived virtual collaborations known as HC-VOs which are created by HC-VBEs to provide a specific service for a specific period to a *Requester.* The responsibilities of *Service* are similar to those of *Task* and it is documented as *<<Service>> Name.*

5.3 HC-VBE Domain Specific Modelling Language

Theoretically, the dynamic nature of VO has the potential to offer solutions to many different problems that require timely solutions, however, when it comes to the application of the concept, there are a number of structural, functional and behavioural barriers that are yet to be finalised. Describing a process in detail helps in simplifying its complexity; models can provide a form of description that "*increases the readability of a process and its evaluation"* [220]. The concept of VO supports collaboration over time and space, but before such a concept is realised it has to be modelled as models facilitate implementation process [221].

Models and visualisation techniques are used in many fields of science such as engineering and manufacturing to facilitate a better understanding of a particular scenario, however "*Visualization of aspects of virtual collaboration has received relatively little research attention in the past*" [36]. A structural model that could visualise how different stakeholders in a typical HC-VO is structured is a significant contribution to the realisation and implementation of the concept in healthcare [78]. The authors of [15] have implemented a virtual medical team creation and management system in Cyprus which is an example of the kind of systems that the DSML developed in this thesis can contribute to its design and development.

Following the directions of [222] and [118], conceptual models independent from implementation details is explicitly chosen to provide a generic view of virtual collaboration for healthcare. Authors in [223] claim that "*Using non-formal representation often helps to gain a common understanding of the problems at hand*". The authors in [224] state that to facilitate the description of challenges facing the healthcare domain due to its complexity, conceptual models can be used. The ability of Service Oriented Architecture (SOA) to show a number of service providers working together, makes it a good candidate to be used for modelling in healthcare. But, SOA has mainly been used to model the technical aspects of interoperability in healthcare systems "*not modelling the actual health care processes*" [14].

Unified Modelling Language (UML) is a popular modelling language which is used widely by system developers to model the behavioural, structural, and conceptual aspect of a process [225]. There are researchers who have attempted to use UML diagrams to model some aspects of healthcare. For instance, UML has been used to model a number of healthcare related processes such as optimising hospital processes [226], organising hospital-based cancer registration process [227]. UML models are capable of modelling different system aspects, one of which is a use case diagram. UML use case is the model that is chosen as the base to develop the DSML for healthcare virtual collaboration in this thesis.

UML use case diagram has become the tool to draw simple and static views of a system where actors and functions of a system are modelled and documented; it is easy to understand and require limited introduction to the model notation [228]. The graphical notations offered by UML to draw a use case diagram are generic not specific, for example the stickman and the oval shape notations pictured in Figure 5.5 are used to represent all types of actors and functionalities of a system, regardless of the type and behaviour of the actors and function. The authors of [185] claim that adopting general purpose modelling languages such as UML are not always suitable to model problems in specific domains, hence the development of a DSML could be considered as the alternative.

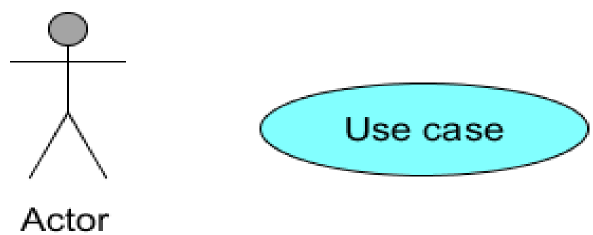


Figure 5.5: UML use case diagram actor and use case graphical notations

The complexity of virtual healthcare provision suggests that there is always the opportunity for a wider range of stakeholders to participate in providing a care as healthcare virtual collaboration can take place on a global level. During a typical healthcare service provision, many stakeholders come together to provide the service, some healthcare professionals and others outside the healthcare sector. Researches such as [13] has used UML to model the execution procedure of treatment provision to patients and they have drawn the conclusion that UML diagrams "*cannot be used directly in the hospital domain*". The author of this thesis has researched the suitability of using UML to model healthcare in [229] and the outcome points towards a similar conclusion that UML diagrams cannot model healthcare scenarios effectively .

Therefore, a healthcare virtual collaboration DSML becomes an important tool for modelling in the sector. In developing the DSML, UML use case diagram is extended using UML profile extension mechanism. The extension is necessary to ensure that the model notations represent specific actors and use cases that are visually separable from each other.

5.3.1 UML Use Case Notation Extension

Domain specific graphical languages can simplify complex problems by allowing for abstractions [223]; building these languages are often complex and require collective effort and time, hence finding the right abstraction for a specific domain is a challenge. For this reason, customising and extending an available general modelling language such as UML can be more affordable as well as more acceptable since it is widely used.

Profiling as a lightweight extension mechanism is being promoted by UML which has played a great role in the widespread use of the language [230]. The mechanism facilitates the introduction of new modelling elements without the need to define a totally new modelling language [230]. [231] Explains how the UML profiling mechanism can be used to develop a new DSML. The mechanism is used in a number of other studies, for examples, [223] proposes the use of UML profile for developing a DSML for embedded systems, and the authors in [129] use the mechanism to define a Service Modelling Language. Authors in [232] propose a domain ontology that can aid the evaluation process of DSML developed using UML profile. Figure 5.6 shows the organiser actor which is part of the HC-VBE-A package extended using UML profiling mechanism form the use case actor profile.

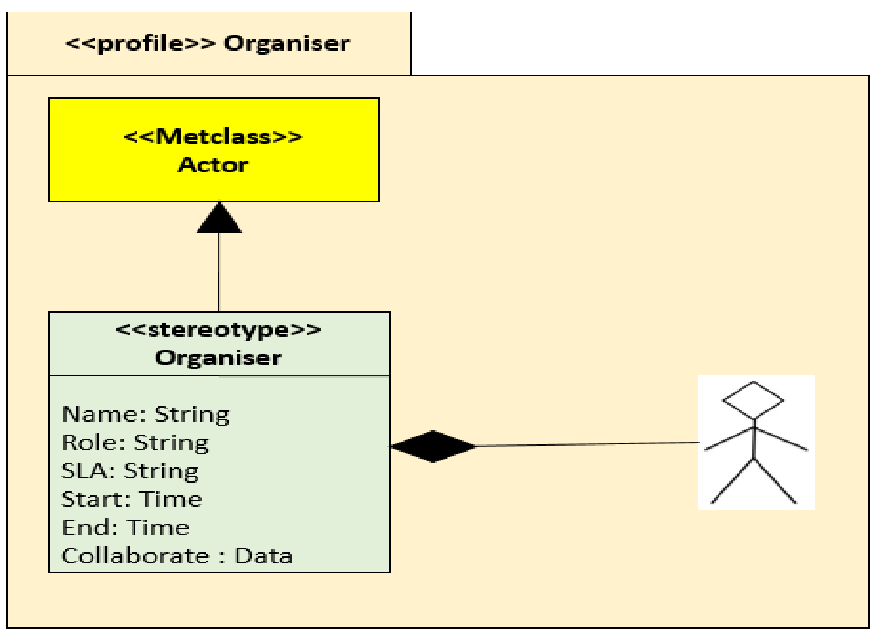


Figure 5.6: UML profile for organiser actor extended from the UML actor notation in this thesis

The UML use case diagram extensions performed to create the healthcare virtual collaboration DSML in this thesis consist of four packages. The packages are specifically developed to model the components of the proposed service and participant classification mechanism presented in Section 5.2. The packages are called healthcare virtual collaboration actor (HC-VBE-A), healthcare virtual collaboration use case (HC-VBE-U), healthcare virtual collaboration relationship (HC-VBE-R) and Healthcare virtual collaboration environment (HC-VBE-E). In HC-VBE-A package, the traditional actor notation is customised using the profile mechanism and four new notations are introduced representing virtual collaboration actors in healthcare as specified in the SPCM which are *Requester, Provider, Organiser and Support.*

Figure 5.7 shows the mapping between the extended use case notations to the service and participant classification mechanism outlined in Section 5.2 and the description of these extensions are presented in Table 5.1.

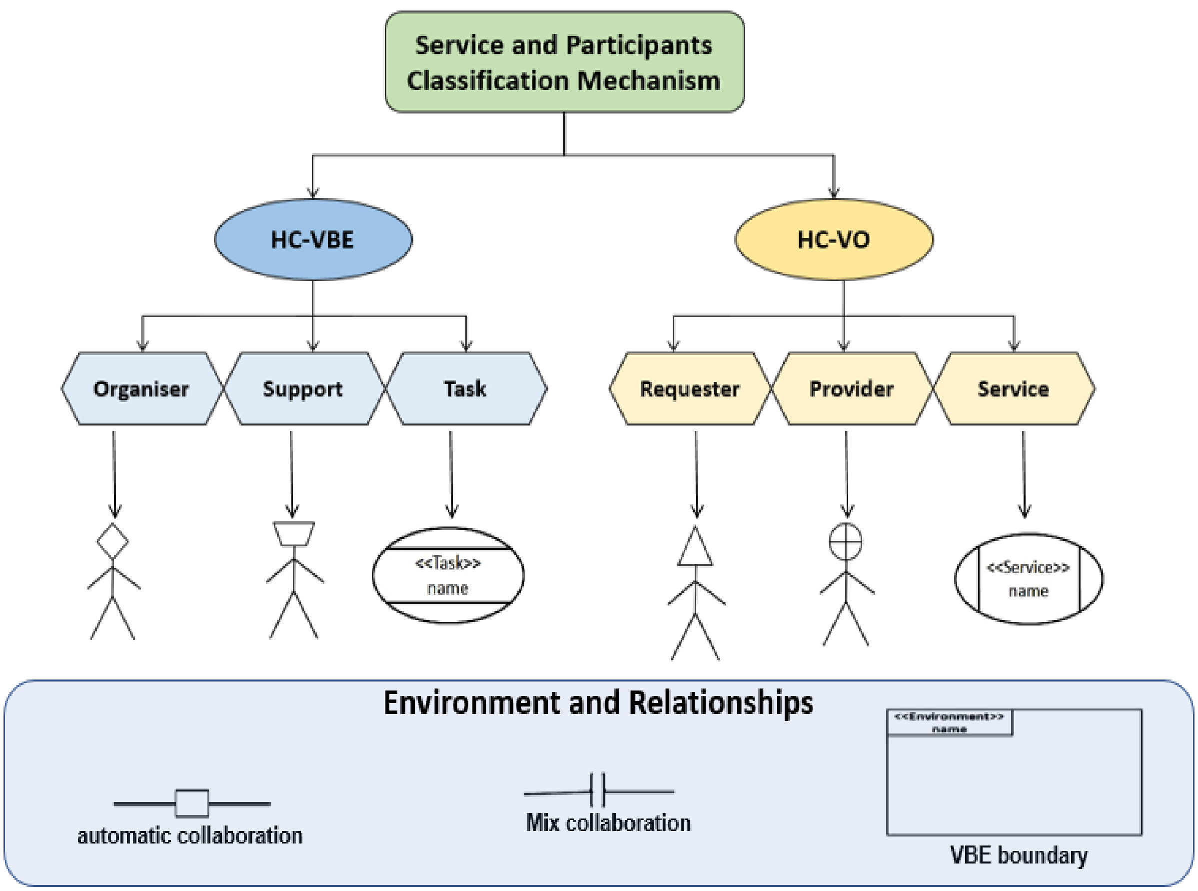


Figure 5.7: The service and participants classification mechanism mapping to the developed DSML for healthcare virtual collaboration

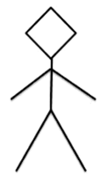
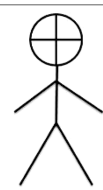
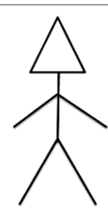
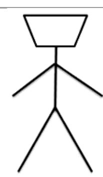
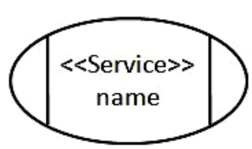
In extending the UML actor notation, different shapes have been used to modify the default UML stickman notation's head which is circle by default, with the aim to sperate the four new actors visually and aid visual recognition by modellers. The inspiration for selecting the-shapes has come from the common traffic signs that are recognisable easily.

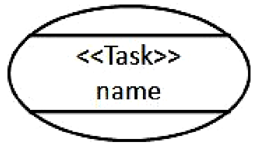
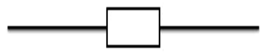
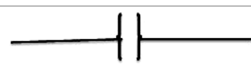
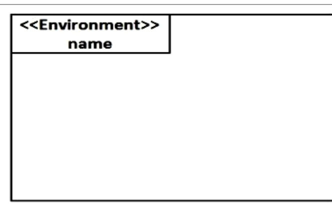
For the healthcare "provider" actor, the stickman notation's head is a circle shape with a cross in the middle which is the sign for healthcare related ensembles such as hospitals. For the healthcare "requester" actor, the stickman notation's head is a triangle shape, indicating (give ways to) which can be interpreted as (need help). For the healthcare "organiser" actor, the stickman notation's head is a Dimond shape, the shape is used in traffic concept for warning and directing drivers i.e. organising their driving. For the "support" actor, the stickman notation's head is a trapezoid shape, representing electronic devices.

In HC-VBE-U package, the use case oval shape notation is customised and two extensions are introduced representing *Tasks* and *Services* of HC-VBE and HC-VO which are specified in the SPCM. Both the "task" and "service" shaped are visually separated by drawing horizontal and vertical lines across the original oval shape. In HC-VBE-R package, the association line is customised and two new association types have been introduced representing electronic and semi-electronic communications. The two new association lines are visually separated by adding a rectangle to the association line representing electronic communication and an added square bracket representing semi-electronic communication.

Semi-electronic means a communication that involves both direct face to face and virtual at the same time. For example, a doctor could be providing a service to a patient in his office directly while collaborating with another doctor virtually about the case of the patient. The final package is the system boundary notation customised to represent the HC-VBE-E where collaboration take place.

Table 5.1: The UML use case notation extension description that make up the developed DSML

Packages	No.	Graphical Notation	Description
HC-VBE-A	1	 <<Organiser>> Name	The notation depicts *Organiser* who participate in the creation and management of HC-VBE. This notation always appears on the top of a HC-VBE model.
	2	 <<Provider>>Name	The notation depicts the healthcare providers who join a HC-VBE to provide a specific virtual healthcare service for a specific duration. This notation always appears on the right of a HC-VBE model.
	3	 <<Requester>>Name	The notation depicts virtual healthcare service requesters such as patients. Requester's job is to ask HC-VBE for a service which subsequently be provided by creating a HC-VO for the request. This notation always appears on the left of a HC-VBE model.
	4	 <<Support>>Name	The notation depicts HC-VBE and HC-VO electronic resources such as databases that provide operational and management supports. This notation always appears on the bottom of a HC-VBE model.
HC-VBE-U	1		The notation depicts HC-VOs that come to existence based on a request made by a requester. The service exists for a specific duration and it is created to achieve a specific goal. It gets dissolved once the goal is achieved. This notation always appears inside a HC-VBE model.

Packages	No.	Graphical Notation	Description
	2		The notation depicts HC-VBE tasks where the task is created for management of a HC-VBE. Tasks are long- term based and may continue for the duration of the HC-VBE life time. This notation always appears inside a HC-VBE model.
HC-VBE-R	1		This notation is used to indicate electronic collaboration using communication technologies between two entities of a HC-VBE. This notation always appears crossing a HC-VBE model between Service or Task and Requester, or Provider or Support or Organiser.
	2		This notation is used to indicate a mix of direct and electronic collaborations between two entities of a HC-VBE. This notation always appears crossing a HC-VBE model between Service or Task and Requester, or Provider or Support or Organiser.
HC-VBE-E	1		This notation represents the HC-VBE where HC-VO is created and live to provide a service.

5.3.2 A Modelling Example

To demonstrate how the DSML developed facilitate the process of modelling a healthcare virtual collaboration, the following scenario is considered.

To reduce cost and provide on demand consultation for patients who require after treatment monitoring, the local healthcare authority in Leicester decides to setup a HC-VBE-Leicester and appoints following participants:

1. A clinical operation manager as *Organiser*
2. An accountant as *Organiser*
3. The local authority central patient record system as *Support*

The participants collaborate in a *Task* to manage the operation of the HC-VBE-Leicester to ensure the smooth running of the virtual environment and the availability of resources for HC-VO creations. Figure 5.8 shows the structure of the HC-VBE-Leicester modelled using the DSML described in Section 5.3.

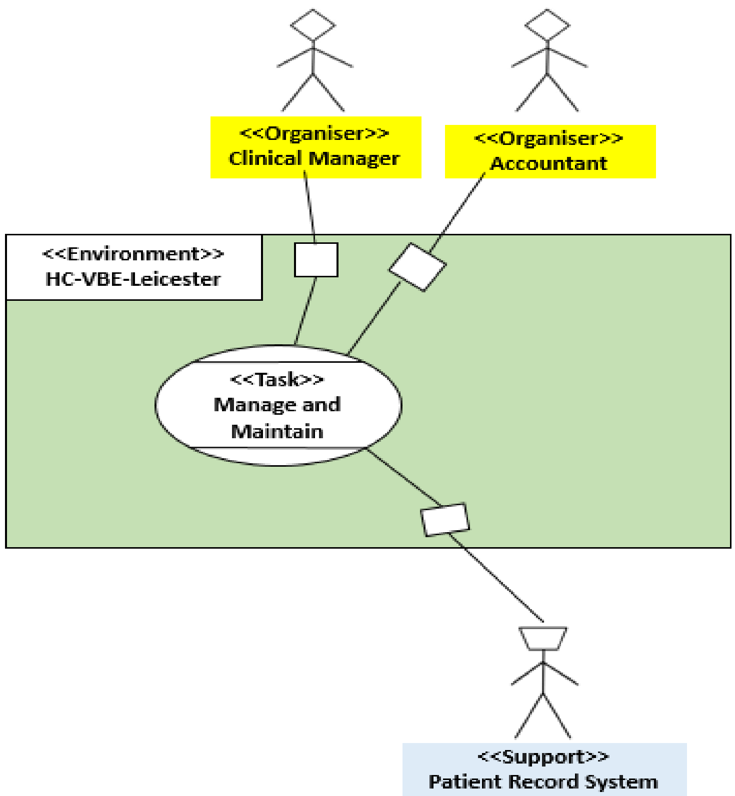


Figure 5.8: Use case Diagram for the HC-VBE-Leicester collaboration scenario modlled uing the developed DSML

5.3.2.1 Using HC-VBE-Leicester to provide care

To model a healthcare service provision by the HC-VBE-Leicester, a case study has been extracted and simplified form [218] as follows:

A decision has been taken to discharge a male patient named John who had left hip total joint arthroplasty in the past 15 days. The progress of the patient will be monitored at his *home. The patient's movement is limited because of his operation and he has to be assisted in his demotics needs as he lives alone.*

Surgical Site Infection is one of the most common possibilities after surgery, if the patient is not cared for properly. the infection is caused by "*contamination of an incision with microorganisms from the patient's own body during surgery*" [233]. To prevent the patient from being infected collaborations between the patient and healthcare professionals in the hospital is crucial. For such a case the HC-VBE-Leicester is asked by Mr. Johan as directed by his surgeon to provide a real-time consultation service which they call *SSI-Prevention* that facilitates:

1. The collaboration between the patient and healthcare providers.
2. Allow his surgeon to access real-time information recorded by a monitoring health device installed at his home.
3. Select and recruit a pharmacy to provide him with the right medication when needed.
4. Select and recruit a carer to look after him in terms of cooking and cleaning.
5. Find and recruit a nurse to treat his surgical wounds.

To model the scenario, the participants of the "*SSI-Prevention*" can be classified based on the SPCM developed as follows:

1. **Organiser**: The Surgeon who performed the operation.
2. **Providers**: A nurse to treat Mr. John's wounds, a pharmacy to provide medication when needed and a carer to cook and clean.
3. **Support**: The local authority's central database and a health monitoring device installed at the patient's home.
4. **Requester**: Mr. John is the service requester
5. **Service**: *SSI-Prevention*.

Figure 5.9 shows the virtual collaboration model for the scenario modelled using the DSML developed.

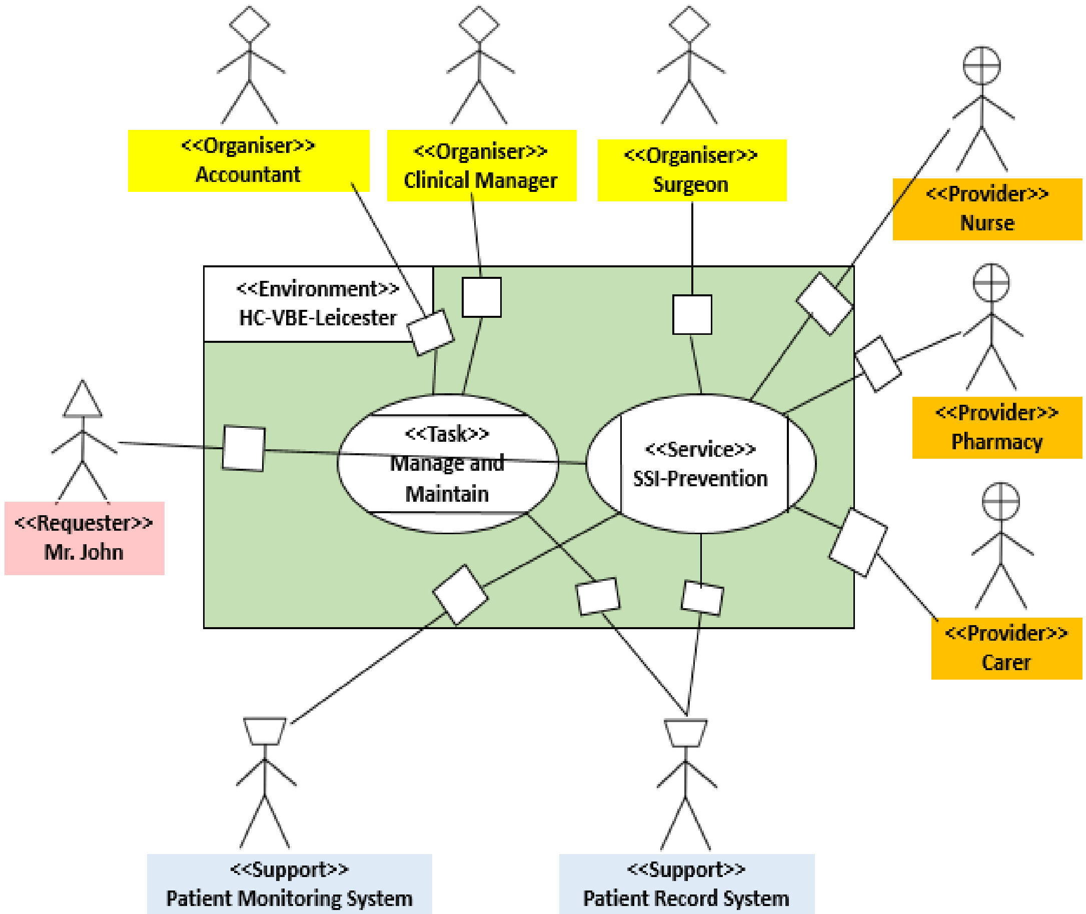


Figure 5.9: Use case diagram for the HC-VO collaboration (SSI-Prevention) modelled using the developed DSML

5.4 Service Orchestration Description Language

To show the processing steps of online services, the term "orchestration" is a familiar word among researchers. The aim of orchestration is simply to show the workflow details of an online activity [234]. The other term that is also used to describe processing steps of online services is "choreography" and the difference is, orchestration is known to represent centrally controlled collaboration whereas in choreography the service providers are loosely controlled [235]. It was decided that orchestration is more suitable for healthcare virtual collaboration and the reason is, in order to ensure all collaborating parties, deliver the right services following enforced terms and conditions, a centrally controlled mechanism is more appropriate.

To model service orchestration there are a number of approaches suggested, for instance, the authors in [236] are proposing to use UML activity diagram. Their approach has great usability potentials as the diagram is frequently used among business service modellers and software developers. However, it suffers from lack of details as the diagram only shows activities without the required data that is needed for each step of the orchestration. The Authors of [234] propose the use of "Reo" which is a graphical modelling language to model orchestration. Their proposed mechanism only shows the connection and data flows between web services with the aim to generate technical code. Their approach lacks details such as the condition under which the orchestration takes place.

Business Process Execution Language (BPEL) [237], is one of the most popular orchestration workflow languages that is becoming industry standard and supported by tech companies such as Microsoft and IBM. BPEL provides the mechanism to implement orchestration of web services. In BPEL, the orchestration between service providers over the web is encoded in XML, and provides a mechanism to send and receive XML messages sequentially and in parallel [237]. Initially, BPEL didn't have the support for human activities, but later, the language was extended and BPEL4People was introduced [238]. The new extension is essential for the purpose of this research since in healthcare virtual collaboration human is involved as service providers alongside machines.

In BPEL, first a service requester sends an input message to be processed and once the request message is received service attributes will be identified as variables and necessary service provision modules are assigned to be invoked. The result of service provision will be sent back to the service requester in the final stage. Figure 5.10 shows the steps BPEL uses to orchestrate services. To address the gaps identified in this section, a mechanism specific to healthcare virtual collaboration service orchestrations is developed and presented in the next section which consists of an orchestration mechanism (HC-VBE-OM) and a service orchestration description language (HC-VBE-SODL).

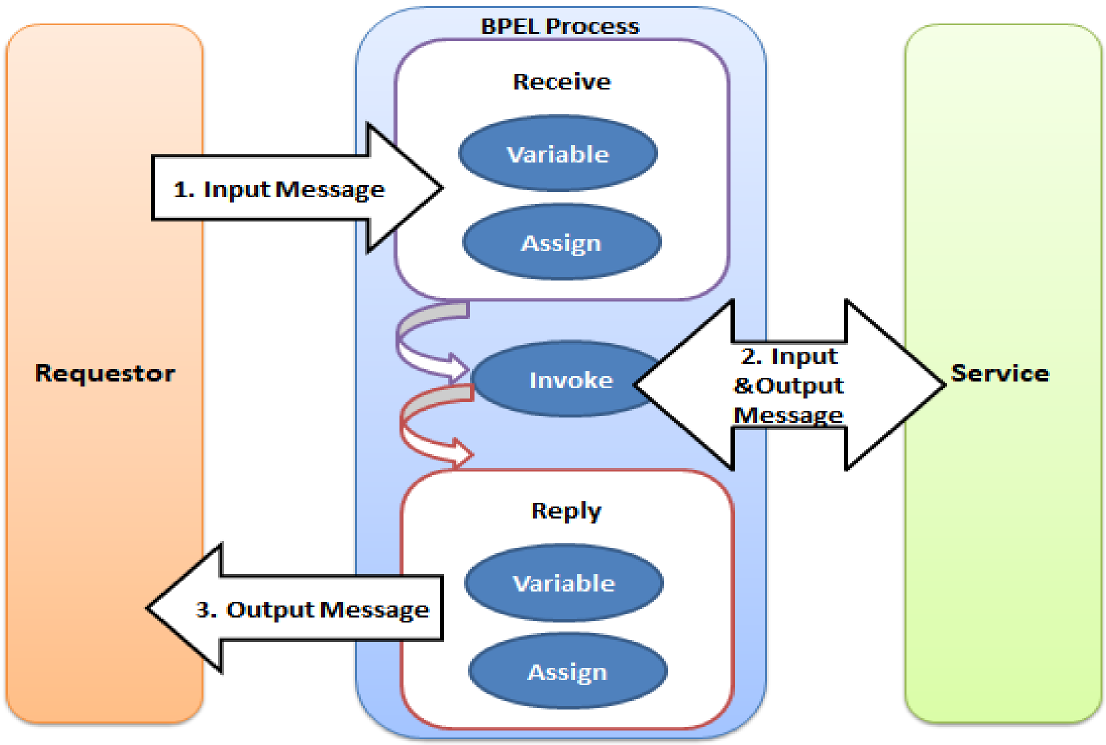


Figure 5.10: BPEL orchestration process. showing how requests are orchestrated

5.4.1 HC-VBE-OM Introduction

Here, an orchestration mechanism is developed that captures three aspects of healthcare virtual collaboration service orchestration which are, the scope of the orchestration, the required information for the orchestration to take place and the actual orchestration process. This is different from BPEL as BPEL only shows the orchestration process without showing the scope and required information. Each aspect of the mechanism captures a number of details of an orchestration. Figure 5.11 shows the three aspects of the mechanism and Table 5.2 provides a short description of each aspect of the HC-VBE-OM.

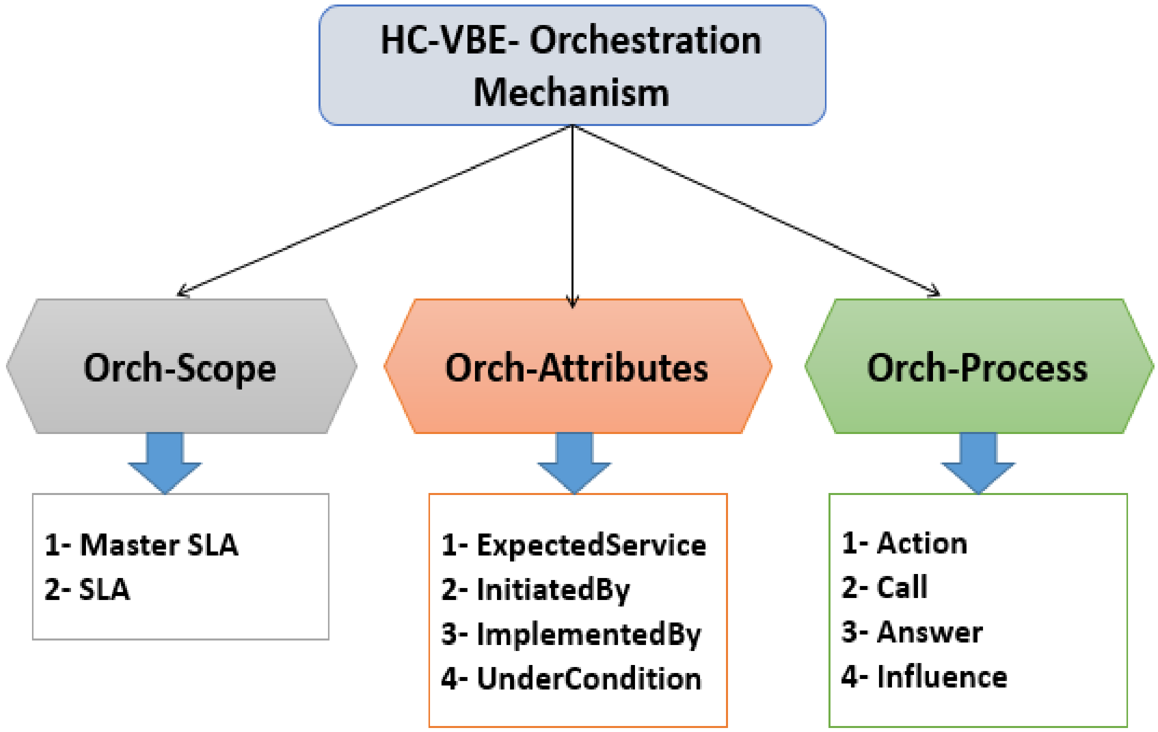


Figure 5.11: the proposed HC-VBE Orchestration mechanism components

Table 5.2: Orchestration mechanism component description

No.	Orchestration Aspect	Reserved word	Explanation
1	**Scope**	1. Master SLA	Represent the scope of the orchestration as each HC-VO will have a Master SLA under which all SLAs are linked. More details regarding Master SLA is provided in Chapter 6.
		2. SLA	In a typical HC-VO there are collaboration between participants, the terms and conditions of the collaboration is assumed to be formalised in an SLA. More details are provided regarding SLA in Chapter 6.
2	**Orchestration Attributes**	1. ExpectedService	Represent the expected service that is going to be orchestrated. This service is identified in the SLA in the Scope section. There might be several

No.	Orchestration Aspect	Reserved word	Explanation
			expected services in an SLA; if that is the case then there is an orchestration for each.
		2. InitiatedBy	Indicates the participant who has requested the service as specified in the SLA in the Scope.
		3. ImplementedBy	Indicates the participant who provides the service as specified by the SLA identified in the Scope.
		4. UnderCondition	This section contains all the constraints under which the orchestration is going to be carried out. If any of the conditions are not true the orchestration does not take place.
3	**Orchestration Process**	1. Action	This indicates what activity is the orchestration is for and starts the orchestration process once the request for the activity is received.
		2. Call	This step is triggered by (Action) and it will invoke the service provider to start providing the service.
		3. Answer	Represents the outcome of the orchestration. Penalty will be issued if the service provision has not met the conditions specified in the SLA otherwise reward will be issued.
		4. Influence	This part identifies the next orchestration that is going to be triggered after the completion of the current orchestration.

To facilitate the implantation of the developed orchestration mechanism in the future, it has been mapped to BPEL4People. Figure 5.12 shows the mapping between the HC-VBE-OM and BPEL4People.

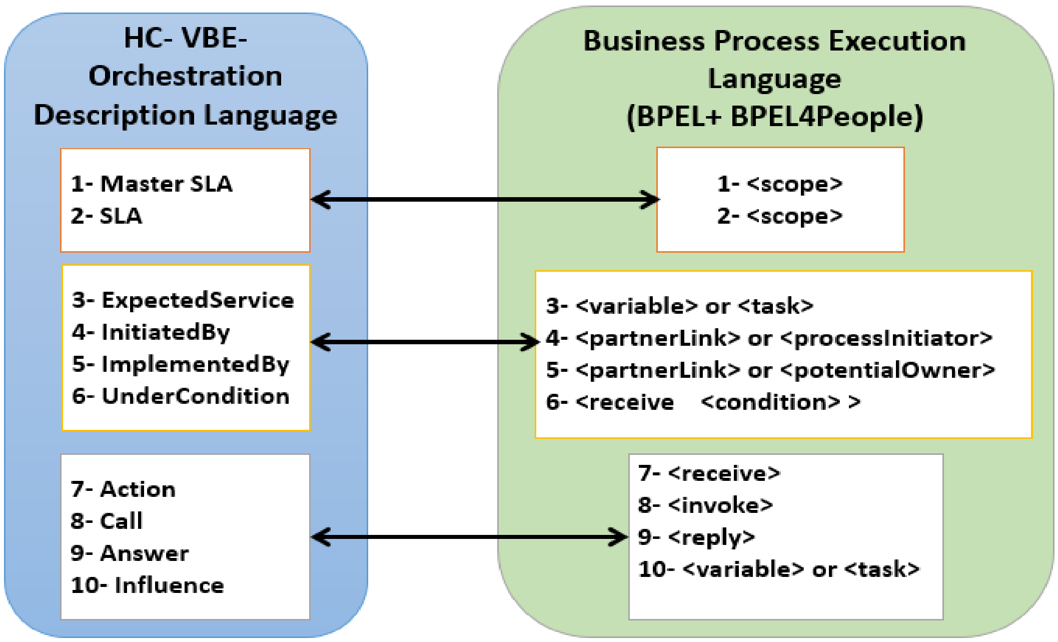


Figure 5.12: HC-VBE Orchestration mechanism mapping to BPEL

To perform the mapping, a similar direction as in [239] was followed to map the developed orchestration framework to BPEL4People. In the mapping, the three main aspects of the orchestration mechanism and their sub sections are stated and mapped to their equivalent BPEL4People XML tags which are described in [237] and summarised in Table 5.3. The mapping is as follows:

1- The orchestration scope which is decided by a *Master SLA* and the *SLA* which the orchestration is for, can be implemented as <scope> tag in BPEL4People.
2- The process component of the orchestration mechanism consists of *ExpectedSerivce* which can be implemented as <variable> or <task> tags, *InitiatedBy* can be implemented as <partnerLinK> or <processInitiator>, *ImplementedBy* can be implemented as <partnerLinK> or <processOwner> and *underCondition* can be implemented as <received <condition>.
3- The third component of the orchestration mechanism consists of *Action* which can be implemented as <receive>, *Call* which can be implemented as <invoke>, *Answer* which

can be implemented as <reply> and *Influence* which can be implemented as <variable> or <task>.

Now the question is, if we can map the orchestration mechanism to BPEL4People why not use BPEL4People instead? The answer is, BPEL4People is an implementation language based on XML that require technical skills to be created and understood. The orchestration mechanism outlined here has a human understandable textual structure that does not require technical skills to create and understand and it is developed for modelling purposes.

Table 5.3:BPEL4People tag descriptions used in the mapping process

No.	Tag	Description
1	<Variable>	Describes the attributes of a service or a requester or provider.
2	<Task>	Describes a human task.
3	<PartnerLink>	Describes the service initiator or owner.
4	<ProcessInitiator>	Describes service initiator.
5	<PotentialOwner>	Describes service owner.
6	<Receive <Condition> >	It is used to specify the conditions of the service that is expected to be provided.
7	<Receive>	The tag is used to specify a service to be provided.
8	<Invoke>	The tag is used to initiate a service to be provided by a partner.
9	<Reply>	The tag contains a response of an accepted service request described in <Receive>.

5.4.2 Orchestration Description Language

As a result of the research carried out on orchestration for this thesis, it was concluded that a graphical orchestration model cannot frame the required information in a given orchestration alone. Therefore, a textual description language to describe an orchestration, following the direction of others such as [240] was developed.

Healthcare is complex and there are many details that have to be accounted for in order to start and end an orchestration. The textual orchestration description language presented in this section is designed to describe the three aspects of the orchestration mechanism as presented in the previous section (scope, attributes and process). To standardise the orchestration textual description language, here the sentence structure and reserved words of the language are outlined. Figure 5.13 shows the structure that each sentence will have. It consists of two parts, the first is called Section Identifier (SI) and the second is called Orchestration Line Statement (OLS). The second part consists of two sub-parts which are processing line requirements and the outcome of the line.

In the first section (1. Section Identifier), there is always one of the 9 reserved words defined in Table 5.4 in the order presented in the table. This part of the sentence is separated from the second part using a colon (:). The next part contains one or more statements, each separated by a dot (.) and then followed by relevant properties of the statement. The "2.1 requirement" sub-section is linked to the "outcome" sub-section using either an equal (=) sign to imply that the two sides of the statement should be equal in order for the next line of the orchestration to be triggered or a right arrow (→) sign to imply that sub section two is the outcome of the sub section one. The "2.2 Outcome" sub-section has the same structure as sub Section 2.1. Each statement in section two (2. Orchestration line statement) ends with a semi-colon (;). In addition to the sentence structure, Tables 5.4 and 5.5 provide a number of logical operators that can be used in the textual orchestration description language.

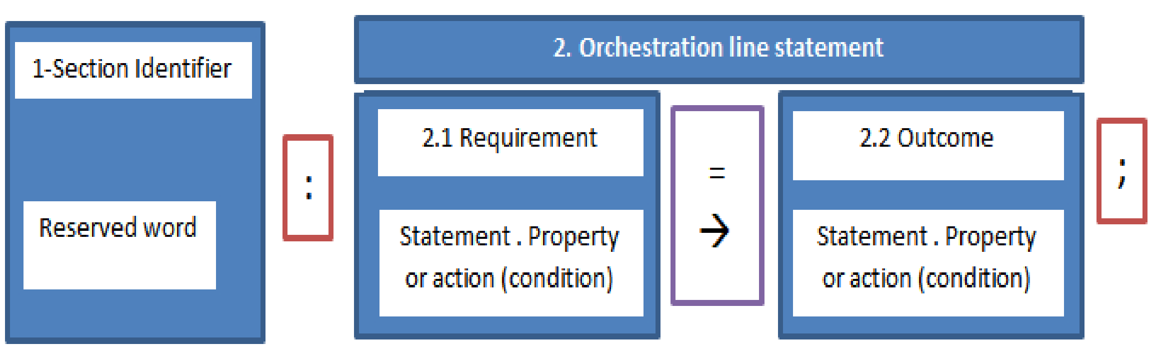


Figure 5.13:Sentence structure of the textual orchestration description language developed

Table 5.4: The developed Textual orchestration description language reserved words

No.	Reserved Word	Purpose
1	Invoke	Request to perform an action
2	Send	Transfer content of an interaction
3	Receive	Arrival of a request from requester
4	Reply	Transfer the content of a completed interaction
5	Wait	Wait while required conditions are not met for an action
6	Complete	An interaction is completed
7	Cancelled	An interaction is cancelled before reaching the planed end
8	Trigger	Initiate an interaction
9	True	A condition is met
10	False	A condition is not met
11	Empty	A request has no content
12	Expire	A request is out of date
13	If	Conditional statement

Table 5.5:Orchestration description language logical operators

No.	Logical operator	Purpose
1	|(OR)	Optional action
2	& (AND)	Parallel action
3	( )	Statement container
4	→ (Causal effect)	Results in
5	All mathematical symbols as it may be needed can be used.	

5.4.3 Orchestration Description Example

To illustrate the applicability of the orchestration language for healthcare virtual collaboration the following simple case study is described using the language.

A local software development company, a private healthcare company and a finance company in the city of Leeds-UK come together to form a HC-VBE called (Leeds-VBE) to provide the following services:

1- Facilitate HC-VO formation based on service requests.
2- Recruit participants (healthcare providers) for HC-VOs to provide the requested service.
3- Create SLA between participants for the services they agree to provide and receive.
4- Monitor the implementation of the SLA in terms of rating services, fines and rewards.
5- Disband HC-VOs and terminate SLAs after accomplishing set goals.
6- Archive required data and information for future use.

To show how Leeds-VBE can serve healthcare service requesters we consider the following simple scenario:

Mr. David is a 40 years old male who recently had a car accident and had an operation on his back after being injured in the accident. He spent two weeks in hospital after his operation and then dismissed and sent home. Due to the operation his movements are restricted and require care at home. He has asked Leeds-VBE to find a carer to take care of his domestic needs and a nurse to treat his operation wounds.

Mr. David has requested that the individuals recruited should fulfil the requirements specified in Table 5.6. It is now the job of Leeds-VBE to process the request and find the right participants based on Mr. David's requirement specification. Once all participants are recruited Leeds-VBE will from a HC-VO called *TreatWound* to implement and monitor the collaboration.

Table 5.6:Healthcare provider requirement specification requested by Mr. David

Participant	Service	Working hours	Availability (time)	Qualification	Distance (miles) from his home	Cost (per hour)
Carer	Treat wound	7am – 3 pm	7am – 5pm	High school	15 miles	£12
Nurse	Domestic house work	3pm – 6pm	24 hours	Qualified Nurse	10 miles	£30

To demonstrate the application of the HC-VBE-SODL, the *TreatWound* orchestration which is provided by a Nurse is described using the orchestration description language in Table 5.7 and each line of the orchestration is explained in Table 5.8.7

Table 5.7:(TreatWound) orchestration described using the Orchestration description language

Sections	Section Components	HC-VBE-Orchestration (TreatWound)
Orchestration Scope	MSLA, SLA	Master.ID = 2, SLA.ID = 5
Orchestration Attributes	ExpectedService:	TreatWound.Service = Master.SLA.Service;
	InitiatedBy:	Patient.Requester = Master.SLA.Requestor;
	ImplementedBy:	Nurse.Provider = Master.SLA.Provider;
	UnderCondition:	TreatWound.Duration = (StartDate= 01/2019 & EndDate = 03/2019); & TreatWound.Payment = £30/hr; & TreatWound.OCL(Frequency)= 1 per Day;
	Action:	TreatWound.Service = TreatWound.Receive;

Sections	Section Components	HC-VBE-Orchestration (TreatWound)
Orchestration Process		& TreatWound.StartDate = True;
	Call:	(TreatWound.Service = Ture) → invoke.Nurse;
	Answer:	(Nurse.Reply = Completed) → TreatWound.Payment = True; If TreatWound.Duration = ((StartDate= 01/2019 & EndDate = 03/2019)= True); & ((TreatWound.OCL(Frequency)= 1 per Day)=True); | (Nurse.Reply = Cancelled) → TreatWound.Payment = False; If TreatWound.Duration = ((StartDate= 01/2019 & EndDate = 03/2019)= False); & ((TreatWound.OCL(Frequency)= 1 per Day)=False);
	Influence:	(TreatWound.Payment = True) → SLA.Archive; | (TreatWound.Payment = False) → SLA.Archive;

Table 5.8: TreatWound Orchestration Explanation

HC-VBE Orchestration (TreatWound)	
1. Scope:	Master.ID = 2, SLA.ID = 5
<u>1. Explanation:</u> (Scope) represent the boundary in which the orchestration takes place. In this example the content of scope navigates to where exactly the orchestration information is obtained. In the statement, the content is obtained from service level agreement with identification number 5 which is administered by a master service level agreement with identification number 2.	

HC-VBE Orchestration (TreatWound)	
2. ExpectedService:	TreatWound.Service = Master.SLA.Service;
<u>2. Explanation:</u> (ExpectedService) represent the service that is agreed on to be provided. The statement indicates that the expected service is (TreatWound) of collaboration type (Service). This service is equal to the (Service) agreed on in the identified SLA which is navigated to by the statement (Master.SLA.Service).	
3. InitiatedBy:	Patient.Requester = Master.SLA.Requester;
<u>3. Explanation:</u> (InitiatedBy) represent the requester (human or device) that has requested the service agreed on in the SLA. The statement indicates that a (Patient) of participant type (Requester) has requested the service. For this orchestration to take place the requester is the same as the one declared in the SLA.	
3. ImplementedBy:	Nurse.Provider = Master.SLA.Provider;
<u>3.Explanation:</u> (ImplementedBy) represent the provider (human or device) that is going to take the responsibility to provide the service. In this example a (Nurse) of participant type (Provider) is going to provide the (TreatWound) service.	
4. UnderCondition:	TreatWound.Duration = (StartDate= 01/2017 & EndDate = 03/2017); & TreatWound.Payment = £30/hr; & TreatWound.OCL(Frequency)= 1 per Day;
<u>4. Explanation:</u> (UnderCondition) represent the conditions under which the service is implemented. The success of the orchestration process will be validated against the stated conditions. These are the conditions under which the two participants (Patient) and (Nurse) have agreed to collaborate. In	

HC-VBE Orchestration (TreatWound)	
this example the conditions are that the duration of the service is 2 months during which a visit is paid daily for which the nurse will be paid £30 per hour.	
5. Action:	TreatWound.Service = TreatWound.Receive; & TreatWound.StartDate = True;
<u>5. Explanation:</u> (Action) represent the activity that is going to take place in the orchestration. In this example the action is the (TreatWound) service. The action will start when it is received by the (process) part of the orchestration and the start date is valid.	
6. Call:	(TreatWound.Service = Ture) → invoke.Nurse;
<u>6. Explanation:</u> (Call) represent the start of the process. In this example when the action condition is true the participant of type (Nurse) is requested to start the action (TreatWound service in this case).	
7. Answer:	(Nurse.Reply = Completed) → TreatWound.Payment = True; If TreatWound.Duration = ((StartDate= 01/2017 & EndDate = 03/2017)= True); & ((TreatWound.OCL(Frequency)= 1 per Day)=True); |(Nurse.Reply = Cancelled) → TreatWound.Payment = False; If TreatWound.Duration = ((StartDate= 01/2017 & EndDate = 03/2017)= False); & ((TreatWound.OCL(Frequency)= 1 per Day)=False);
<u>7. Explanation:</u> (Answer) represent the result of the action. In this case if the Nurse returned the (Completed) message with all conditions observed, payment will be made otherwise payment will not be made.	

HC-VBE Orchestration (TreatWound)	
8. Influence:	(TreatWound.Payment = True) → SLA.Archive; | (TreatWound.Payment = False) → SLA.Archive;
8. Explanation: (Influence) represent the next orchestration that will be triggered to start. In this case the orchestration for the (Archive) service will be triggered.	

5.5 HC-VBE-M-F Evaluation Results

Framework implementation, testing methods, data collection and analysis process are already described in Section 4.3. In this section, system developers' acceptance evaluation results for the HC-VBE-M-F are presented and discussed. The results are produced using data collected during the survey, modelled and analysed using Structural Equation Modelling technique in AMOS software. The SEM model developed based on the HC-VBE-TAM-Provider is pictured in Figure 4.15 and described in Section 4.3.7.1.

5.5.1 Overall Analysis Results

This section provides the results for Mean, Standard Deviation, Factor loading, and Significance *p* value obtained as a result of analysing the collected data using the questionnaire designed based on the HC-VBE-M-F-TAM. The questionnaire used can be found in Appendix D. "Mean" is the average of all values given to an observed item by surveyed participants. The Mean results for the observed items are between 4.71 and 5.25 which indicate agreeability of participants with the measuring statements in the questionnaire. The result is significant and conveys that the concepts developed in the HC-VBE-M-F and demonstrated through the developed Java application prototype is acceptable by system developers.

Standard deviation measures the deviation of answers from the mean and the smaller the better. The standard deviation values are between 1.101 and 1.693 which indicates that the answers given by research participants were close to each other since the standard deviation values are not too large. This result shows that research participants view about the modelling tool were fairly consistent. This finding increases the credibility of the results and provides a good acceptability support for the modelling framework. The result of individual item factor loading indicates strong link between observed items and their unobserved variable with values between 0.768 and 0.942 which are all above the acceptable cut-off value 0.5 [241]. The factor loading results suggests the effectiveness of individual measurement items in measuring the unobserved acceptance factors in the extended TAM which subsequently increases measurement reliabilities.

To measure the significance of relations between the unobserved variables and their observed items, significance *p* value is computed for each construct. Significance test is necessary in SEM to ensure that the result is not produced by chance and it is widely accepted that a value is considered significant when ($p<0.05$) [205]. Significance computed values are indicated as *** in AMOS analysis results output which indicates that $p<0.001$. The result of all items is significant which suggests a high probability that the results are not produced by chance. Table 5.9 summarises the overall data analysis results for the modelling framework acceptability evaluation. The table shows statistical results for each questionnaire item within the context of their unobserved variables.

Table 5.9: Overall data analysis results for HC-VBE-TAM-Modelling framework which includes the Mean, Std., Factor loading and Significance value

Unobserved Variable	Observed Variable and its related questionnaire item	Mean	Std. Deviation	Factor Loading	*p* < 0.05 (Significance)
Perceived Ability to Model (PAM)	PAM1	4.79	1.500	0.925	$p<0.001$
	Models produced using the HC-VBE modelling package represents virtual collaboration in healthcare.				
	PAM2	4.82	1.541	0.837	$p<0.001$
	Models produced using the HC-VBE modelling package simplifies complex healthcare virtual collaboration scenarios.				

Unobserved Variable	Observed Variable and its related questionnaire item	Mean	Std. Deviation	Factor Loading	$p < 0.05$ (Significance)
	PAM3	4.96	1.598	0.917	p<0.001
	Models produced using the HC-VBE modelling package represent roles of virtual healthcare stakeholders.				
	PAM4	4.71	1.357	0.867	p<0.001
	Models produced using the HC-VBE modelling package describes the collaboration process between virtual healthcare stakeholders.				
Perceived Usefulness (PU)	PU1	4.96	1.374	0.879	p<0.001
	Using the HC-VBE modelling package improves my healthcare virtual system development process.				
	PU2	5.25	1.404	0.942	p<0.001
	Using the HC-VBE modelling package saves me effort and time to understand a healthcare virtual collaboration scenario.				
	PU3	4.86	1.297	0.812	p<0.001
	Using the HC-VBE modelling package would be more effective to use for modelling healthcare virtual collaboration systems than other modelling languages.				
	PU4	4.82	1.278	0.846	p<0.001
	Overall, I find the HC-VBE modelling package useful for modelling healthcare virtual collaboration systems.				
Perceived ease of use (PEU)	PEU1	4.96	1.478	0.902	p<0.001
	Learning to use HC-VBE modelling package would be easy for me.				

Unobserved Variable	Observed Variable and its related questionnaire item	Mean	Std. Deviation	Factor Loading	*p* < 0.05 (Significance)
	PEU2	4.79	1.101	0.858	*p*<0.001
	I would find it easy to model healthcare virtual collaboration systems using the HC-VBE modelling package.				
	PEU3	5.07	1.386	0.909	*p*<0.001
	It would be easy for me to become skilful at using the HC-VBE modelling package.				
	PEU4	5.07	1.585	0.942	*p*<0.001
	I would find the HC-VBE modelling package easy to use.				
Attitude towards using (AU)	AU1	5.14	1.693	0.950	*p*<0.001
	Using the HC-VBE modelling package would be a good idea.				
	AU2	4.89	1.257	0.895	*p*<0.001
	Using the HC-VBE modelling package makes modelling healthcare systems more interesting.				
	AU3	4.93	1.609	0.935	*p*<0.001
	Using the HC-VBE modelling package would be a pleasant experience.				
	AU4	4.82	1.219	0.871	*p*<0.001
	I would like to use the HC-VBE modelling package.				
Intention to use (IU)	IU1	4.86	0.970	0.848	*p*<0.001
	I intend to use the HC-VBE modelling package.				
	IU2	4.82	1.090	0.768	*p*<0.001
	It is likely that I will use the HC-VBE modelling package.				

Unobserved Variable	Observed Variable and its related questionnaire item	Mean	Std. Deviation	Factor Loading	*p* < 0.05 (Significance)
	IU3	4.82	0.983	0.888	*p*<0.001
	I expect to use the HC-VBE modelling package.				
	IU4	5.00	1.361	0.866	*p*<0.001
	I am willing to recommend other people to use the HC-VBE modelling package.				

5.5.2 Intermeasurement Correlation

Intermeasurement correlation shows the link between all observed items, Table 5.10 shows the analysis result of intermeasurement correlations for the questionnaire items examining the HC-VBE-M-F-TAM. There are 20 measurement items in the questionnaire. Each questionnaire item is correlated to all other questionnaire items in a questionnaire including itself. A perfect correlation value which is 1, is produced when a questionnaire item is correlated with itself perfectly, but the values would be less than 1 in all other cases.

The intermeasurement results for all questionnaire item in this case are between 0.4 and 0.9 which are above the 0.3 acceptable cut off point. The results prove that the scores given to all items as answers are closely related. This means that research participants shared similar opinions on measurement items and they were all positive. Intermeasurement values provide a detail map of the scores given to individual items in a questionnaire. If the majority of correlation values are above 0.3 that indicates that the questionnaire items have adequately captured users view of the technology being tested in this context.

Table 5.10: HC-VBE-TAM-Modelling framework intermeasurement correlations

	PAM1	PAM2	PAM3	PAM4	PU1	PU2	PU3	PU4	PEU1	PEU2	PEU3	PEU4	AU1	AU2	AU3	AU4	IU1	IU2	IU3	IU4
PAM1	1.00																			
PAM2	0.78	1.00																		
PAM3	0.85	0.75	1.00																	
PAM4	0.84	0.68	0.78	1.00																
PU1	0.79	0.80	0.74	0.73	1.00															
PU2	0.84	0.72	0.90	0.78	0.83	1.00														
PU3	0.69	0.71	0.64	0.69	0.81	0.75	1.00													
PU4	0.77	0.77	0.74	0.78	0.76	0.77	0.72	1.00												
PEU1	0.72	0.78	0.80	0.64	0.71	0.83	0.75	0.76	1.00											
PEU2	0.82	0.68	0.82	0.73	0.68	0.83	0.63	0.74	0.79	1.00										
PEU3	0.77	0.73	0.79	0.74	0.64	0.71	0.67	0.68	0.82	0.69	1.00									
PEU4	0.75	0.73	0.76	0.72	0.70	0.79	0.71	0.70	0.84	0.79	0.91	1.00								
AU1	0.87	0.78	0.85	0.81	0.78	0.86	0.72	0.75	0.77	0.83	0.78	0.81	1.00							
AU2	0.79	0.66	0.74	0.74	0.77	0.88	0.72	0.77	0.76	0.81	0.64	0.78	0.86	1.00						
AU3	0.76	0.71	0.82	0.80	0.74	0.84	0.76	0.77	0.81	0.77	0.78	0.83	0.87	0.84	1.00					
AU4	0.79	0.59	0.80	0.68	0.70	0.83	0.62	0.60	0.67	0.83	0.62	0.70	0.87	0.78	0.79	1.00				
IU1	0.74	0.68	0.78	0.70	0.61	0.71	0.57	0.73	0.75	0.77	0.67	0.68	0.80	0.72	0.80	0.73	1.00			
IU2	0.63	0.60	0.65	0.59	0.56	0.61	0.40	0.53	0.59	0.65	0.52	0.56	0.68	0.61	0.71	0.70	0.67	1.00		
IU3	0.75	0.71	0.80	0.63	0.71	0.78	0.62	0.65	0.79	0.75	0.69	0.70	0.82	0.73	0.83	0.81	0.75	0.73	1.00	
IU4	0.76	0.78	0.80	0.70	0.75	0.78	0.69	0.75	0.85	0.67	0.79	0.77	0.79	0.76	0.85	0.65	0.70	0.70	0.75	1.00

5.5.3 Characteristics of Constructs

At construct level, the result supports strong acceptability for the concepts developed in the HC-VBE-M-F. The mean value for each construct variable computed as an average for all observed item answers for a particular construct is close to 5 with standard deviations between 0.978 and 1.371. Table 5.11 shows the result for all constructs tested, the number of observed items per construct, means and standard deviation computed for the 28 samples. The significance of means and standard deviations results on the acceptability evaluation has already been explained in Section 4.3.8. The result suggests that on construct level the survey participants' acceptance attitude towards the modelling framework were positive since the values are close to 5, which equals to "Agree" in Likert-Style measures. The result also suggests that on construct level the answers were similar since the standard deviation values are not too large.

Table 5.11: Statistical results for HC-VBE-M-F-TAM construct characteristics

Construct statistics				
Constructs	**Observed Items**	**Mean**	**Std. Deviation**	**N**
Perceived Ability to Model (PAM)	4	4.821	1.371	28
Perceived Usefulness (PU)	4	4.973	1.220	28
Perceived Ease of Use (PEU)	4	4.973	1.288	28
Attitude Towards Using (AU)	4	4.946	1.356	28
Intention to Use (IU)	4	4.875	0.978	28

5.5.4 Data Validity and Reliability

In survey research, one indicator of measurement validity and reliability is internal consistency reliability of items in a questionnaire; valid and reliable measurement should produce high consistency of answers between items measuring the same construct. To ensure measurement validity and reliability, internal consistency reliability is computed for the collected data based on three most used statistical validity and reliability calculation methods which are Cronbach's Alpha [210], Construct Reliability (*CR*) and Average Variance Extracted (*AVE*) [208].

The acceptable value for *AVE* is 0.5 or above and the value computed for all constructs in this part of the study are above the cut off value ranging from 0.712 to 0.834. These results suggest that the amount of variance produced as a result of correct data collected for each construct is much higher than the amount of variance which may have been produced as a result of errors in the data collected. The suggestion supports strong data reliability which is vital for validating the technology acceptance claims made with regard to the modelling framework developed in this thesis.

CR acceptable value is 0.7 or above, the result for all constructs are above the value starting from 0.908. The acceptable value for Cronbach's Alpha is 0.7 again the result for all constructs are above the value starting at 0.902 and the overall test value is 0.982. These results suggest strong data validity and reliability which supports the conclusions reached for the *AVE* results. Kaiser-Meyer-Olkin Measure has been computed to ensure sampling adequacy and the result is 0.885 which indicates that the sample used in the study is adequate as values above 8 is considered acceptable [242]. The adequacy of the sample data is important to be proven statistically which in turn increases the findings made as result of analysing the sample data.

The Individual construct factor loading indicate strong connections between the construct and its measured questionnaire item as all values are above 0.9 which is much higher than the 0.5 acceptable value. The correlations between the constructs in the model as values start with the correlation between IU and PU being the lowest (0.814) which is much higher than the 0.3 acceptable value. The strong correlation between the constructs supports the validity of the model which in turn support the empirical conclusions made with regard to the acceptability of the modelling framework. Table 5.12 shows the summary of results obtained for collected data reliability and validity.

Table 5.12: HC-VBE-M-F-TAM data reliability and validity results

Constructs	AVE >0.5	CR>0.7	Cronbach's Alpha> *0.7*	Factor Loading	PAM	PU	PEU	AU	IU	Whole Cronbach's Alpha> *0.7*	Kaiser-Meyer-Olkin Measure of Sampling Adequacy
Perceived Ability to Model (PAM)	0.787	0.937	0.933	0.949	1					0.982	0.885
Perceived Usefulness (PU)	0.759	0.926	0.931	0.945	0.908	1					
Perceived Ease of Use (PEU)	0.816	0.947	0.940	0.931	0.882	0.853	1				
Attitude Towards Using (AU)	0.834	0.953	0.947	0.956	0.895	0.889	0.879	1			
Intention to Use (IU)	0.712	0.908	0.902	0.945	0.876	0.814	0.852	0.902	1		

5.5.5 Model Fit Indices

Model fit indices are calculated to find out whether the model used fits the data and it is acceptable. As explained in Section 4.3.8.10 that many fit indices have been suggested by researchers but the most recommend ones are Chi Square (CMIN in AMOS), CFI, TLI, IFI, RMSEA and SRMR [214][215][213]. Based on the recommendations, Table 5.13 summarises the model fit indices computed in AMOS for the HC-VBE-M-F-TAM.

The computed Chi Square value for the model is 1.318 which is within the recommend value of 1-3. Chi Square is a measure of badness of fit, a value that is not significant

(p>0.05) indicates that the model is acceptable. This means that the covariance matrix calculated based on the collected data is similar to the predicted covariance matrix by the model. In this case, the Chi Square value suggest that the model designed to test the acceptability of the framework is acceptable and is fit for the intended purpose. CFI compares the fit value of the model with a fit value of a base model (alternative model) with value closer to 1 indicates an acceptable fit. The CFI value computed is 0.925 which has exceeded the recommended 0.90 cut of value and hence indicates a good fit. These results suggest that the model used to test the acceptability of the framework is closer to ideal, hence indicate the fitness of the model.

TLI and IFI are both comparative fit indices similar to CFI with computed values of 0.913 and 0.928 respectively. They both support the claim that the model fit is acceptable since the values are above the 0.9 cut off value. RMSEA calculates the difference between covariance matrix value for the same observed item in both the tested and predicted model. The recommended value is 0.08 or smaller, the value computed for the HC-VBE-M-F-TAM is 0.108 which is slightly bigger (0.0208 difference), however since all other fit measures are within the acceptable cut off values, this can be overlooked and be considered as acceptable.

SRMR is the final fit value computed which measures the standardised difference between predicted and observed covariance matrix with a recommended value of 0.08 or smaller. The computed SRMR value for the HC-VBE-M-F-TAM is 0.048 which is smaller than 0.08 and suggests a good model fit. The model fit values collectively support the fitness of the model to test the acceptability of the framework by prospective users and the results produced from it can be relied on.

All the results so for far presented were computed to show whether the results produced in testing the hypothesises are statistically sound or not. Collectively the results suggest the hypothesis results are statistically sound. The results of the hypotheses testing are presented in the next section.

Table 5.13: HC-VBE-M-F-TAM fit results

Overall fit index	**Description**	**Computed Value**	**Recommended Value**
CMIN/DF	Chi Square/ Degree of Freedom	1.318	Between 1 and 3
CFI	Comparative fit index (baseline comparison)	0.925	CFI ≥ 0.90
TLI	Tucker Lewis Index (baseline comparison)	0.913	TLI ≥ 0.90
IFI	Incremental fit index (base line compression)	0.928	IFI ≥ 0.90
RMSEA	Root Mean Square Error of Approximation (Absolute fit indices)	0.108	RMSEA ≤ 0.08
SRMR	(Standardized) Root Mean Square Residual	0.048	SRMR ≤ 0.08

5.6 HC-VBE-M-F Discussions

This section discusses the results obtained for this part of the evaluation with regard to the two research questions stated in Chapter 1. The questions focus on the modelling aspect of healthcare virtual collaboration and the extent to which the research questions have been answered is examined.

RQ1: How to classify the main stakeholders in virtual collaboration for healthcare?

To be able to model healthcare virtual collaboration the first step is to develop a generic classification model for the roles and services in the sector. With this in mind and to answer the research question, an in-depth literature search was conducted to understand healthcare in terms of stakeholders and services. The challenge was to deduce a generic classification mechanism that is applicable to all possible scenarios of healthcare virtual collaboration. Healthcare is a broad and complex sector which is quite difficult to carry out a holistic analysis for in terms of roles and services. To guide the research, VBE and VO concepts are used as a theoretical base and as a result, a generic virtual collaboration role and service classification mechanism which is called Service and Participant Classification Mechanism (SPCM) is developed and described in Section 5.2. The mechanism classifies services and participants for a given virtual collaboration scenario at an abstract level. The mechanism is simple and can be applied to any healthcare virtual collaboration scenario to classify the roles and service. The applicability of the mechanism is demonstrated with a simple healthcare virtual collaboration example in Section 5.2.1. The evaluation results show that the mechanism is seen by system developers as acceptable for classifying roles and service in healthcare. This result is significant and important since the rest of the concepts developed in this thesis are based on the SPCM.

RQ2: How to model and describe service provision for healthcare virtual collaboration?

The research outcome obtained in the process of answering RQ1 served the based to answer RQ2, which led to developing a DSML for healthcare virtual collaboration. In Section 5.3 a modelling language which is called HC-VBE-DSML is developed and described. The language enables healthcare virtual collaboration system developers to model a scenario in terms of roles and services. The modelling language serves as a generic tool that provides graphical notations specific to certain roles and services as well as a collaboration orchestration mechanism for healthcare, based on VBE and VO concepts. The graphical notations are packaged in a DSML which is developed based on UML use case diagram. The DSML is developed with the aim to be simple, easy to learn and comprehensive in representation. With regard to the service description part of RQ2 a Service Orchestration Description language is developed. The language is text-based which can be used by system developers to describe service provision in a given healthcare virtual collaboration scenario. The orchestration is mapped to BPEL4People for implementation purposes in the future.

To evaluate the modelling approach for healthcare virtual collaboration the modelling language was implemented as a Java application and the application was evaluated for user acceptance using TAM as a theoretical evaluation framework. TAM is adapted through extending it for this part of the study, a detail description for the extension process is provided in Section 4.3.2. Based on the HC-VBE-M-F-TAM seven hypotheses were defined in Section 4.3.2.1. The result of testing those hypotheses based on the data analysis carried out in AMOS show that H_1 with a significance value of less than 0.05 is accepted; which means PAM has a significant effect on PU. The result provides empirical proof that research participants believe that the modelling framework is capable of modelling virtual collaboration in healthcare domain (indicated by *p*-value for PAM construct in Table 5.14) and this will influence its usefulness. The *p*-value for the causal effect of PAM on PEU hypothesised in H_2 is 0.001 which is less than 0.05. This means that H_2 is accepted and PAM has a positive effect on PEU. The interpretation of this result is that research participants believe PAM of the modelling framework will contribute to its PEU.

H_3a which hypothesises the causal effect of PEU on PU is rejected with a *p*-value of 0.927. This leads to the conclusion that the research participants didn't believe that PEU will have a causal effect on PU. A possible reason for this finding could be the fact that the modelling framework is based on UML use case which is considered easy to use and useful, not one causing the other. This explanation could also be applied to H_3b which is rejected with a *p*-value of 0.116 which hypothesises the causal effect of PEU on AU. The result indicates that research participants didn't believe that PEU of the modelling framework changes their AU as they have already indicated their intention to use, shown by the result of IU construct with a mean value close to 5 (Table 5.3 in Section 5.5.3).

The causal effect of PU on AU hypothesised by H_4a is accepted with a *p*-value of 0.001 which indicates that since the research participants found the modelling framework useful, they also think of using it and the usefulness factors will influence their AU. This finding contradicts the result of H_4b which hypothesises the causal effect of PU on IU and it is rejected with a *p*-value of 0.646. According to this result PU will not lead to IU. Having said that, the evaluation results show that research participants intend to use the modelling framework as the mean value of IU is close to 5 (Table 5.3 in Section 5.5.3) and H_5 which hypothesises the causal effect of AU on IU is accepted with a *p*-value of 0.015. Overall, these results show that the surveyed participants were positive about the contribution that the HC-VBE-M-F makes towards modelling the structural and aspect of VBE and VO based virtual collaboration in healthcare. Table 5.14 summarises the hypotheses test results and the bold lines in Figure 5.14 illustrates the accepted paths (hypotheses) in the HC-VBE-M-F-TAM.

Table 5.14: HC-VBE-M-F-TAM hypotheses testing results

Hypos.	**Evaluated Causal Effect**			**Sig.Level at $p<0.05$**	**Acceptance**
H_1	Perceived Usefulness (PU)	<---	Perceived Ability to Model (PAM)	$p<0.001$	Accepted
H_2	Perceived Ease of Use (PEU)	<---	Perceived Ability to Model (PAM)	0.001	Accepted
H_3a	Perceived Usefulness (PU)	<---	Perceived Ease of Use (PEU)	0.927	Not Accepted
H_3b	Attitude Towards Using (AU)	<---	Perceived Ease of Use (PEU)	0.116	Not Accepted
H_4a	Attitude Towards Using (AU)	<---	Perceived Usefulness (PU)	0.001	Accepted
H_4b	Intention to Use (IU)	<---	Perceived Usefulness (PU)	0.646	Not Accepted
H5	Intention to Use (IU)	<---	Attitude Towards Using (AU)	0.015	Accepted

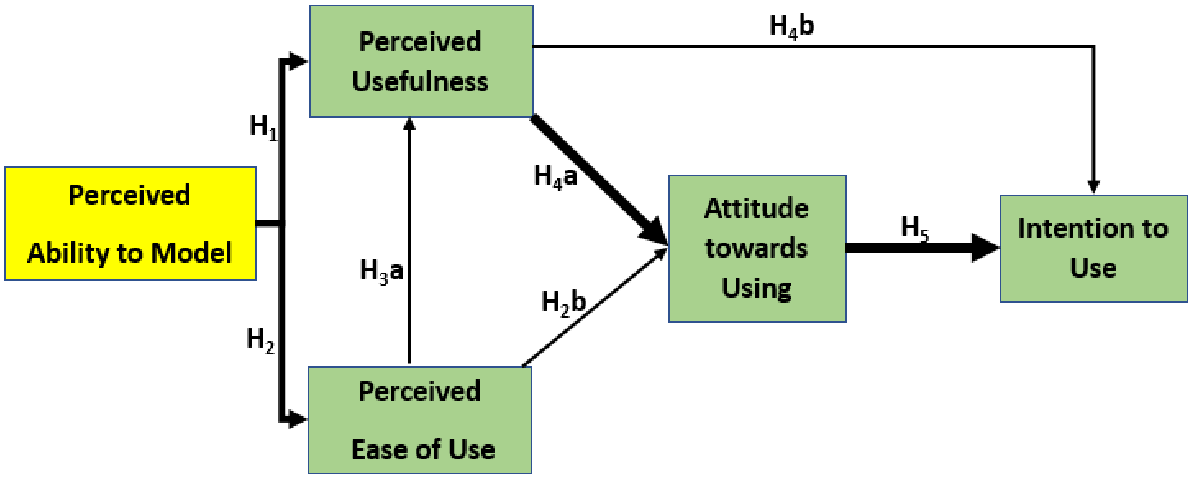


Figure 5.14: HC-VBE-TAM-M-F accepted hypotheses

5.6.1 The HC-VBE-M-F Limitations

The HC-VBE-M-F is developed with the aim to be simple, generic and capable to model all VBE and VO based healthcare virtual collaboration scenarios. The structural aspect of the model which is based on UML use case diagram provides a set of simple notations to model roles and functions in healthcare virtual collaboration, however there are several important system feature that requires to be accommodated in a model such as system performance, availability, security which cannot be modelled using the developed modelling language. The process aspect of the model which is developed as an orchestration description language can describe possible steps in a given healthcare virtual collaboration service statically, however, it lacks a formal simulation or validation procedure to evaluate the correctness of processes described.

5.7 Chapter 5 Summary

This chapter presented the Healthcare Virtual Collaboration Modelling Framework (HC-VBE-M-F) and the concepts and mechanisms that make up the framework are explained in detail. The content of the chapter is summarised in the following points:

1- In order to understand the healthcare sector, a detail map of the roles and services of the sector is deduced from literatures available on major research data-bases such as

Springer and Elsevier. In total 6 classes of roles and services are identified which are care providers, executives, consumers, care environments, electronic devices and healthcare services. The identified roles and services are used as a base to develop a participant and service classification mechanism.

2- A Service and Participant Classification Mechanism (SPCM) is developed that classifies healthcare virtual collaboration participants and services. The mechanism uses the VBE and VO concepts as a guide for the classification. On VBE level, healthcare virtual collaboration participants and services are classified into *Organiser*, *Support* and *Task*. On VO level the participants and service are classified into *Provider*, *Requester* and *Service.* The mechanism is generic and can be used to classify participants and service of all VBE-based healthcare virtual collaboration.

3- A domain specific modelling language based on UML use case diagram graphical notations is developed to model the roles and services identified by the SPCM. To develop the modelling language, UML profiling technique is used to extend the notations. The actor notation (stickman notation) is extended four times with different head shapes to represent the four identified participants (*Organiser*, *Support, Provider* and *Requester)*. The use case oval shape of UML is extended twice to represent *Task* and *Service*.

4- A Service Orchestration Mechanism (SOM) is developed to describe the processing flow of a healthcare virtual collaboration service. The mechanism includes an orchestration description language that uses structed sentences to describe the steps in a given service.

5- The evaluation results show that the framework is acceptable by system developers participated in the survey and their intension to use systems developed based on the modelling framework is positive.

In the next chapter, a healthcare virtual collaboration framework is presented which is developed based on the modelling framework presented in this chapter.

Chapter 6 : Collaboration Framework

This chapter presents a healthcare virtual collaboration framework that has been developed based on the modelling framework in Chapter 5. The framework is comprised of a conceptual description presented in Sections 6.1 and 6.2 with aim to manage and organise virtual collaborations for healthcare. A member selection mechanism is described in Section 6.3, a healthcare provider validation mechanism is described in Section 6.4 and a set of service level agreements (SLA) templates that formalises the agreements between collaborating participants are described in Section 6.5. The results and findings of the user acceptance evaluation for the framework which is implemented as a mobile application are presented and discussed in Section 6.7. Finally, a summary of the chapter is provided in Section 6.8.

6.1 Healthcare Virtual Collaboration Framework

The current centralised model of healthcare provision cannot deal with today's healthcare challenges such as the rise in demand and increased cost of care [9]. Moving the healthcare sector towards a multi-provider model where a number of individuals and organisations collaborate together to provide services are seen as the future of healthcare [14][15][16]. In this section, the author presents and describes a virtual collaboration framework for healthcare which is called Healthcare Virtual Breeding Environment Framework (HC-VBE-F) developed based on the role and service concepts developed in the modelling framework in Chapter 5. The aim of the framework is to facilitate and organise virtual collaboration and resource sharing for healthcare. Figure 6.1 shows the framework components which are a conceptual framework, a member selection mechanism, a healthcare provider validation and verification framework and a set of SLA templates.

This chapter aims to answer the remaining research questions as listed below:

1- How to manage and organise virtual collaboration for healthcare?

2- How to select, verify and validate participants for healthcare virtual collaboration.

3- How to regulate virtual collaboration for healthcare?

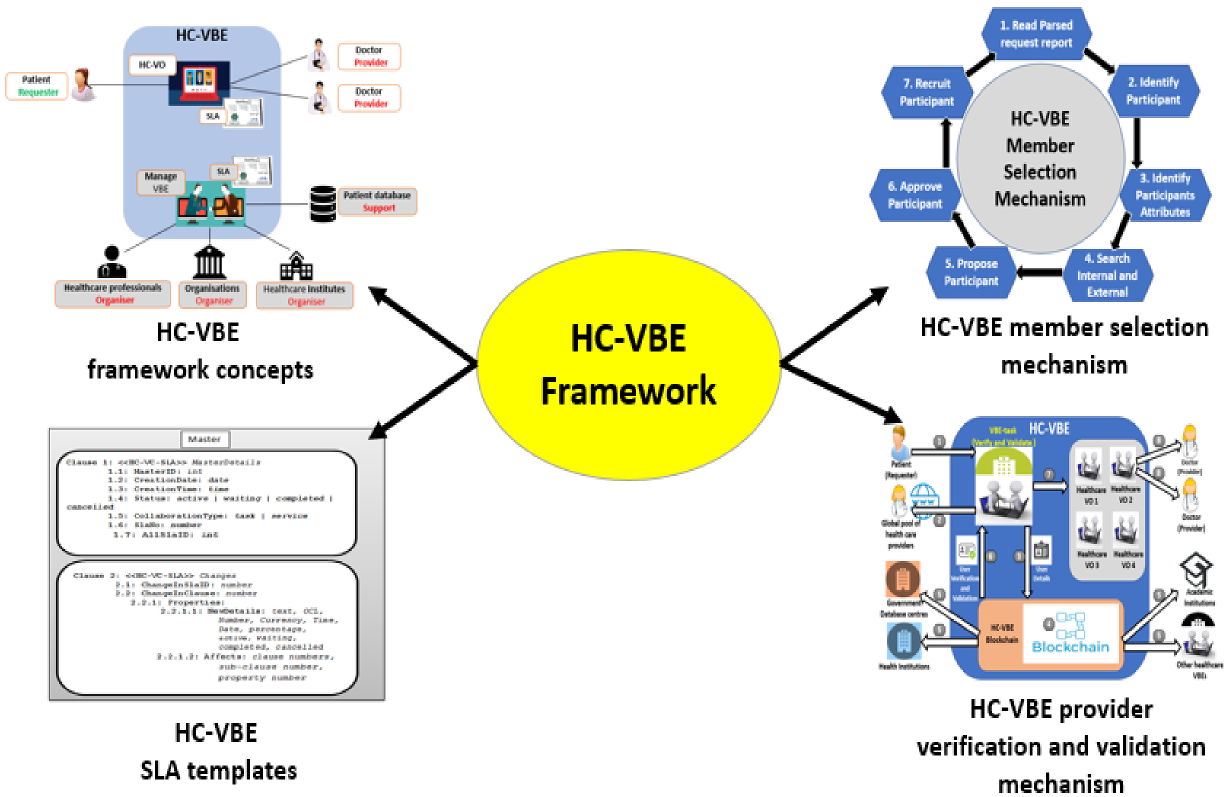


Figure 6.1: Components of the healthcare virtual collaboration framework which consist of a conceptual framework, a member selection mechanism, a provider validation and verification mechanism and SLA templates.

6.2 The HC-VBE Framework Description

The theoretical base of the framework is drawn from two well-researched virtual collaboration concepts which are VBE and VO [27] [31] [32]. The concepts originally developed for the world of business to address collaboration management and regulation challenges in virtual settings and recently they have been considered for application in education, e-commerce and teleworking [46] [47]. In healthcare, the concepts have been researched for specific healthcare services, for example, VO concept is considered in a TeleCare pilot-study for collaboration and patient record sharing between stroke specialists in The Netherlands [243] . The researchers describe VO but they fall short in providing a working framework and they have not explained how the concept of VO is utilised in their approach. The authors of [244] explain a virtual hospital project in Finland in which VO is used as theoretical base for virtual collaboration in a hospital without presenting the workflow and management process for the collaboration.

As a solution to provide a type of mental healthcare which is not bound to physical structures in hospitals, the authors in [245] suggest the use of VO but similarly they don't provide any clarity as to how the concept is going to be used to provide the virtual care. To create a platform for radiologist to collaborate and share medical images and other resources a MammoGrid Virtual Organisation is suggested by [246]. They describe a number of functionalities of the VO on technical level without explaining the processing steps that the VO implements in organising the collaboration and resource sharing. These studies focus on a specific aspect of healthcare and none provide a comprehensive framework for healthcare collaboration and resource sharing in a virtual organisation setting.

There is clearly a gap in researches carried out on the use of VBE and VO concepts in healthcare as the studies cited are the only ones managed to be found and they are more than 13 years old. To contribute to the body of literature and fill in the gaps identified in the use of VBE and VO in healthcare, a comprehensive framework is presented in the next few sections. The framework is described on conceptual level, component level and process level as shown in Figure 6.2. On conceptual level, the figure shows the general architecture in terms of roles and services. On component level, the figure shows the main components that make up the framework which will be explained in detail in terms of component functionalities and groupings in later sections. Finally, on process level, the figure shows a flowchart like diagram which describes how the framework works to organise and facilitate virtual collaboration for healthcare.

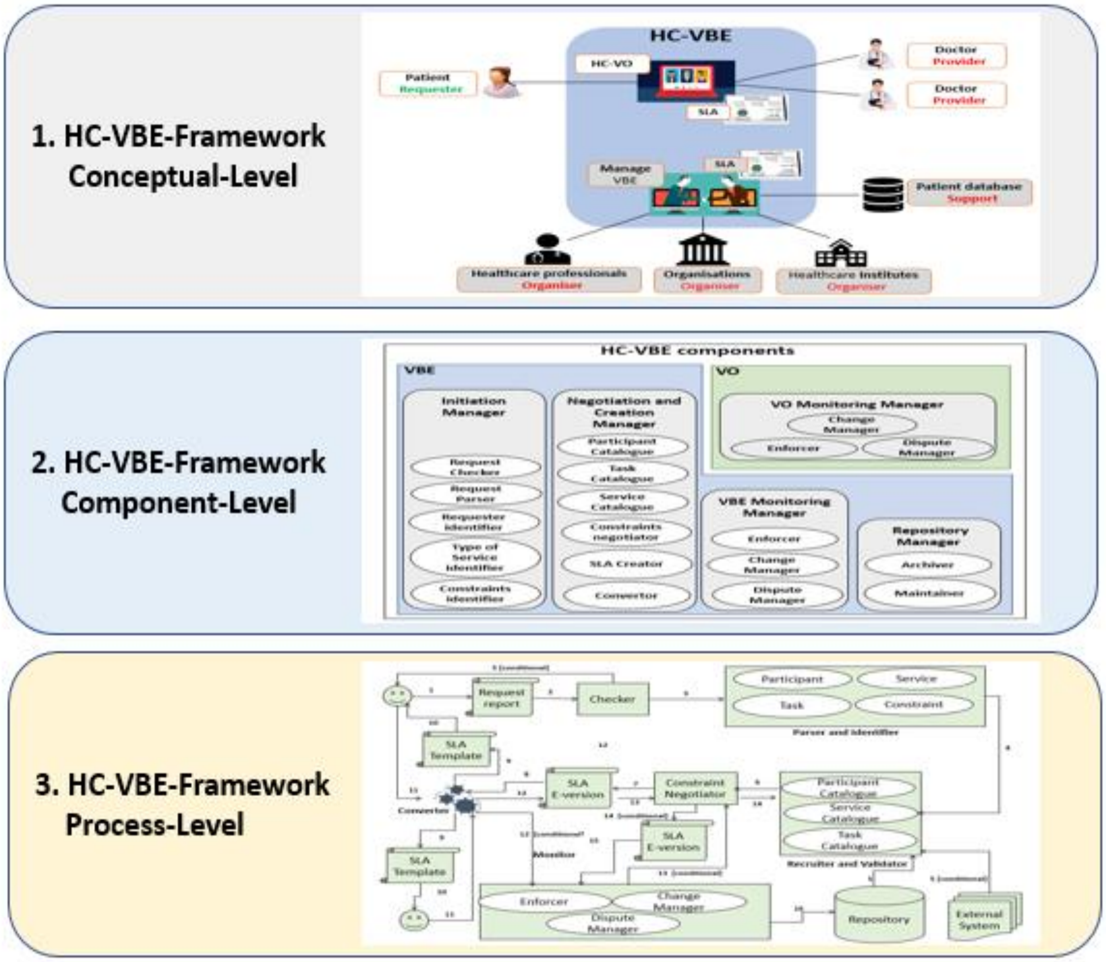


Figure 6.2: Illustrating the HC-VBE-F description on conceptual, component and process levels

6.2.1 The HC-VBE Framework Concept

Healthcare has a dynamic nature in which the duration of care and the required resources are varied from one case to another [247]. The dynamicity of care provision is even more prominent in virtual healthcare since collaboration and resource sharing requires real-time synchronisations and managements. Therefore, a framework to facilitate the management and coordination aspects of healthcare virtual collaboration becomes essential. The framework developed here aims to facilitate the creation of virtual environments where healthcare professionals, health institutions and other organisations, supported by ICT infrastructures, can come together to provide healthcare services. The framework also facilitates the management of healthcare collaboration on both HC-VBE and HC-VO levels. A single HC-VBE can create many HC-VOs based on requests for healthcare services send to the HC-VBE by requesters. The HC-VBE facilitates parallel but sperate running of created HC-VOs. Electronic Service Level Agreement (SLA) serves the base for the terms and conditions under which each HC-VO is created. SLAs are agreed between requesters and providers prior to creation of the HC-VO for a particular request. In virtual environments, SLA is a widely accepted mechanism to regulate collaborations and resource sharing.

One of the advantages of employing SLA is guaranteeing a trustful relationship between collaborating parties. In virtual organization, members are recruited and discharged as per task requirements, therefore, it is possible that many of the members collaborate with each other for the first time. A major part of healthcare services depend on trust as it provides psychological comfort to service providers and consumers [138]. It is in human nature to be cautious about trusting someone you meet or work with for the first time; this is even more difficult in virtual settings as collaborating members don't meet each other face to face. The concerns can be addressed in an understandable and enforceable SLA [248]. SLA can also formalise service expectations as claimed by [249].

In a virtual setting where unidentified number of participants are online to provide a service, it is always a challenge to select the right one for the services requested. With this challenge in mind, in Section 6.3, a member selection mechanism is presented which is an important part of the HC-VBE framework. The framework makes use of SLA templates generated based on healthcare service requests send to the HC-VBE, and selects the right participant based on a number of criteria such as qualification and reputation. Once the right participant is identified and selected from a pool of providers, verifying and validating the credentials of the selected participant presents another challenge that has to be addressed. To address the challenge, in Section 6.4 a virtual healthcare provider verification and validation framework that uses blockchain technology is presented.

Figure 6.3 shows the overall infrastructure of the framework. In the diagram, *Requesters* appear on the left of the system boundary, *Providers* appear on the right, O*rganisers* who manage the VBE appear on top and *Support* appears at the bottom of the system boundary. Participants and resources join force under independently managed entities which is called *Service* in the case of short goal-based collaboration and *Task* in the case of long-term management-oriented collaboration. All participants are bound by SLAs approved by participants in a given collaboration settings. Before explaining the components, which make up the framework, it has to be noted that the framework is designed under the assumptions that:

1. Human participants have the necessary competence to use computers and smart devices.
2. The internet and local networks are the mediums facilitating the communications between participants.
3. Expected healthcare services are the ones which are virtually achievable such as consultation services.

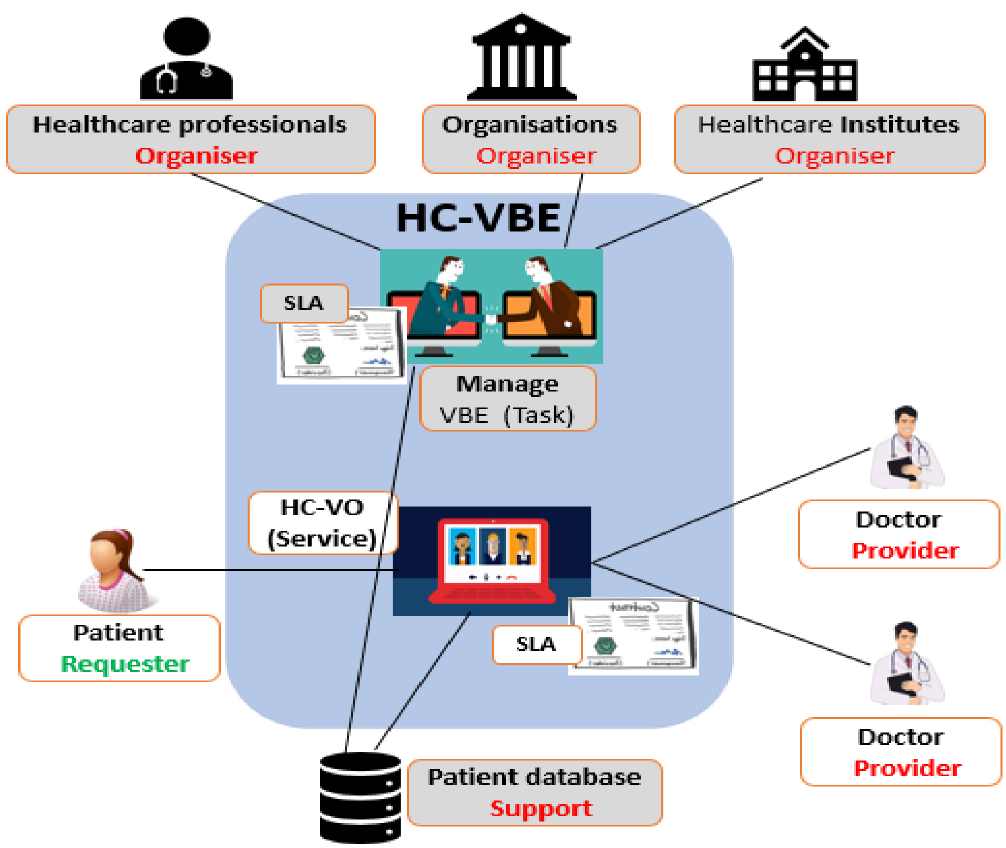


Figure 6.3: The HC-VBE framework general structure that shows the classification of collaborating participants and HC-VBE and HC-VO created based on SLA

6.2.2 Framework Component Description

HC-VBE and HC-VO participants in the framework can be human or electronic devices collaborating and sharing resources through communication technologies [27]. In designing the framework, the SPCM described in Section 5.2 and published in [250] is used. In this section, each of the components of the framework which is shown in Figure 6.4 are described.

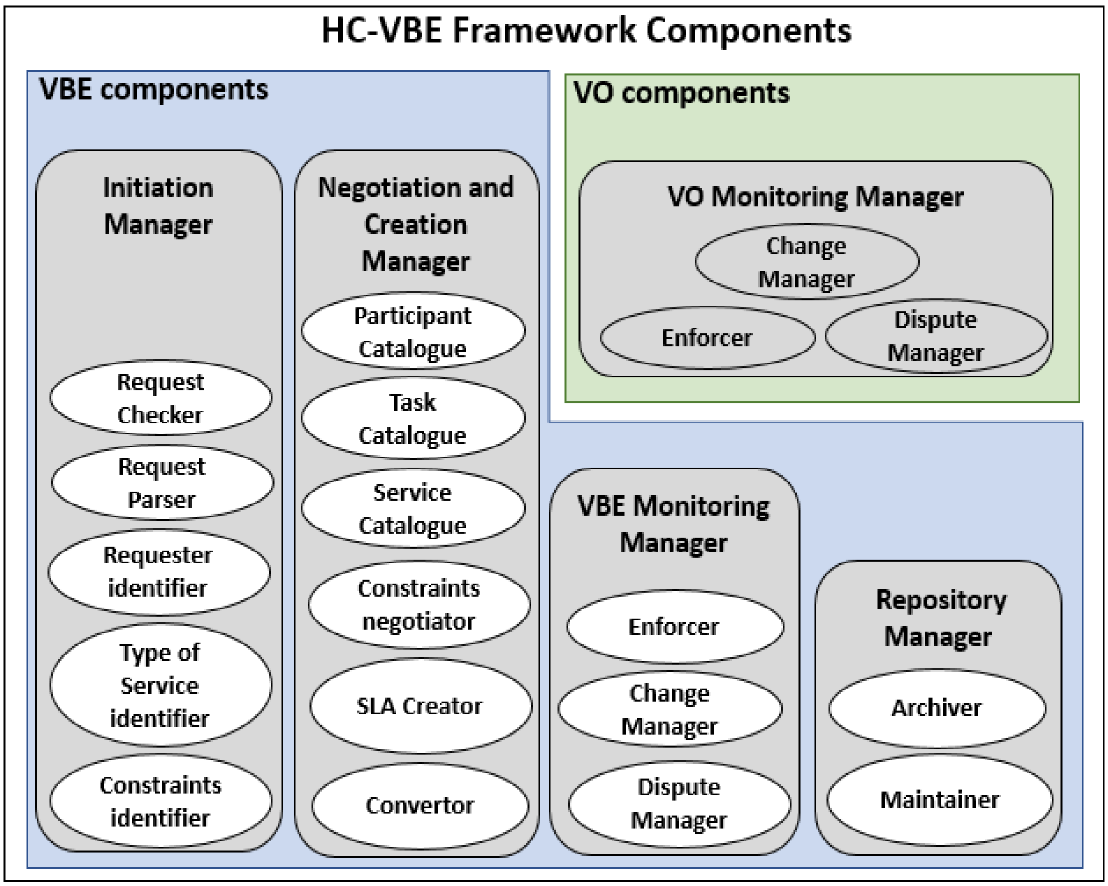


Figure 6.4: HC-VBE components grouped in 5 groups (Initiation Manger, Negotiation and Creation Manager, VBE Monitoring Manager, Repository Manager and VO Monitoring Manager)

6.2.2.1 VBE Initiation Manager

The component manages healthcare requests sent by participants (e.g. patients) to the HC-VBE for a service (e.g. regular heart rate check) and has five use cases as defined below. A service request could be a simple function triggered by a registered *Requester* or *Organiser* or a detailed request for a service [250]. In both cases, the HC-VBE generates a request report. The report contains the necessary information for creating an SLA and makes it available to the *Request Checker* use case for processing.

- **Request checker**

It analyses the request report sent by the HC-VBE and carries out the following checks:

1- Validity check: Checks the validity of the following attributes:

a- Date of the request.

b- Time of the request.

c- Requester details such as ID and attributes.

d- Requested service description, by checking that the necessary information is provided in specified fields of the request report.

2- Scope check: It is carried out to ensure that the service requested is within the scope of the HC-VBE. The check mechanism was not intended to be specified here but it can be for example by searching for keywords in the service description attributes of the request report.

3- Completeness check: Checks the availability of the required data to trigger an SLA creation process.

- **Request parser**

The function of this use case is to parse the content of the *request report* into internal conceptual representation which is the classification of roles and services as per the SPCM [250].

- **Requester identifier**

Once the parsed request report is made available, this use case identifies the requesters of the service by searching for the followings:

a- Name and ID of participants

b- Role types of the requester (Requester or Organiser)

- **Type of service identifier**

The function of this use case is to identify the requested service type in the request report. To do so, it searches through the parsed report to identify if the request report is for a *Service* or *Task*. If it is not specified in the report then the use case searches for indications to decide what is the request for, and it uses a number of indications to make the decision:

a- To decide the request is for *Service*, information generated by the *Requester identifier* use case is used. If the request is made by a participant with role type *Requester* then the use case decides that the requested service is of type *Service*, this is because *Requester* can only request a *Service* formation [250].

b- To decide the request is for *Task*, it uses the information generated by the *Requester identifier* use case. If the request is made by participant with role type *Organiser* then the use case decides that the request service is of type *Task*, this is because *Organiser* can only request a *Task* formation [250].

- **Constraint identifier**

Constraints play a vital role in specifying meticulous details of an SLA such as duration of service, quality of service, rewards, and penalties. The use case checks for constraints in the request report and make it available to the *Constraint negotiator* use case described later in this section. Since SLA contains terms to be fulfilled by each participant, a constraint-based mechanism is necessary to regulate the terms; for this, Object Constraint Language (OCL) can be used following the footsteps of others such as [85] and [141] and also for the following reasons:

1- It has become the default language for expressing specification requirements [251]. It is flexible and facilitates future extensions as separate OCL expressions can be written for each parameter based on the purpose of the parameter [85].

2- It is a general purpose and text-based specification language which requires a low learning curve. A text-based human readable SLA can be an effective way to speed up the negotiation process required for VO formation. Such mechanism can be implemented and provided as a negotiation tool to human participants; such tool has already been considered and implemented by other researchers [252].

3- OCL-based constraint can be converted to Web Ontology Language (OWL) which is machine readable and helpful during framework implementation, as claimed by authors of [253]. The authors provide a direct mapping between OCL and OWL which is pictured in Figure 6.5. The mapping is done between specific OCL expression and OWL tags, for instance, OCL *context* is mapped to <sch:pattern id> tag.

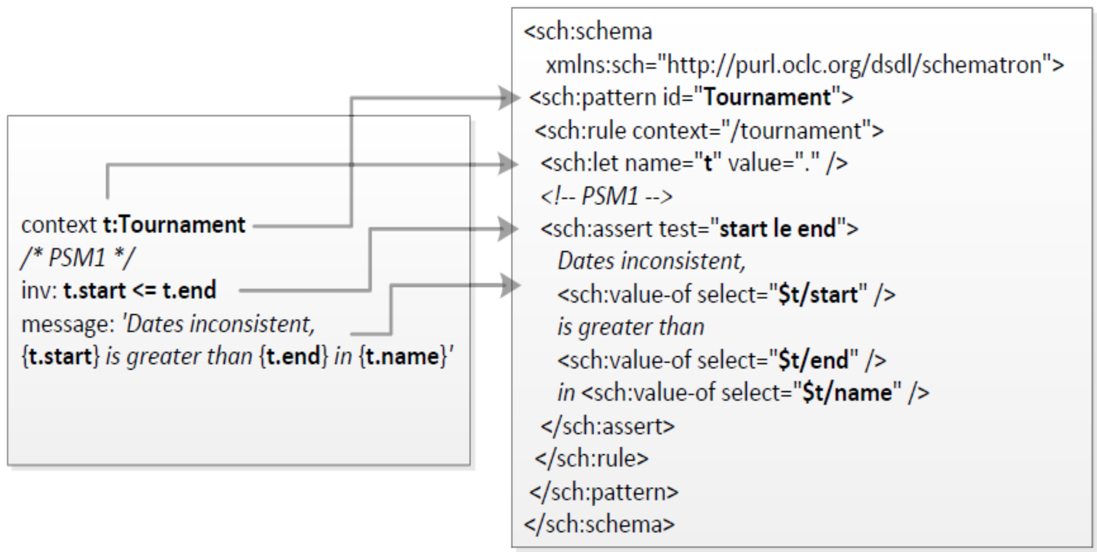


Figure 6.5: OCL to OWL mapping between OCL expression and OWL tags taken from [250]

6.2.2.2 Negotiations and Creation

This component facilitates the negotiation and creation of SLA, based on the healthcare service request processed by the *Initiation Manager* component. It supports the following use cases:

- **Participant catalogue**

This use case has a number of important functions as follows:

a- Keeps record of previous participants of a HC-VBE in terms of member identification attributes, ratings, availability, specialty, performance history and any other required information.

b- Search for suitable participants within the record to identify a suitable participant for the requested service. This set uses the participant selection mechanism described in Section 6.3.
c- Trigger an advertisement for specific participants such as *Provider* and *Support* when such participants are not available within the internal catalogues.
d- Approve participant applications in collaboration with the registration use case of the HC-VBE.

- **Task catalogue**

The functions of this use case are as follows:

a- Keep record of previous *Task* implemented by a HC-VBE in terms of task descriptions, task identification attributes and task durations.
b- Search for reusable *Task* based on the requested service requirements. This is to speed up the *Task* formation and implementation process within the VBE to deliver the fastest service possible to healthcare service requesters.
c- Process the details of a new *Task* as it is formed in order to stipulate them in the SLA that is going to be created for the participants of the *Task*.

- **Service catalogue**

The functionalities here are similar to the one of *Task catalogue* but instead of *Task* the functions are performed for *Service*.

- **Constraints negotiator**

Constraint negotiation is one of the essential tasks in bringing all participants together to agree on an SLA. The function of this use case is crucial in the framework. It is responsible for presenting all available options to participants so that they can make a decision on the conditions under which they want to participant or receive the healthcare service. The use case has the following main functions:

a- Fetch the constraints in the service request report
b- Make the constraints available to all prospective participants
c- Present all participants who are willing to fulfil the specified constraints in the request report. The mechanism of the presentation is not specified but could be based on percentage of constraint acceptance by each participant.

d- Stipulate in an SLA, the confirmed and agreed on constraints.

- **SLA creator**

The use case puts together all gathered information and generate SLAs. The task here is closely linked with the result of the other use cases detailed so far. An SLA is generated for each HC-VBE participant that participate in service provision in a given HC-VBE collaboration settings so that each participant knows their exact roles, obligations and rewards.

- **Convertor**

Not all who participate in healthcare virtual collaborations are computer or system experts, normally ordinary people are the main customers of such services. Therefore, it is important to have an SLA which is written in human readable and understandable format. The functions of this use case are:

a- Convert machine readable SLA into human readable text.

b- Convert SLA created by a HC-VBE into machine readable OWL.

If any changes made to the clauses of an SLA during service provision the convertor will convert the changes from machine readable format into human readable format and vies-versa. Figure 6.6 illustrates the conversion process where the converter is the bridge between text-based SLA and OWL-based SLA and the double headed arrows indicate bi-directional conversion capability. The conversion process and mechanism are not outlined in this thesis since it is an implementation matter that may differ from one virtual collaboration system to the next.

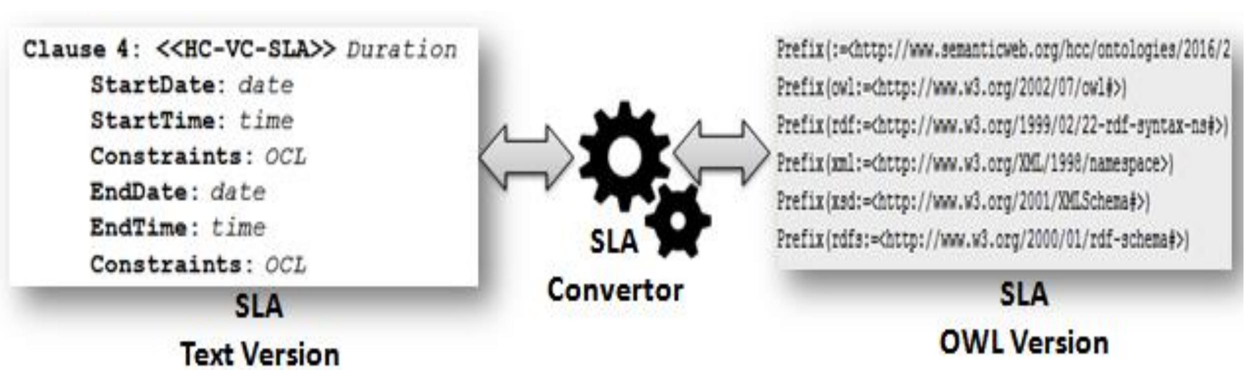


Figure 6.6: A view of the convertor use case working mechanism

6.2.2.3 Monitoring Manager

Once an SLA is created and sent for implementation, it has to be monitored to ensure that the terms and conditions are observed and respected. The Monitoring Manager component performs the monitoring function through the following use cases:

- **Enforcer**

The function of this use case is to ensure that the terms and conditions stipulated in an SLA are observed and implemented by performing the followings:

a- Match continuously the participants attributes stipulated in the implemented SLA to the ones provide the service in the *Task*. The matching can be performed by comparing participant IDs and Names for example.

b- Monitor the implementation of the attributes of services stipulated in an SLA through checking service satisfaction indicators such as satisfaction ratings by service requesters to ensure that the full agreed services are provided.

c- Trigger the process of rewarding participants in terms of ratings and payments once the services requested are fully delivered and confirmed by service requesters.

d- Trigger the process of fining participants who have violated the terms and conditions of an SLA.

- **Change manager**

The use case manages and detects changes that may be made to an SLA during implementation. Changes can be requested by participants of an SLA before and during SLA execution. For instance, changes can be requested to enhance SLA terms and conditions to better the services provided or the other way around. In case of changes, the use case performs the followings:

a- Gather information such as the change requester IDs and the change requested.

b- Specify the clause numbers in the SLA that the change affects.

c- Notify all affected participants of the change.

d- Trigger the *Convertor* use case to convert the changes to text and OWL version.

e- Replace an old SLA with a new one and make it available for the *Monitoring Manager* use case for implementation.

- **Dispute manager**

This use case processes all complaints sent to a HC-VBE regarding an SLA content adherence, for example, a service requester could rate a service provider poorly for the service provided. In such a case, the service provider can complain about the rating and the use case has to process the complaint, for this, it takes the following actions:

a- Identify the SLA which the complaint is about by searching for the SLA attributes provided in the complaint such as ID of the SLA.

b- Identify the parties involved in the complaint from the identified SLA.

c- Compare results gathered during SLA implementation with the information provided in the complaint.

d- Inform involved parties of the complaint outcome.

e- Make changes to records held about the SLA and affected participants.

6.2.2.4 Repository Manager

This is the last component which includes two use cases as follows:

- **Maintainer**

To keep all records about a specific SLA up to date, regular checks have to be made in collaboration with other use cases especially the *Change manager*. Therefore, regular checks and keeping records up to date is the main function of this use case.

- **Archiver**

This use case has the following functions:

a- Create a Master SLA for each *Task* and *Service* where SLAs for all participants are placed under one umbrella for the purpose of implementations and linkage. Figure

6.7 illustrates the Master SLA where (p) represents a participant within a specific virtual collaboration to which an SLA is created. All changes and referral requests for SLA clauses are made through the Master SLA to which the SLA is belong.

b- Archive SLAs created and provide access to each one for future references and reuses. This part of the use case plays an essential role in dispute management since it holds records about all SLAs and make them available for access at any time.

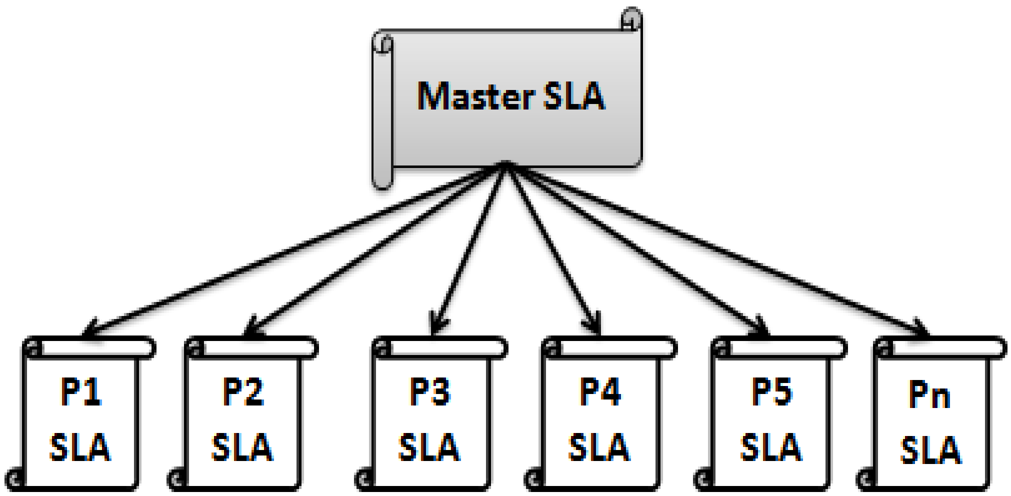


Figure 6.7:Master SLA concept where a number of SLA can be linked together under one Master SLA

6.2.2.5 VO Monitoring Manager

This component performs the same functions as *VBE Monitoring Manager* component except here the monitoring is performed for HC-VOs which have different participants and the duration of service provision is shorter than the one of HC-VBE.

6.2.3 The HC-VBE Framework Working Steps

This section provides a step by step description of the HC-VBE-F working process. The descriptions provided are none-technical as technical implementations are left for framework implementers' preference in the future. The framework organises and manages virtual collaboration for healthcare in 16 steps pictured in Figure 6.8.

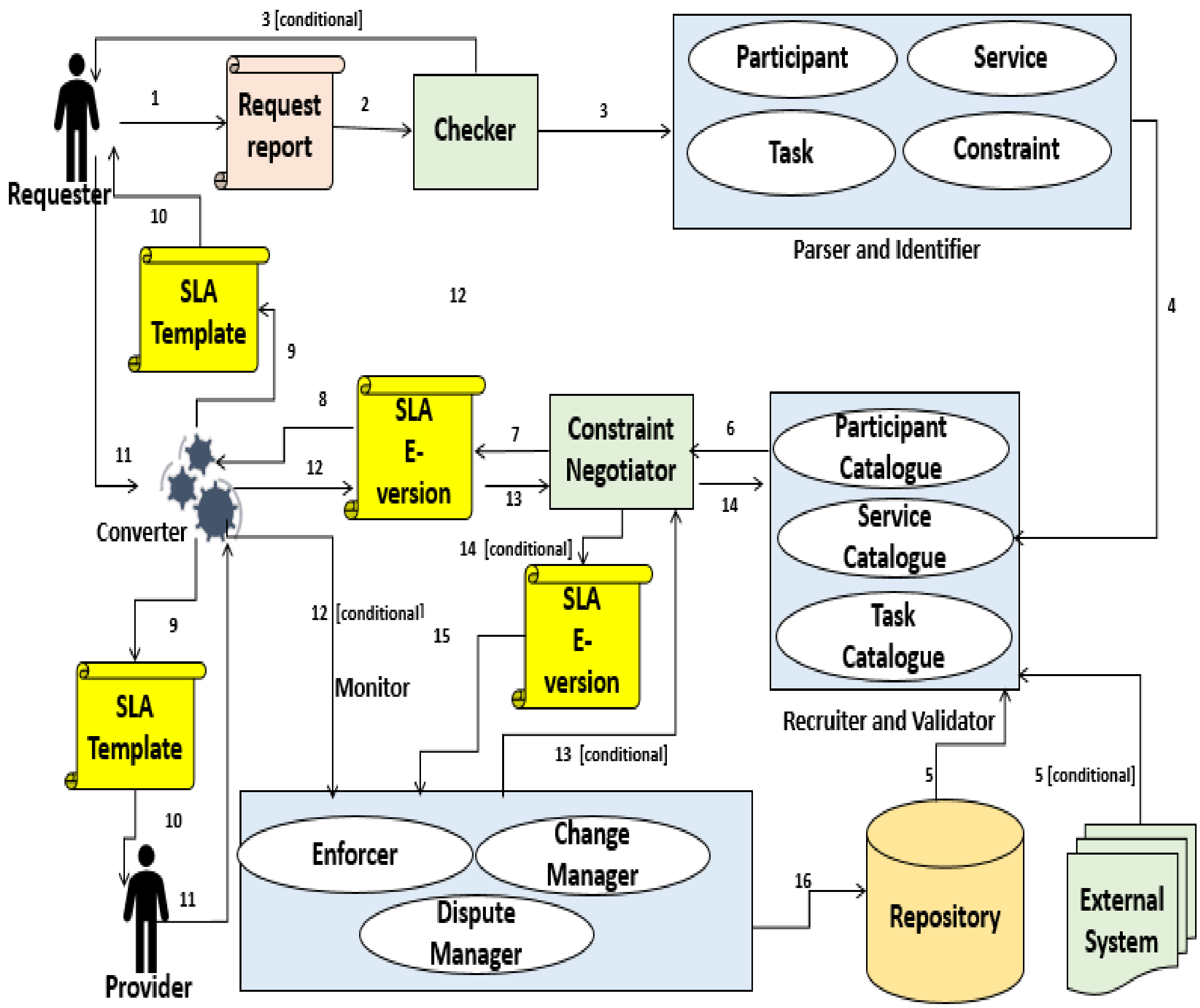


Figure 6.8: HC-VBE-F processing steps showing the steps numbered and their directions specified

Before any participant can initiate a healthcare virtual collaboration, they will have to register in a HC-VBE system. Participants (requesters, providers and organisers) will have to fill in a registration form to ensure that all required participant's information is available for SLA creation and enforcement purposes. Once participants filled in the registration form and their details are approved by a HC-VBE, they can start making service requests in the case of requesters, provide a service in the case of providers and provide management services in the case of organisers.

The main processing flows for a HC-VBE system are:

1- After a service request form is submitted by a service requester, the HC-VBE creates a request report with similar content to the one shown in Figure 6.9 and sends it to the *checker* use case to be checked. The request report will be created based on the SLA templates described in Section 6.5.

Request report

Requester details:

1- Id: …………………………… (e.g. 10)
2- Name: ……………………… (e.g. Hoger Mahmud)
3- Address :…………………… (e.g. Huddersfield, UK)
4- Contract information:...(e.g. hoger@gmail.com)

Service requested

1- Service title:……………... (e.g. head ache consultation)
2- Type of service:……………(e.g. service)
3- Service description:…… (e.g. continuing headache at front part of head)
4- Service constraints (duration, payment rate):………(e.g. consultation for 1 hours on 24-12-2018 between 14:00 till 15:00 will pay 50 pounds)

Providers required

1- Title :……………………………..(e.g. Neurologist doctor)
2- Qualification :………………..(e.g. BSc in Medicine)
3- Constraints (availability):.(e.g. be available in the afternoon)

Figure 6.9: Request report example with possible contents

2- The report will be checked by the *checker* function of the system which carries out the following checks to make sure that the request report is complete. If any information is missing the requester will be notified to provide the missing information.

a. Requester details
b. Service requested
c. Providers required
d. Service conditions
e. Offered payment amount

3- After the check is completed, the system sends the request report to be parsed (separate the information contained in it) for providers and service required. The parsing process uses the SPCM described in Section 5.2.

4- The parsed information from the request report will then be sent to the *recruiter and creator* components to search the catalogues for the right participants. It also initiates a *Service* or a *Task,* based on the request made.

5- To recruit the requested participants, first, the internal database is searched, in the event that the right participant could not be found the system advertises the request to external HC-VBEs to find the right participants.

6- Once the right participants and services are identified, the information will be collected and sent to the *negotiation* component to start negotiating the terms and conditions of the service.

7- The *negotiation* component then generates an SLA (OWL-based version) based on the identified information.

8- The HC-VBE sends the OWL-based SLA to the *converter* use case.

9- The *converter* use case converts the OWL-based SLA to a text-based human readable SLA.

10- The converted template will be sent to both requesters and providers for review and approval.

11- Providers and requesters read the SLA and either approve it or request changes to it. In the case of change requests, the agreement will be sent back for renegotiation. This process cycles through until the final agreement is reached.

12- Once the SLAs are approved by all parties they will be converted back to OWL-SLA and sent to the *Monitoring and enforcement* component for implementation. At this stage, a *Service* (HC-VO) will be created if the original request was for a *Service* and a *Task* (VBE management) will be created if the original request was by organisers for *Task*.

13- After a *Service* is created and running, if any change was requested to be made to the approved SLAs during the run, the request will be sent back to the *negotiation* use case to be approved by all parties before implementation.

14- In the event of change requests approval, they will be accommodated in the old SLAs and converted to OWL-based SLA and send it back to the *enforcement and monitoring* component.

15- After the service provision is complete, then the *monitoring* use case either reward the provider and charge the requester or it will fine the provider for not observing the terms and conditions of the SLA.

16- Finally, all SLAs will be archived in a repository for referral and reuse in the future. Figure 6.10 is the overall UML activity diagram for the HC-VBE-F which shows the activities performed by each component and the flow of information between the components.

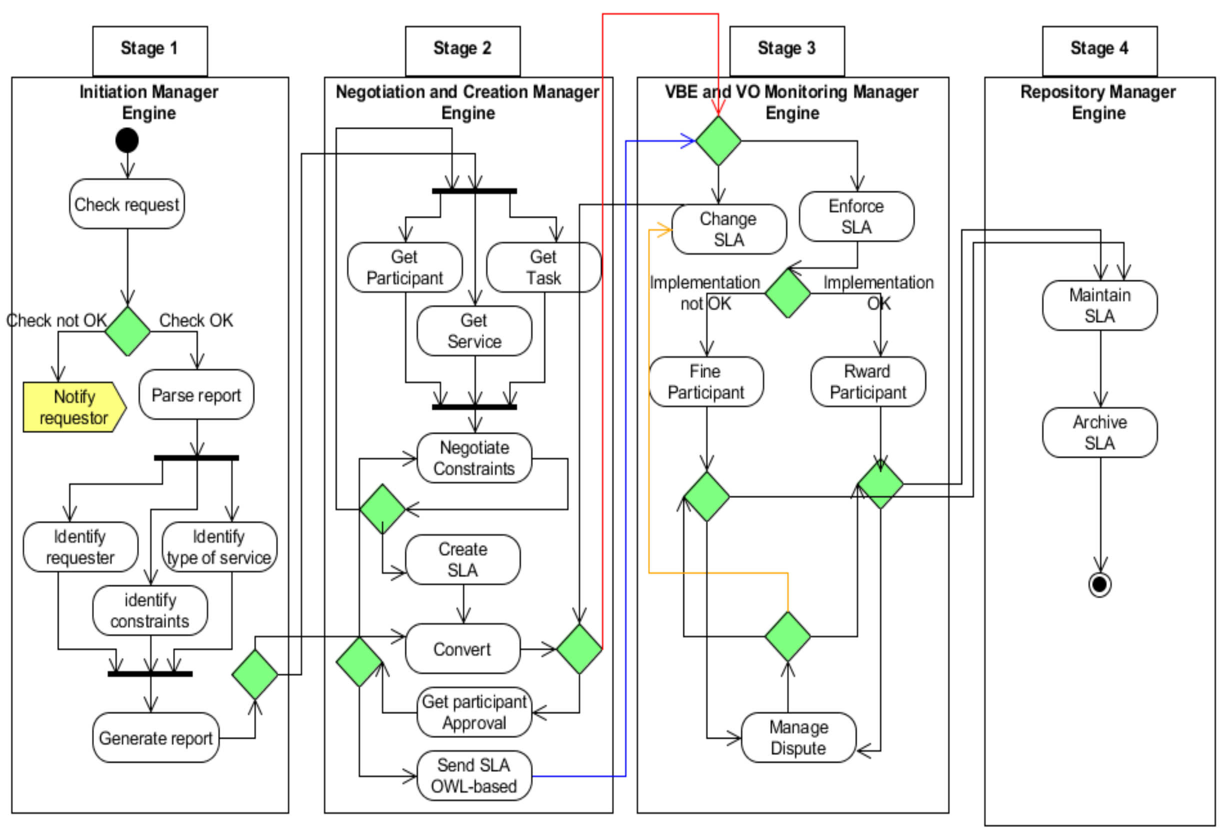


Figure 6.10: The framework UML activity diagram that show the flow of activity stage by stage

Finally, as described, the developed framework is a generic one that supports the identification, recruitment and management of healthcare virtual collaboration participants which may come together to provide a healthcare service. The framework has advantages over other proposed frameworks. For example a virtual telehealth framework is suggested in [254]. Similar to the proposed framework in this thesis, the authors have developed the framework with the aim to facilitate healthcare provision virtually. The framework is designed specifically to manage stroke cases collaboratively and facilitate doctor to doctor consultation.

One of the main differences is, the authors have stated that patients using their framework can only request a service in the time allocated by healthcare professionals, which clearly is a limitation on the use of the framework. The framework described in this thesis enable requesters to request a healthcare service on demand and be serviced in real-time. This is because patients can request services at any time they may wish and there will always be a healthcare provider to provide the service requested. The second difference is that the authors state that healthcare providers can only be recruited from the local repository but the developed HC-VBE framework is designed for global level collaboration where providers are recruited from a pool of providers around the world. The third difference is that the framework is designed to provide specific services whereas the developed HC-VBE framework is generic and can be used to provide all types of healthcare virtual services.

6.3 HC-VBE Member Selection Mechanism

Collaborating and working in a virtual world lacks direct performance supervision, which means, enforcing timely performance requirements on collaborating parties may not be achieved easily. One way to deal with this issue is to make sure that the right collaborating participant is selected. Researches such as [255] emphasises the importance of effective mechanism for member selection in dynamic domains and [256] states that, in dynamic and complex environments where many possible partners and technologies exist, member selection process is a challenge. The Authors of [257] state that having the right team member in a team is an essential success factor that should be taken seriously.

How to select the right member? Under what criterion? Are questions researched by researchers in different fields and the issue is yet to be resolved. The authors of [258] claim that there is a lack of unified framework for team member selection. The challenge in virtual collaboration is even greater, because besides having the right professional skills, collaborating virtually, requires participants to be technically competent in the technology that is going to be used for the collaboration [259].

According to [256], there are two member selection processes, the first considers historical member performance and the second uses predetermined criterions to assess the suitability of new members. Historical member performance can be gaged through reputation. The concept of reputation has been considered in some researches for the purpose of member selection. For instance, reputation accumulation processes where members can rate other members based on personal experience and collaboration results, are considered by authors in [260] and [261]. Defining the right criterion is also a challenge that is being researched, for instance, [262] identifies partner characteristics, knowledge and capability, and degree of fitness as three criterions to be considered for partner selection. Over recruitment and under recruitment is another issue realised by researchers in the field [257]. In this section a task-based member selection mechanism is outlined by which problems such as over recruitment is avoided.

To tackle the issue in virtual enterprises, a partner selection mechanism is developed by [255] that considers both time and cost as the two main selection determinate criterion. In a similar attempt, a temporal team member selection framework is suggested by [258]. The authors of [263] use combinational auction to deal with partner selection issue which may work in a domain where time is not an important factor as the selection takes time to be finalised based on who offers more for a product. However, this kind of mechanism is not suitable for healthcare domain as service quality and fitness has to be considered alongside cost and time.

To select the right member for healthcare virtual collaboration, a 7-step member selection mechanism (HC-VBE-MSM) pictured in Figure 6.11 is developed. The mechanism makes use of the SPCM described in Section 5.2 and the HC-VBE-F described in

Section 6.2 to select a member for virtual collaboration. The mechanism's working steps are described in the next section.

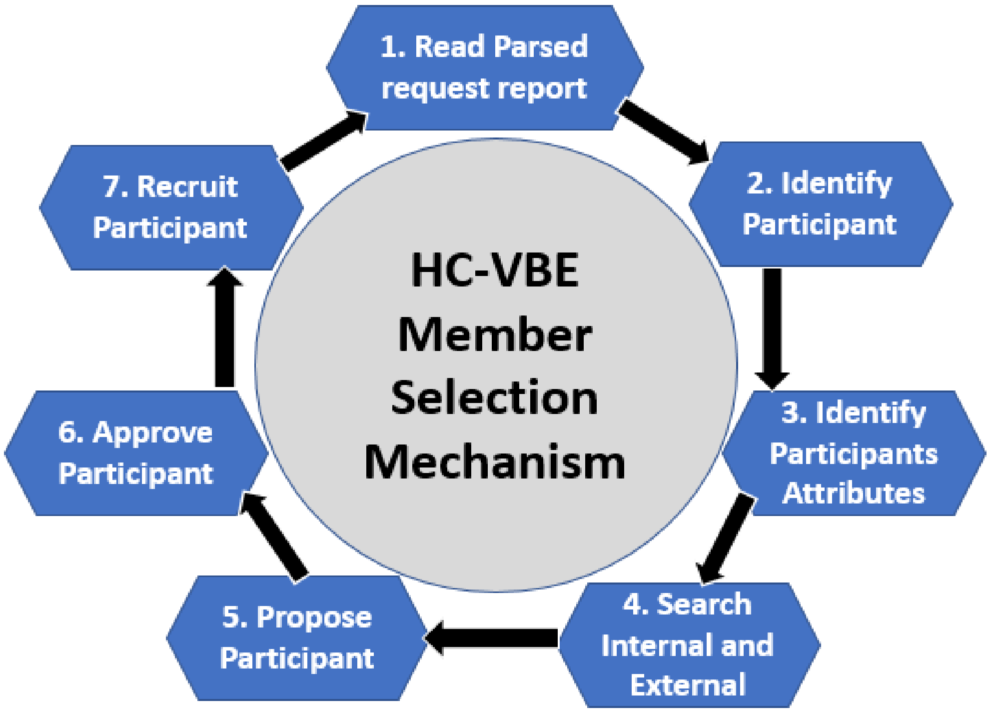


Figure 6.11: A seven steps HC-VBE Member Selection Mechanism, developed to work within the HC-VBE-F

6.3.1 Member Selection Mechanism Steps

In this section each step in the mechanism is described.

Step 1: Read parsed request report

It is assumed per the HC-VBE-F, as a result of processing the initial request from a healthcare requester a parsed report has been generated in which participants in the report are separated based on the SPCM. The member selection mechanism makes use of the parsed report, reads and analyses its content and start initiating the member selection process based on the information provided in the record.

Step 2: Identify participant

Having analysed the parsed report in the previous step, now the required participant is identified. For instance, if a healthcare member of type *provider* and title "psychologist" is requested, this step in the mechanism will note this information and pass It on to the next stage of the member selection process.

Step 3: Identify participant attributes

The information in the previous step now has to be analysed further to identify the attributes of the participant. The process in this step is vital to ensure all the necessary details of the identified participant is noted and processed before passing it on to the next stage of the selection process.

Step 4: Internal or External search

In this step, participants who possess the required attributes and roles are searched for in order to be contacted for possible service provision. First, the search will be in the HC-VBE repository; this is to speed up an SLA finalisation process as details of previous participants are already saved and the search list is shorter. The search will be moved to external HC-VBEs if the right participant could not be found or negotiation fails. As per the HC-VBE-F, in this case, the participant requirements are advertised to external HC-VBEs for possible offers.

Step 5: Propose participant

As the result of the search, if the required participant is found, then the member credentials are going to be verified and validated using the provider verification and validation mechanism described in Section 6.4. After verification and validation, the HC-VBE-MSM proposes the details of the provider to the requester for possible negotiation. At this stage, the status of the proposed member is undecided in terms of recruitment and it will be decided in the next step.

Step 6: Approve participants

If the negotiation in the previous step is successful then the mechanism notifies both requesters and providers to approve each other. The approval will serve as a base for the SLA that is going to be created for both. This is a preliminary approval just to enable the process of SLA creation to be triggered, the final approval is going to be made when the created SLA is approved by both requesters and providers.

Step 7: Recruit participant

After both collaborators (requester and provider) approve each other, at this stage, the SLA between them are finalised and the provider will be formally recruited. This will lead to the start of HC-VO formation process. Figure 6.12 is the UML activity diagram for the HC-VBE-MSM process. The diagram shows the activities that are performed throughout the seven-step mechanism.

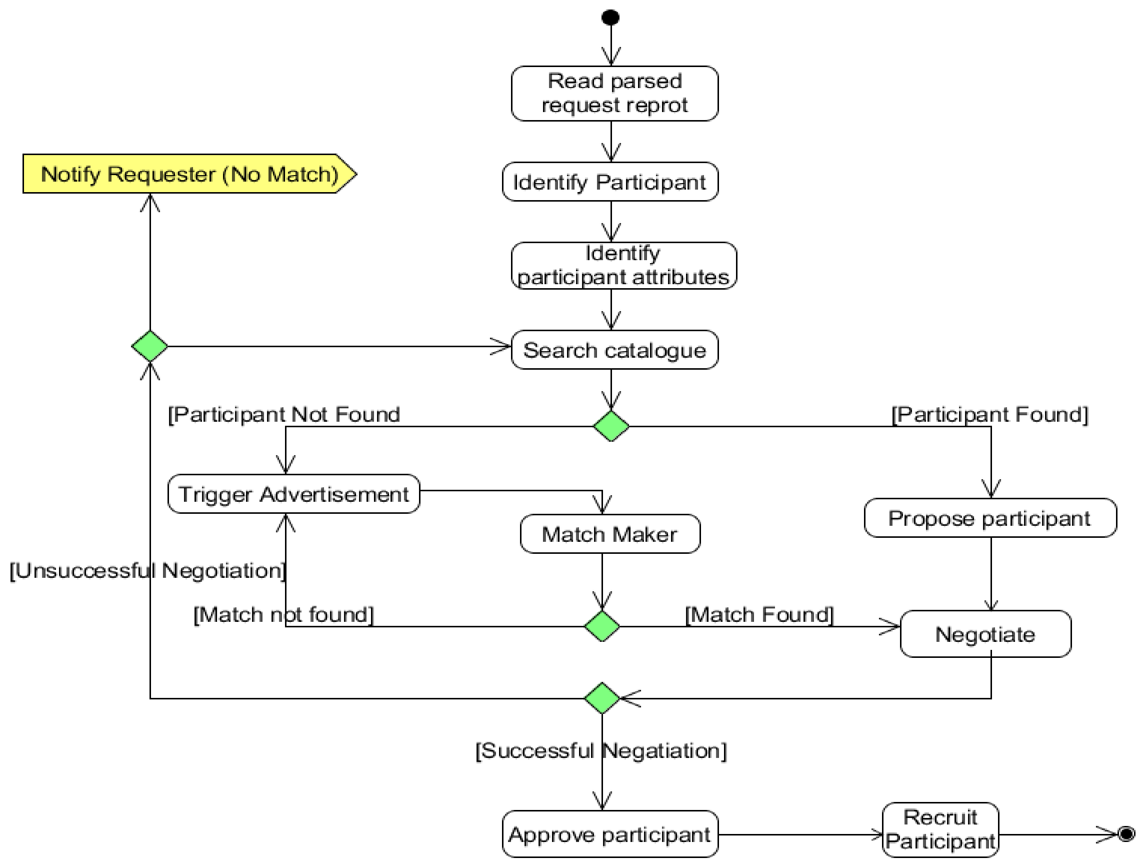


Figure 6.12: HC-VBE -MSM activity diagram showing the flow of activities to select a participant

6.4 HC-VBE Provider Verification and Validation Mechanism

Technology-based healthcare systems have altered the way care is provided to those in need with emphasis on raising the quality of care and reducing the cost of care [264]. Virtual healthcare is one of the ways that technology is playing a decisive role in its delivery, however, there are challenges that are yet to be addressed. In virtual healthcare settings, it is highly probable that healthcare providers and receivers do not know each other, which formulates the user validation and verification challenge.

Patients are entitled to be served by qualified healthcare professionals with their credentials verified and validated. Moreover, to prevent information falsification and identity assumption it is vital that virtual collaboration systems in healthcare offer the assurance needed regarding the identity and attributes of the collaborators.

This section describes a healthcare provider verification and validation mechanism (HC-VBE-PVVM) which is developed based on blockchain technology. A brief background on blockchain technology is provided in Section 2.8 which serves the foundation for the development of the mechanism. Blockchain technology is sighted for huge potentials in many areas of services, and reputable companies such as the Tierion/Philips partnership (Netherlands), GEM (U.S.), IBM, Guardtime (Europe) and Brontech (Australia), are all considering the technology in addressing challenges related to their needs [265]. Healthcare providers are taking a keen interest in applying the technology to solve healthcare provision related challenges as claimed in a study by Deloitte [266].

There are studies such as [267] that claims current user authentication systems such as password and usernames have not been very successful and suggest blockchain is the technology that can provide the full solution. The thesis author does not intend to comment on the technical implementation of blockchain for healthcare provider verification and validation but rather provide a conceptual description of the mechanism. The implementation details and challenges may require a separate research to be carried out in the future. In this section, the main participants, the authentication system conceptual structure and the processing steps that serve the bases of the mechanism are provided. To shed some lights on the applicability of the mechanism it is applied to a simple healthcare scenario. The HC-VBE-PVVM described in the next section has been published in a peer reviewed journal in [268].

6.4.1 HC-VBE-PVVM Description

Blockchain has been considered in a diverse fields of research ever since it was reported in 2008 [92], and its famous crypto currency application (Bitcoin) in 2009 [269]. Healthcare is one of the fields that researchers are considering the technology as a possible solution to some healthcare provision related challenges. The technology is already used for patient identification [270], patient record control [271] and healthcare record sharing between stakeholders securely [264]. A swiss company (Healthbank (www.healthbank.coop)) is developing a blockchain-based system to control healthcare data transaction verification and validation. The technology is considered for healthcare provider qualification validation and verification in [272] in a similar way as the proposed mechanism without specifying the verification and validation process.

Care provider reputation plays an important role in raising quality as healthcare requesters seek providers with high reputation; to secure the authenticity of provider reputation, blockchain has been used by the authors of [273]. To prevent drug counterfeiting, Hyperledger is using blockchain to develop a system in collaboration with a number of well-known companies such as IBM, Cisco and Intel [274]. To provide a secure platform to enable healthcare specialists to share information, a network based on blockchain has been launched by Gem Health in the US [275]. Blockchain technology is believed to play a vital role in healthcare which has created a buzz to an extend that some healthcare researchers call it a revolution [287]. For long, the concern around to be sure that the person you talk to online is who they claim to be, has been present. Despite the invention of many authentication techniques the concern is yet to be addressed fully.

The mechanism presented here aims to aid healthcare virtual collaboration system developers with a step by step roadmap that enables them to use blockchain technology for healthcare service provider validation and verification purpose. The mechanism works under the following assumptions:

1- Healthcare systems are developed based on the HC-VBE-F concepts developed in this thesis where any request for healthcare service is processed and provided virtually.

2- A number of virtual collaborators including HC-VBEs, healthcare institutes, governmental agencies and academic institutes participate in creating a blockchain to share and validate healthcare providers credentials. HC-VBEs seek the verification and validation of healthcare providers that they intend to recruit for service provision. Healthcare institutions validate reputational attributes such as length of experience and professionalism of the healthcare provider to whom the verification and validation are required. Academic institutes are responsible to verify and validate the academic qualifications that the healthcare providers claim to hold.

Under the above assumptions, a HC-VBE-PVVM that performs its function in a seven-step process. The mechanism components and working steps are shown in Figure 6.13. Each working step of the mechanism is described in Section 6.4.1.1.

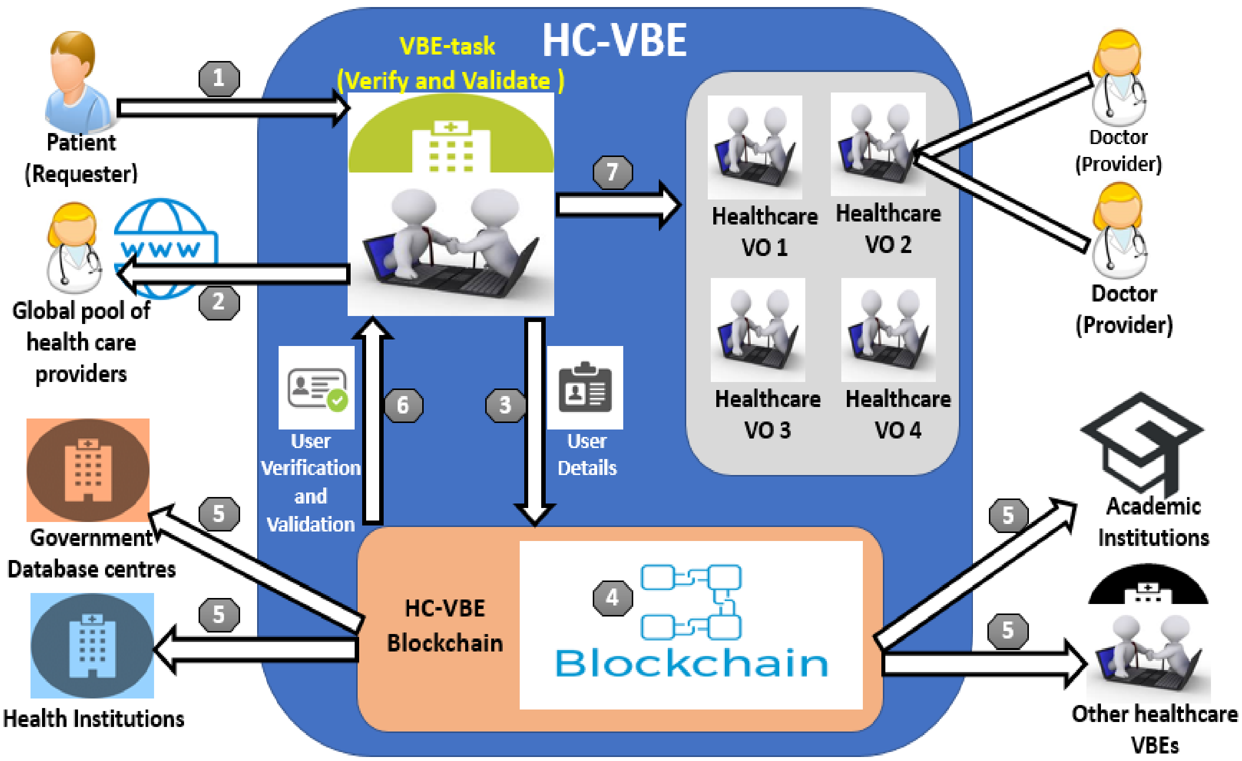


Figure 6.13:HC-VBE provider verification and validation mechanism steps and components

6.4.1.1 PVVM Working Steps

The following steps describe how the HC-VBE-PVVM works:

1- **Service request initiation:** In a HC-VBE, requests will be received for a service from a requester in a form of a request report as explained in Section 6.2.3. Once this took place, the HC-VBE takes the necessary steps as in Section 6.3.1 to find and contact a service provider.

2- **Provider identification:** If the provider requested is found within the local database it means the provider has already gone through the verification and validation process, in that case, the provider will be recruited to provide the service after mutual acceptance by both healthcare providers and requesters. Otherwise, a newly unverified and unvalidated provider can be found and contacted from a pool of external providers.

3- **Provider validation and verification request:** After the newly found provider declares its intention to provide a particular healthcare service, the HC-VBE sends a verification and validation request to the formed blockchain. The mechanism broadcasts the information provided by the healthcare provider in the blockchain to be verified and validated.

4- **Blockchain verification and validation initiation**: As result of the previous step, now all nodes in the chain has received the request and the process of verification and validation can start. In blockchain, verifying and validating a transaction which is known as mining, comes with an incentive (e.g. financial payment) and the node with most computational power wins the incentive. Having made that clear, now the nodes in the chain compete to verify and validate the providers information requested by the HC-VBE. The competition speeds up the verification and validation process.

5- **Provider information comparison**: In this step, the information received by the nodes are processed and compared with blocks held by relevant authorities (e.g. academic institute or hospital where the provider has claimed to have worked). In blockchain technology, there are several methods that is used for the comparison process such as Proof of Work (PoW).

6- **Verification and validation result**: When the process of information comparison is completed, the requester HC-VBE will be notified of the outcome and the result of the process will be broadcasted to other nodes to update their records.

7- **VBE result processing**: If the provider's information and credentials are verified and validated successfully then the HC-VBE will take the necessary steps to recruit the provider, and subsequently form a HC-VO for the healthcare requester and the approved provider. Otherwise, the HC-VBE will take steps to find new healthcare providers for the requested service and repeat the steps 2-7.

Finally, the initiation of using blockchain technology to address a well-recognised challenge in healthcare virtual collaboration, sums up the original contribution of this part of the research. However, the mechanism is conceptual and it is yet to be implemented. The mechanism has the potential to be a possible future PhD research as further research and implementation is required to fully realise the mechanism and prove its contribution in the field of healthcare, empirically.

Researchers mention that despite the acclaimed contribution of blockchain technology to the healthcare sector conceptually, the implementation and adaption of the technology is very slow due to the fact that it requires significant computational resources and the cost of its use is challenging to estimate [278]. Having said that, the technology deemed full of potential and there are studies that suggest the opportunities for its use in healthcare. For example, the authors of [282] suggest several potential services that blockchain can provide in healthcare such as bringing stakeholders of healthcare closer by removing third parties during collaboration and sharing resources, hence reducing transaction charges and keeping records secure and trusted.

6.4.1.2 HC-VBE-PVVM Application Example

The mechanism is designed to provide verification and validation for virtual healthcare service providers that offer to provide a service in HC-VBEs. One of the most common virtual healthcare services is consultation. The service's purpose is to hold conversation with a patient in order to guide the patient on healthcare concerns. To show the applicability of the mechanism the scenario below is considered:

Mr. David has recently developed a pain in his back after a fall while playing football. After a number of hospital visits for close check-ups, he has been advised by a specialist that he has to perform a number of specific exercises in the next few months to manage the pain. His local doctor has introduced him to a HC-VBE where he can request consultations with a physiotherapist on a weekly basis.

Now Mr. David can use the virtual services provided by the HC-VBE to receive guidance regarding his exercise without the need to visit his local healthcare institute. In order to receive the care, he takes the following steps:

1- He fills in a request form after registering himself in the HC-VBE system for a physiotherapist consultation. In the form, he explains his health issue and specifies the attributes of the physiotherapist as (having good reputation, minimum 6 years of experience, qualified by an EU university and should speak good French as he is a French national). He also specifies the duration of the service and the amount he is willing to pay for the service. He sends the request to the HC-VBE for processing.

2- The HC-VBE takes the steps outlined in Section 6.3.1 to find a physiotherapist that matches the request made by Mr. David. The HC-VBE search in the service providers local repository does not yield a close match. Now the HC-VBE advertises the request to external HC-VBEs and a physiotherapist who claims that he is a French national with 9 years of experience and an EU graduate with close matches to the other attributes specified in the request, offers to provide the service.

3- The HC-VBE now uses the outlined verification and validation mechanism to ensure the claims made by the provider are correct or false. To perform the verification and validation checks the HC-VBE takes the steps 3-7 described in section 6.4.1.1.

6.5 HC-VBE Service Level Agreement Templates

Managing SLA in a complex, multiparty and dynamic environment such as healthcare virtual collaboration is a challenge. The challenge is recognized by researchers in the area and they all point to the need of a comprehensive SLA framework [276][277]. To manage SLA in virtual and distributed environments, various approaches such a modelling SLA based on business objectives have been suggested by authors in [278][279][280]. The main management tasks in SLA lifecycle have been researched intensely and there is a common agreement that negotiation, creation, monitoring and closure are the four major tasks in the cycle [281][282] [283][284] [87]. On a practical level, for SLA negotiation and creation, efficient protocols are required, for such requirements some significant works are on-going such as the extension to WS-Agreement by [285]. The approaches are proposed for domains other than healthcare and they do not present a clear and comprehensive SLA management process. Similar to the approach taken in this thesis, the authors of [286] propose a SLA framework for federated virtual organisation without providing details as to how the SLAs are created and managed. In Section 6.2 within the HC-VBE-F a clear SLA life-cycle management process is provided where the SLA negotiation, creation and monitoring process is described.

As for the structure and content of SLA, the concept of SLA template is commonly used to provide a consistent structure and content for SLAs created for a specific domain or purpose [88][89][90]. A template, provides the structure and the main sections that should be included in an SLA, such as involved parties, service attributes and constraints. Templates also speed up the agreement process during negotiation since participants learn what is required from them and what they will get in return. The majority of virtual service providers such as those in could computing businesses, offer SLAs based on specific templates [287]. In a fast-changing environment such as healthcare having an electronically enforceable SLA to guarantee the delivery of the right service at the right time and at the right cost is essential. Another important point is the fact that not all services provided in healthcare can be provided electronically, human involvement therefore is inevitable. [135] Claims popular SLA mechanisms such as WSLA [140], CC-Pi [133] and WS-Agreement suffer from flexibility and support for services that have human involvement.

All available electronic SLAs are machine readable and could be difficult for ordinary human user to read and understand. The SLA templates presented in this section have a text-based version which supports human readability and involves human decision making in the process which makes it different from others. This work is a step forward in formalising the structure of SLAs for HC-VBE. As for the HC-VBE-SLA template implementation they can be implemented in OWL, and OCL can be used to define service constraints. Figure 6.14 is a section of the Master SLA template implemented in OWL. In a separate approach, the authors in [288] propose an RDF-based language to represent contracts, however the language is semantic web specific which limits its use as not all virtual organisations necessarily base their collaboration on semantic web architecture.

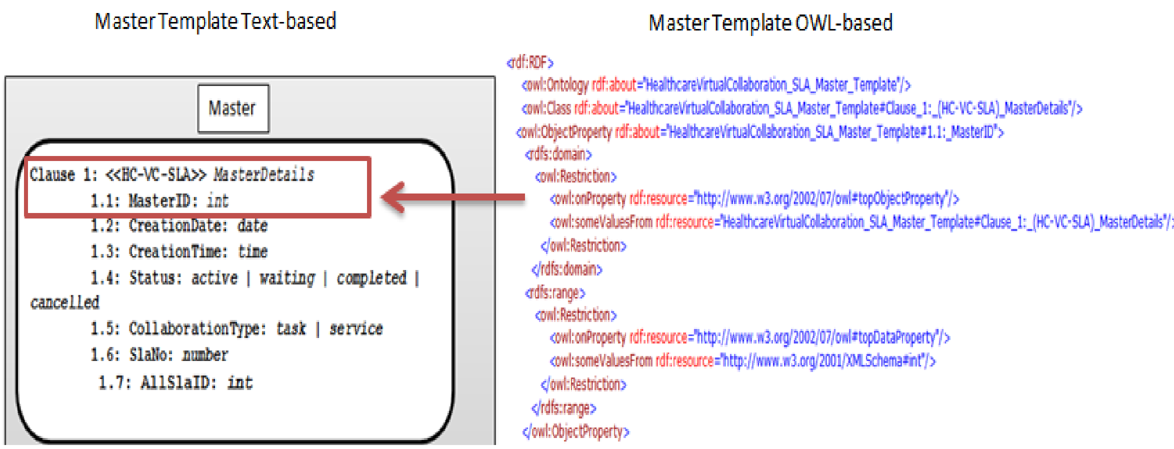


Figure 6.14: A section of the OWL version of the Master SLA

To enforce, monitor and manage SLAs, the authors of [289] suggests GSMA architectures and the authors of [131] Identify the main components of a typical SLA which is used as a guide to develop the clauses of the developed SLA templates in this section. Here, two templates are going to be presented; the first template is a Master SLA described in Section 6.5.1 and the second template is a general SLA described in Section 6.5.2. Figure 6.15 shows the template package developed for the HC-VBE-F which consists of two templates namely HC-VBE-SLA and HC-VBE-Master-SLA.

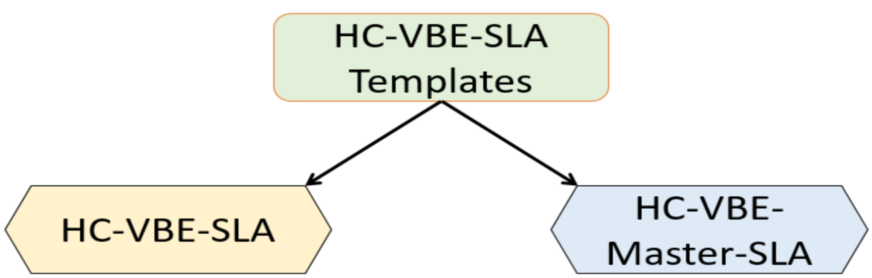


Figure 6.15: HC-VBE-SLA template package components

Each template consists of a number of clauses and the naming convention of each clause is as follows:

- Clause Number: <<HC-VBE-SLA>> Name, where *Number* and *Name* are variables i.e., they are different for each clause.

To ensure that the templates are designed objectively, the following attributes are identified to be considered in the templates:

1- Be generic, this is to ensure that it can be used as a base for all possible HC-VBE collaborations SLA creation.

2- Be simple and clear in terms of structure and content.

3- Be readable by both human and machine.

4- Be modified and adapted with ease.

The templates are text-based, human readable, scalable and are the base for all SLAs created in VBE and VO based healthcare virtual collaborations. For better readability, referrals, navigations and amendments, each clause and its sections are numbered. The same numbering system shall appear in the OWL-based version of the SLA templates. Figure 6.16 shows a section of the OWL version of the Master template detailed in the next section which is implemented using Protégé software.

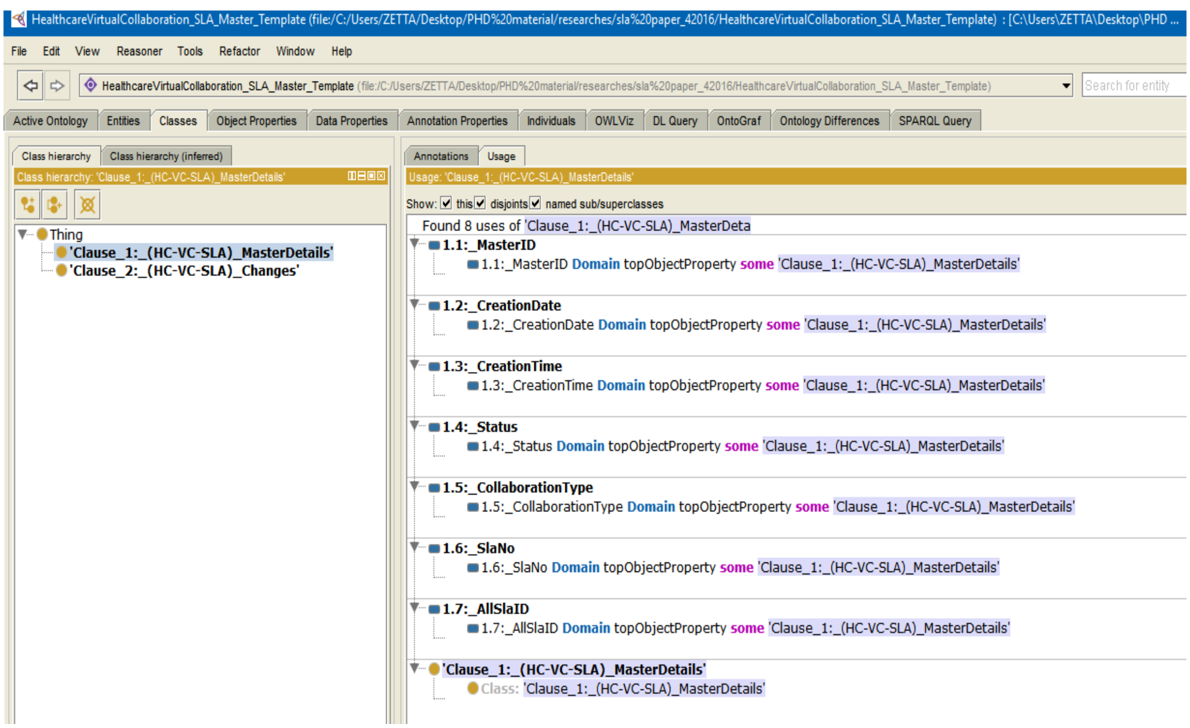


Figure 6.16: A screenshot of the Mater SLA template implementation in Protégé

6.5.1 HC-VBE Master SLA Template

The purpose of having a Master SLA in the repository manger is already explained in Section 6.2.2.4; here the basic structure and content of a master template is described. As it is shown in Figure 6.17, the master consists of two clauses:

1- **Master details**: The function of this clause is to hold basic required data about the Master SLA for identification purposes such as id, creation date, creation time, status of the master, the number of SLAs it contains and finally the id of each SLA contained in the master. The information contained in this clause is described in Table 6.1.

2- **Changes:** The clause holds a record of all the changes that are going to take place in the SLAs contained in a given Master SLA. The information contained in this clause is described in Table 6.2.

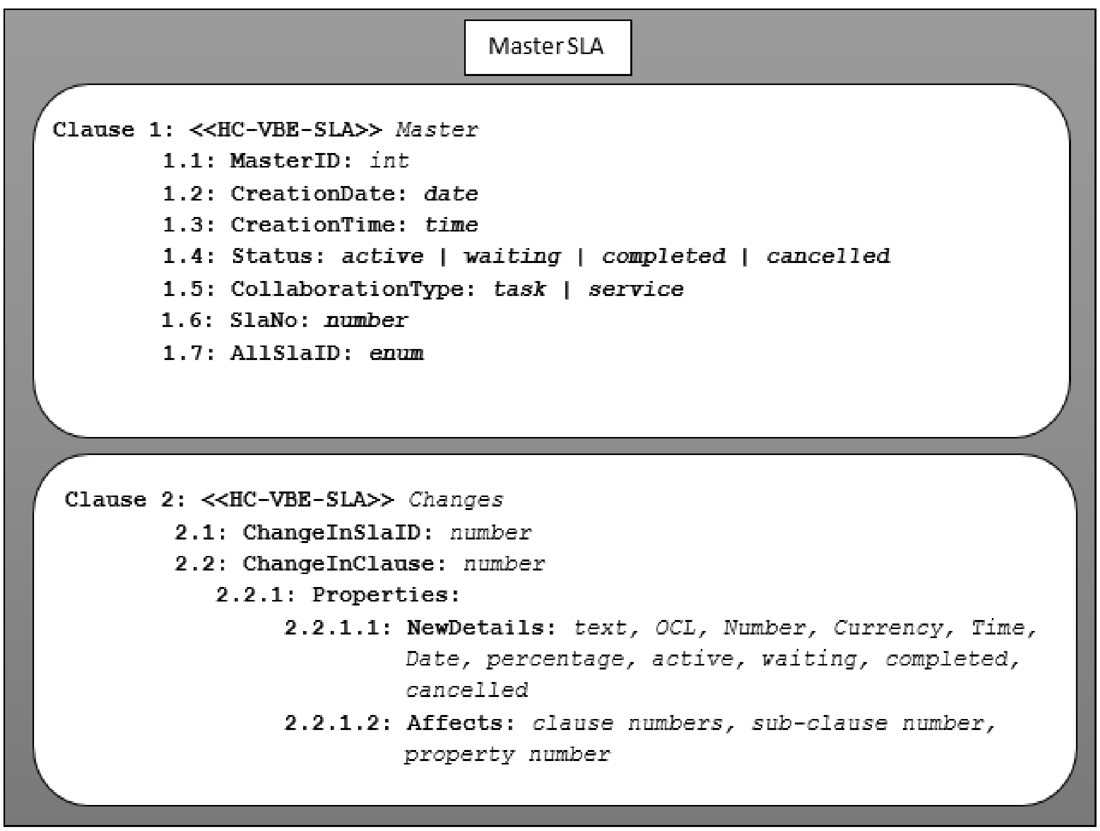


Figure 6.17: Text based Master SLA template developed for the HC-VBE-F

Table 6.1: Master SLA clause 1 description

Clause Section	Data	Type	Description
1	<<HC-VBE-SLA>> *Master*		This indicates that this is a master-SLA template.
1.1	MasterID	integer	A unique Identification number by which the master is identified and referred to during implementation and monitoring.
1.2	CreationDate	date	The date that the Master SLA is created and the type of data that it holds is *date.*
1.3	CreationTime	time	The time that the Master SLA is created and the type of data that it holds is *time.*
1.4	Status	active | waiting | completed | cancelled	This is the status of the Master SLA which can only be at one of the four status below: 1- **Active:** Indicates that the master is currently active and being implemented. 2- **Waiting**: Indicates that the master is yet to be approved or activated. 3- **Completed:** Indicates that the master was successfully implemented. 4- **Cancelled:** Indicates that the master was cancelled before it was activated or completed. The statuses are separated by (|) which is an *OR* logical operator.
1.5	CollaboratationType	task | service	The type of the collaboration for which the master is created which is either *Task* or *Service.* The two different types of HC-VBE services are separated by (|) which is an *OR* logical operator.
1.6	SlaNo	number	Indicates the number of SLAs contained within the master. The type of data that is held in the line is

Clause Section	Data	Type	Description
			number, starting with 1 as no Master SLA can be created without containing at least 1 SLA.
1.7	AllSlaIDs	enum	Each SLA that is linked to the Master SLA has a unique ID. Here all SLAs' ID contained in the Master SLA are listed.

Table 6.2: Master SLA clause 2 description

Clause section	Data	Type	Explanations
2	<<HC-VBE-SLA>> *Changes*		This is where the changes with regard to SLAs contained within the Master SLA are recorded.
2.1	ChangeInSlaID	integer	The ID of the SLAs in which the changes occur and the type of data it holds is *integer*.
2.2	ChangeInClause	number	The clause number of the SLA in which the change occurs. The type of data it holds is a number since each clause is numbered.
2.2.1	Properties		The attributes of the change are under this section.
2.2.1.1	NewDetails	Text (|,&) OCL (|,&) Number (|,&) Currency (|,&) Time (|,&) Date (|,&) Percentage (|,&) active (|,&) waiting (|,&) completed (|,&)	The new details that will be replaced in the affected SLA is recorded here. The data it holds can be a mixture of the data types specified. The data types change per the line number of the SLA that the change takes place. As each line numbered holds a different data type, therefore the reason this section has so many different data types is because it has to accommodate changes requested to any section of the SLA. The (|,&) are the *OR* and *AND* logical operator which indicates that the data type can be alone or with other data types.

Clause section	Data	Type	Explanations
		cancelled (|,&)	
2.2.1.2	Affects	ID(|,&) clause numbers (|,&) sub-clause number (|,&) property number (|,&)	This indicates the SLAs that are going to be affected as the result of the changes described in the previous section. which can be any of the data types specified. The (|,&) are the *OR* and *AND* logical operator which indicates that the data type can be alone or with other data types.

6.5.2 HC-VBE General SLA Template

This section describes a general SLA template to be used as a base for all the SLAs that will be created by a HC-VBE. The template consists of six clauses which are General, Collaborator 1, Collaborator 2, Expected Service, Duration and Enforcement. Each clause is designed for a specific purpose and a diagrammatical view of the template shown in Figure 6.18. In this section the content of each clause is described.

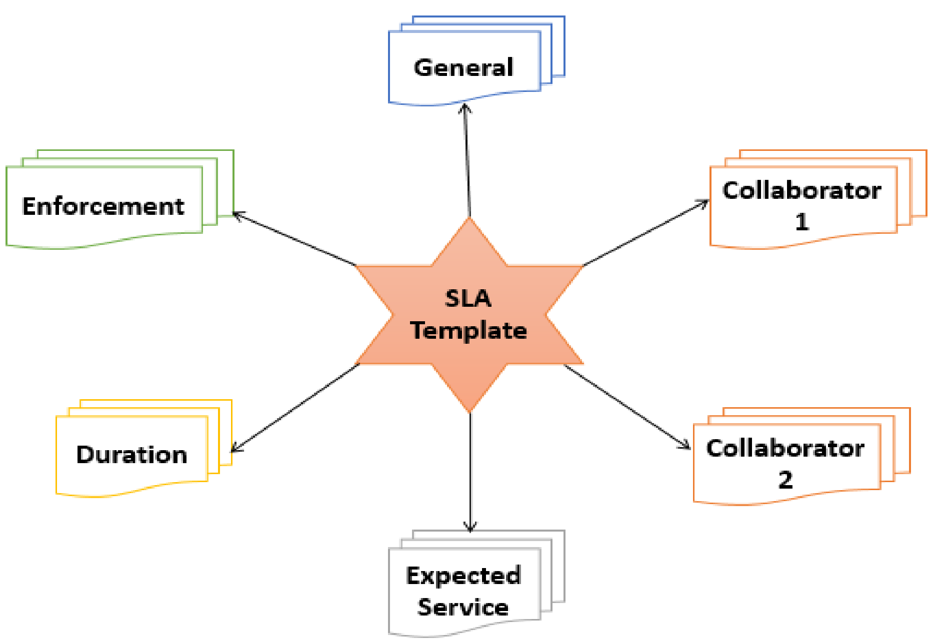


Figure 6.18: The main six clauses of the developed general SLA template for HC-VBE

1- **<<HC-VBE-SLA>> General**: The purpose of this clause is simply to present a basic information about an SLA such as the SLA ID, creation date and time. Figure 6.19 shows the structure and content of the clause as will be seen by healthcare requesters and providers and Table 6.3 describe each line in the clause.

```
Clause 1: <<HC-VBE-SLA>> General
        1.1: ID: int
        1.2: CreationDate: date
        1.3: CreationTime: time
        1.4: Status: active | waiting | completed | cancelled
        1.5: MasterID: inter
```

Figure 6.19: HC-VBE-SLA template Clause 1 structure and content

Table 6.3 : The general SLA template first clause description

Clause Sections	Data	Type	Explanations
1	<<HC-VC-SLA>> General	text	This is the header name of the clause and the information contained in this clause is “general” and relevant to the whole SLA.
1.1	ID	integer	A unique identification number by which the SLA is recognised and referred to. The data type of the line in the SLA is *integer.*
1.2	CreationDate	date	This is the creation date of the SLA and it is represented by a *date* data type.
1.3	CreationTime	time	This is the time of SLA creation and it is represented by a *time* data type.
1.4	Status	active | waiting |	This is where the status of the SLA is shown and there are four states:

<table>
<tr><th>Clause Sections</th><th>Data</th><th>Type</th><th>Explanations</th></tr>
<tr><td></td><td></td><td>completed | cancelled</td><td>Active: Means the SLA is currently being implemented.
Waiting: Means the SLA is awaiting activation or approval.
Completed: Means the SLA has been successfully implemented.
Cancelled: Means the SLA is cancelled before it was activated or completed.
The statuses are separated by (|) which is an OR logical operator.</td></tr>
<tr><td>1.5</td><td>MasterID</td><td>integer</td><td>This is the Master SLA ID to which the SLA is belong. It holds an integer data type.</td></tr>
</table>

2- **<<HC-VBE-SLA>> Collaborator 1**: The clause contains required information about the participant (requester) who the SLA is created for. The clause's structure and content are shown in Figure 6.20 and described in Table 6.4 which is also the same for clause 3. The assumption here is that every participant has pre-registered and their details and credentials are approved.

```
Clause 2: <<HC-VBE-SLA>> Collaborator 1
        2.1: Participant: Requestor | provider | Organiser |
Support
           2.1.1: Properties:
                2.1.1.1: ID: int
                2.1.1.2: Name: text
                2.1.1.3: ContactDetails: text and number
                2.1.1.4: Credentials: textand number
                2.1.1.5: Constraints: OCL
```

Figure 6.20: HC-VBE-SLA template Clause 2 structure and content

Table 6.4: The general SLA template second and third clause description

Clause sections	Data	Type	Explanations
2&3	<<HC-VC-SLA>> Collaborator	text	The word "Collaborator" indicates that this section holds data about a HC-VBE participant.
2&3.1	Participant	Requestor | Provider | Organizer | Support	The participant type for whom the SLA is created and must be one of the four types. The role of each type is explained in section 4.1. The statuses are separated by (|) which is an *OR* logical operator.
2&3.1.1	Properties		The properties of the participants are recorded under this section.
2&3.1.1.1	ID	integer	When participants register for the first time, they are assigned a unique ID by which they are recognised and referred to. Here the ID of type *integer* is displayed.
2&3.1.1.2	Name	text	The name of the participant that was recorded during registration, it is represented as *text* data type.
2&3.1.1.3	ContactDetails	text and number	The contact details of the participant recorded during registration, could be both *text* and *number*, text is for address and number is for telephone for examples.
2&3.1.1.4	Credentials	Text and number	This is a brief description of the approved credentials of the participant such as qualifications and years of experience.
2&3.1.1.5	Constraints	OCL	This part displays all the constraints that the participants has put in place in order to participate in the collaboration. Constraints are written in OCL to make it short and concise for human and aid the conversion process to OWL

Clause sections	Data	Type	Explanations
			version later. An example of constraint can be the duration that the participant is available to collaborate.

3- **<<HC-VBE-SLA>> Collaborator 2:** This clause contains required information about the participant (Provider) who provides a healthcare service; Figure 6.21 shows the structure of the clause and Table 6.4 presents the information recorded in this section.

```
Clause 3: <<HC-VBE-SLA>> Collaborator 2
        3.1: Participant: Requestor | provider | Organiser |
Support
           3.1.1: Properties:
                3.1.1.1: ID: int
                3.1.1.2: Name: text
                3.1.1.3: ContactDetails: text and number
                3.1.1.4: Credentials: textand number
                3.1.1.5: Constraints: OCL
```

Figure 6.21: HC-VBE SLA template Clause 3 structure and content

4- **<<HC-VBE-SLA>>Expected Service**: The clause contains details of the expected service to be provided by the provider named in the SLA, Figure 6.22 shows its structure and content and Table 6.5 describes the content of the clause.

```
Clause 4: <<HC-VBE-SLA>> ExpectedService
        4.1: HasRollIn: Service | Task
           4.1.1: Properties:
                4.1.1.1: Description: text
                4.1.1.2: Constraints: OCL
```

Figure 6.22: HC-VBE-SLA template Clause 4 structure and content

Table 6.5: The general SLA template fourth clause description

Clause sections	Data	Type	Explanations
4	<<HC-VC-SLA>> ExpectedService		This is the name of the section which indicates that purpose of the clause.
4.1	HasRollIn	service | task	Here the type of the service that is going to be provided is indicated to be *Service* or *Task* as per the SPCM in section 4.1.
4.1.1	Properties		The attributes of the expected service will be listed under this section.
4.1.1.1	Description	Text	A text-based description of the expected service will be provided as part of this line.
4.1.1.2	Constraints	OCL	The constraints that shapes the expected service such as the method of service provision, the rate of the service and the type of the service are provided under this section.

5- **<<HC-VBE-SLA>> Duration:** This clause contains the details of the duration in terms of start and end date and time of the expected service. Figure 6.23 shows the structure and content of the clause and Table 6.6 describes the content of the clause.

```
Clause 5: <<HC-VBE-SLA>> Duration
        5.1: StartDate: date
        5.2: StartTime: time
        5.3: Constraints: OCL
        5.4: EndDate: date
        5.5: EndTime: time
        5.6: Constraints: OCL
```

Figure 6.23: HC-VBE-SLA Template Clause 5 structure and content

Table 6.6: The HC-VBE-SLA template fifth clause description

Clause sections	Data	Type	Explanations
5	<<HC-VC-SLA>> *Duration*		The name of the section which indicates that it contains duration related data.
5.1	StartDate	date	The start date of the expected service is noted here with a data of type *date*.
5.2	StartTime	time	The start time of the expected service is noted here with data of type *time*.
5.3	Constraints	OCL	All the constraints relevant to the start time and date are recorded here using OCL such as the time is am or pm.
5.4	EndDate	date	The end date of the expected service is noted here with a data of type *date*.
5.5	EndTime	time	The end time of the expected service is noted here with data of type *time*.
5.6	Constraints	OCL	All the constraints relevant to the end time and date of the expected service are recorded here using OCL such as am or pm.

6- **<<HC-VBE-SLA>> Enforcement:** The clause contains the SLA enforcement attributes that must be monitored during implementation. Figure 6.24 shows the structure and content of the clause and Table 6.7 describes the content of the clause.

```
Clause 6: <<HC-VBE-SLA>> enforcement
        6.1: QoS: criterions
           6.1.1: Properties:
                6.1.1.1: Availability: percentage
                6.1.1.2: Accessibility: percentage
                6.1.1.3: Satisfaction: percentage
                6.1.1.4: ResponseTime: time
                6.1.1.5: Constraints: OCL
        6.2: Reward: payment and promotion
           6.2.1: Properties:
                6.2.1.1: Payment: currency
                6.2.1.2: Rating: number
                6.2.1.3: Constraints: OCL
        6.3: Penalties: payment and promotion
           6.3.1: Properties:
                6.3.1.1: Payment: currency
                6.3.1.2: Rating: number
                6.3.1.3: Constraints: OCL
```

Figure 6.24: HC-VBE-SLA template Clause 6 structure and content

Table 6.7: The HC-VBE-SLA template fifth clause description

Clause sections	Data	Type	Explanations
6	<<HC-VC-SLA>> *enforcement*		The name of the section which indicates the SLA enforcement related data will be held here.
6.1	QoS (Quality of Service)	criterions	This sub-section is concerned with the quality of the expected service as described in the next sub-sections which holds data of type QoS.
6.1.1	Properties		These are the quality of service properties that are going to be monitored during service implementation.

Clause sections	Data	Type	Explanations
6.1.1.1	Availability	percentage	The percentage that the service is expected to be available. Measurement mechanism is beyond the scope of this research. Measurement type should be in percentage for transparency reasons.
6.1.1.2	Accessibility	percentage	The percentage that the expected service is expected to be accessible during collaboration. Measurement mechanism is beyond the scope of this research. Measurement type should be in percentage for transparency reasons.
6.1.1.3	Satisfaction	percentage	This is the satisfaction rate expected to be achieved after service provision from healthcare requesters point of view. Measurement mechanism is beyond the scope of this research. Measurement type should be in percentage for transparency reasons.
6.1.1.4	ResponseTime	time	The speed of the required response during expected service provision. Measurement mechanism is beyond the scope of this research. Measurement type should be in time for transparency reasons.
6.1.1.5	Constraints	OCL	All constraints related to the quality of the expected service are recorded here using OCL such as expected allowed waiting period for a response to be provided.
6.2	Reward	Payment and promotion	The expected reward if the criterion of the quality of expected service is fulfilled. It can be

Clause sections	Data	Type	Explanations
			in a form of payment as well as promotions done through rating the service provider.
6.2.1	Properties		The properties of the reward are described under this section.
6.2.1.1	Payment	currency	The amount of payment in currency that the participant should receive after successful service provision.
6.2.1.2	Rating	number	The rate of promotion that the participant will receive after successful service provision. Rating are provided as numbers. The rating mechanism is technical and beyond the scope of this research.
6.2.1.3	Constraints	OCL	All the constraints related to the reward are recorded here using OCL.
6.3	Penalties	payment and promotion	This part records the details of penalties the participant incurs in terms of payment and promotion.
6.3.1	Properties		The properties of the expected penalties
6.3.1.1	Payment	currency	The amount of payment in currency that the participant will be fined after unsuccessful service provision.
6.3.1.2	Rating	number	The rate of demotion the participant will receive after unsuccessful service provision.

Clause sections	Data	Type	Explanations
6.3.1.3	Constraints	OCL	All the constraints related to the penalties are recorded here using OCL such as the precise conditions that the healthcare service provider will incurs the penalty.

6.6 HC-VBE-F Evaluation Results

This section provides two separate sets of evaluation results computed to examine users' acceptance of the HC-VBE-F implemented as a mobile application prototype. The first set of results are the evaluation results from healthcare providers perspective and the second set of results are the evaluation results from healthcare requesters perspective. The framework was evaluated by 200 participants, 100 of which were healthcare providers and the other 100 were healthcare requesters using the steps outlined in Sections 4.3. In Section 6.7 the results of the hypotheses testing defined for both extended TAMs (HC-VBE-TAM-Provider and HC-VBE-TAM-Requester) are discussed compared.

6.6.1 HC-VBE-TAM-Provider Evaluation Result

Framework implementation and data collection process is already described in Sections 4.31 and 4.3.6. Here, the healthcare providers acceptance evaluation results for the HC-VBE-F are presented and discussed. The results are produced using the data collected during the survey and analysed using Structural Equation Modelling technique in AMOS software. The SEM model developed based on the HC-VBE-TAM-Provider is pictured in Figure 4.16 and described in Section 4.3.7.2.

6.6.1.1 Overall Data Analysis Results

This section reports on Mean, Standard deviation, Factor loading, Significance value and Intermeasurement Correlation values which were computed for the data collected using the questionnaire designed for healthcare providers and can be found in appendix B.

Mean is the average of all values given to an observed item by surveyed participants. The Mean results for the observed items are between 6.08 and 6.54 which indicate strong agreeability of participants with the measuring statements in the questionnaire. The result is significant in the context of this research which conveys that the concepts developed in the HC-VBE-F and demonstrated through the developed mobile application prototype is acceptable by healthcare providers. This is because scale 6 represent high agreeability in the Likert Scale questionnaire as stated in Section 4.3.4.

Standard deviation measures the deviation of answers from the mean and the smaller the better as small values indicate that participants answers to individual questionnaire items were close. The standard deviation values are between 0.769 and 1.203 which indicates that the answers given by research participants were close to each other. This result shows that research participants views about the concepts behind the mobile application protype were fairly consistent. This finding increases the credibility of the results and provides a good acceptability support for the HC-VBE-F. The result of individual item factor loading indicates a strong link between observed items and their unobserved variables with values between 0.710 and 0.912 which are all above the acceptable cut-off value 0.5 [241]. The factor loading results suggest the effectiveness of individual measurement items in measuring the unobserved acceptance factors in the HC-VBE-TAM-Provider model which subsequently increases measurement reliabilities which is important for the validity of the hypotheses testing results.

To measure the significance of relations between the unobserved variables and their observed items, the significance value which is symbolised as p value is computed. Significance test is necessary in SEM to ensure that the result is not produced by chance and it is widely accepted that the significance value is when ($p<0.05$) [205]. Significance computed values are indicated as *** in AMOS analysis results output, which indicates that $p<0.001$. The result of all items is significant which suggests a high probability that the results are not produced by chance. Table 6.8 summarises the overall data analysis results for HC-VBE-F acceptability evaluation from healthcare providers perspective.
The table shows statistical results for each questionnaire item within the context of their unobserved variables.

Table 6.8: HC-VBE-TAM-provider overall data analysis results which includes the Mean, Standard deviation, Factor loading and Significance value

Unobserved Variable	Observed Variable and Related Questionnaire Item	Mean	Std. Deviation	Factor Loading	*p*< 0.05 (Significance)
Perceived healthcare Globalisation (PHG)	PHG1	6.38	0.982	0.764	*p*<0.001
	Using the HC-VBE application enhances healthcare providers collaboration.				
	PHG2	6.50	0.980	0.879	*p*<0.001
	Using the HC-VBE application helps making healthcare more widely available.				
	PHG3	6.48	0.990	0.792	*p*<0.001
	Using the HC-VBE application provides the opportunity to serve healthcare seekers around the world.				
	PHG4	6.54	0.834	0.750	*p*<0.001
	Using the HC-VBE application would be instrumental in globalising healthcare.				
Perceived Clinical Effectiveness (PCE)	PCE1	6.49	0.893	0.840	*p*<0.001
	Using the HC-VBE application would facilitate providing the right care through making patient history available.				
	PCE2	6.51	0.916	0.808	*p*<0.001
	Using the HC-VBE application would facilitate providing the right care through recruiting specialist care provider.				
	PCE3	6.22	1.031	0.762	*p*<0.001
	Using the HC-VBE application would facilitate providing timely care through anytime collaboration capability.				
	PCE4	6.47	0.881	0.845	*p*<0.001
	Using the HC-VBE application would facilitate providing care in the right place through anywhere collaboration capability.				

Unobserved Variable	Observed Variable and Related Questionnaire Item	Mean	Std. Deviation	Factor Loading	$p< 0.05$ (Significance)
Perceived Usefulness (PU)	PU1	6.23	1.162	0.815	$p<0.001$
	Using the HC-VBE application improves my performance in providing care.				
	PU2	6.38	1.003	0.834	$p<0.001$
	Using the HC-VBE application improves my availability to provide care.				
	PU3	6.36	1.010	0.912	$p<0.001$
	Using the HC-VBE application improves my patient management tasks.				
	PU4	6.51	1.000	0.785	$p<0.001$
	Overall, I find the HC-VBE application useful in providing healthcare.				
Perceived ease of use (PEU)	PEU1	6.08	1.203	0.855	$p<0.001$
	Learning to use the HC-VBE application would be easy for me.				
	PEU2	6.16	0.982	0.784	$p<0.001$
	I would find it easy to provide care using the HC-VOBE application.				
	PEU3	6.33	0.975	0.846	$p<0.001$
	It would be easy for me to become skilful at using the HC-VBE application				
	PEU4	6.22	1.088	0.710	$p<0.001$
	I would find the HC-VBE application easy to use.				
Attitude towards using (AU)	AU1	6.61	0.777	0.766	$p<0.001$
	Using the HC-VBE application would be a good idea.				
	AU2	6.47	0.810	0.793	$p<0.001$
	Using the HC-VBE application makes providing healthcare more interesting.				
	AU3	6.39	0.920	0.777	$p<0.001$
	Using the HC-VBE application would be a pleasant experience.				

Unobserved Variable	Observed Variable and Related Questionnaire Item	Mean	Std. Deviation	Factor Loading	*p*< 0.05 (Significance)
	AU4	6.36	0.938	0.752	*p*<0.001
	I would like to use the HC-VBE application				
Intention to use (IU)	IU1	6.38	0.908	0.785	*p*<0.001
	I intend to use the HC-VBE application.				
	IU2	6.33	0.922	0.722	*p*<0.001
	It is likely that I will use the HC-VBE application.				
	IU3	6.35	0.903	0.863	*p*<0.001
	I expect to use the HC-VBE application.				
	IU4	6.43	0.769	0.829	*p*<0.001
	I am willing to recommend other people to use the HC-VBE application.				

6.6.1.2 Intermeasurement Correlation

Intermeasurement correlation shows the link between all observed items, Table 6.9 shows the analysis results of intermeasurement correlations for the questionnaire items examining the HC-VBE-TAM-Provider. There are 24 measurement items in the questionnaire. Each questionnaire item is correlated to all other questionnaire items in a questionnaire including itself. A perfect correlation value which is 1 is produced when a questionnaire item is correlated to itself, but the values would be less than 1 in all other cases. The intermeasurement results are between 0.264 and 0.756 which indicates that some of the intermeasurement are weak since the acceptable cut off point is 0.3. Having said that the vast majority of the intermeasurement results prove that the scores given to most of the items are closely related. This means that the research participants shared similar opinions on measurement items. Intermeasurement values provide a detail map of the scores given to individual items in a questionnaire. If the majority of correlation values are above 0.3 that indicates the questionnaire items have adequately captured users view of the technology being tested in this context.

Table 6.9:HC-VBE-TAM-provider intermeasurement correlation results

	PHG1	PHG2	PHG3	PHG4	PU1	PU2	PU3	PU4	PEU1	PEU2	PEU3	PEU4	ECE1	ECE2	ECE3	ECE4	AU1	AU2	AU3	AU4	IU1	IU2	IU3
PHG1	1.00																						
PHG2	0.68	1.00																					
PHG3	0.62	0.73	1.00																				
PHG4	0.51	0.66	0.60	1.00																			
PU1	0.61	0.48	0.58	0.49	1.00																		
PU2	0.64	0.62	0.60	0.61	0.76	1.00																	
PU3	0.59	0.65	0.60	0.63	0.75	0.73	1.00																
PU4	0.53	0.55	0.55	0.62	0.64	0.61	0.76	1.00															
PEU1	0.44	0.40	0.26	0.36	0.31	0.31	0.35	0.28	1.00														
PEU2	0.42	0.43	0.40	0.44	0.49	0.45	0.53	0.41	0.69	1.00													
PEU3	0.51	0.47	0.33	0.38	0.38	0.33	0.43	0.34	0.76	0.60	1.00												
PEU4	0.34	0.44	0.29	0.36	0.34	0.37	0.37	0.27	0.55	0.60	0.62	1.00											
ECE1	0.58	0.75	0.50	0.54	0.62	0.62	0.72	0.51	0.45	0.46	0.56	0.44	1.00										
ECE2	0.43	0.65	0.55	0.51	0.60	0.65	0.70	0.53	0.27	0.46	0.39	0.47	0.73	1.00									
ECE3	0.51	0.62	0.54	0.53	0.54	0.61	0.67	0.58	0.42	0.50	0.49	0.49	0.63	0.64	1.00								
ECE4	0.56	0.64	0.60	0.61	0.64	0.66	0.74	0.62	0.39	0.45	0.45	0.41	0.71	0.66	0.61	1.00							
AU1	0.49	0.54	0.57	0.58	0.50	0.57	0.62	0.58	0.30	0.47	0.33	0.37	0.48	0.48	0.42	0.62	1.00						
AU2	0.60	0.63	0.62	0.59	0.59	0.59	0.66	0.59	0.36	0.51	0.38	0.39	0.60	0.57	0.57	0.71	0.66	1.00					
AU3	0.51	0.54	0.53	0.53	0.58	0.60	0.65	0.55	0.33	0.40	0.42	0.33	0.60	0.57	0.56	0.63	0.65	0.61	1.00				
AU4	0.39	0.48	0.49	0.59	0.53	0.58	0.59	0.50	0.48	0.58	0.37	0.42	0.55	0.57	0.46	0.61	0.58	0.51	0.62	1.00			
IU1	0.32	0.38	0.32	0.42	0.35	0.37	0.47	0.43	0.43	0.53	0.41	0.41	0.39	0.36	0.40	0.49	0.44	0.44	0.44	0.61	1.00		
IU2	0.24	0.34	0.31	0.40	0.30	0.32	0.38	0.30	0.24	0.43	0.29	0.26	0.35	0.35	0.39	0.49	0.41	0.45	0.35	0.42	0.53	1.00	
IU3	0.42	0.43	0.40	0.46	0.51	0.40	0.60	0.56	0.40	0.55	0.42	0.35	0.46	0.48	0.46	0.60	0.50	0.56	0.41	0.55	0.67	0.66	1.00

6.6.1.3 Characteristics of Construct

At construct level, the result supports strong acceptability by the healthcare providers for the concepts developed in the HC-VBE-F. The mean value for each construct variable computed as an average for all observed items for a particular construct is above 6 with standard deviation of less than 1. Table 6.10 shows the constructs, the number of items used to calculate the means, their mean and standard deviation values. The result suggests that on construct level the survey participants' acceptance attitude towards the HC-VBE-F were positive since the values are above 6 which are equals to "quite Agree" in Likert-Scale measures. The result also suggests that on construct level the answers were similar since the standard deviation values are less than 1.

Table 6.10: HC-VBE-TAM-provider construct characteristics results which includes Mean and Standard Deviation

Item Statistics				
Constructs	**Observed Items**	**Mean**	**Std. Deviation**	**N**
Perceived Clinical Effectiveness (PCE)	4	6.423	0.803	100
Perceived Healthcare Globalisation (PHG)	4	6.475	0.808	100
Perceived Usefulness (PU)	4	6.370	0.922	100
Perceived Ease of Use (PEU)	4	6.198	0.906	100
Attitude Towards Using (AU)	4	6.458	0.722	100
Intention to Use (IU)	4	6.373	0.747	100

6.6.1.4 Data Validity and Reliability

Sections 4.3.8.(6,7,8 and 9) have already explained the importance of measurement validity and reliability as well as the most common validity and reliability statistical methods. Here the statistical data validity and reliability values computed for the data collected from healthcare providers through the survey questionnaire designed for HC-VBE-TAM-Provider are presented. The acceptable value for *AVE* is 0.5 or above and the values computed for all constructs in this part of the study are above the cut-off value ranging from 0.596 to 0.702. These results suggest that the amount of variance produced as a result of correct data collected for each construct is much higher than the amount of variance which may have been produced as a result of errors in the data collected. The suggestion supports strong data reliability which is vital for validating the technology acceptance claims made with regard to the HC-VBE framework developed in this thesis.

CR acceptable value is 0.7 or above, the result for all constructs are above the value starting from 0.855. The acceptable value for Cronbach's Alpha is 0.7 again the result for all constructs are above the value starting at 0.856 and the overall Cronbach's Alpha value is 0.959. These results suggest strong data validity and reliability. Kaiser-Meyer-Olkin Measure is used to measure sampling adequacy and the computed value is 0.919 which indicates that the sample used in the study is adequate as values above 8 is considered excellent [242]. The adequacy of the sample data is important to be proven statistically which in turn increases the findings made as result of analysing the sample data.

The Individual construct factor loading indicates strong connections between the construct and its measured questionnaire item as all values are above 0.7 which is much higher than the 0.5 acceptable value. The correlations between the constructs in the model as values start with the correlation between PEU and PU being the lowest (0.488) which is higher than the 0.3 acceptable value. The strong correlation between the constructs supports the validity of the model which in turn support the empirical conclusions made with regard to the acceptability of the HC-VBE framework. Table 6.11 shows the summary of results obtained for collected data reliability and validity.

Table 6.11: HC-VBE-TAM-provider Data validity and reliability results

Latent Variables	AVE >0.5	CR>0.7	Cronbach's Alpha> *0.7*	Factor Loading	PCE	PHG	PU	PEU	AU	IU	Whole Cronbach's Alpha> *0.7*	Kaiser-Meyer-Olkin Measure
Perceived Clinical Effectiveness (PCE)	0.664	0.887	0.884	0.910	1						0.959	0.919
Perceived Healthcare Globalisation (PHG)	0.636	0.875	0.873	0.866	0.772	1						
Perceived Usefulness (PU)	0.702	0.904	0.904	0.888	0.818	0.773	1					
Perceived Ease of Use (PEU)	0.641	0.877	0.872	0.716	0.599	0.533	0.488	1				
Attitude Towards Using (AU)	0.596	0.855	0.856	0.904	0.775	0.752	0.780	0.559	1			
Intention to Use (IU)	0.643	0.877	0.874	0.750	0.592	0.499	0.567	0.519	0.662	1		

6.6.1.5 HC-VBE-TAM-Provider Model Fit

Model fit values indicate that the results generated from the model can be reproduced and the model is statistically acceptable. In Section 4.3.8.10 the most recommended fit indices are described which are Chi Square (CMIN in AMOS), CFI, TLI, IFI, RMSEA and SRMR [214][215][213]. The model fit indices computed for the HC-VBE-TAM-Provider are summarised in Table 6.12. The computed Chi Square value for the model is 1.460 which is within the recommend value of 1-3. Chi Square is a measure of badness of fit, a value that is not significant (p>0.05) indicates that the model is acceptable. This means that the covariance matrix calculated based on the collected data is similar to the predicted covariance matrix by the model. In this case the Chi Square value suggest that the model designed to test the acceptability of the framework is acceptable and is fit for the intended purpose

CFI compares the fit value of the model with a fit value of a base model (alternative model) with value closer to 1 indicates an acceptable fit. The CFI value computed is 0.914 which has exceeded the recommended 0.90 cut-of value and hence indicates a good fit. These results suggest that the model used to test the acceptability of the framework is closer to ideal, hence indicate the fitness of the model. TLI and IFI are both comparative fit indices similar to CFI with computed values of 0.903 and 0.916 respectively which are above the 0.9 cut off value. The model fit results indicate a good fit with the data and therefore, the model is acceptable.

RMSEA calculates the difference between covariance matrix value for the same observed item in both the tested and predicted model. The recommended value is 0.08 or smaller, the value computed for the HC-VBE-TAM-Provider is 0.08 exactly. The final fit measure is SRMR which measures the standardised difference between observed and predicted covariance matrix with a recommended value of 0.08 or smaller. The computed SRMR value for the model specified is 0.063 which is smaller than 0.08 and this result again indicates a good model fit.

The model fit values collectively support the fitness of the model to test the acceptability of the framework by prospective users and the results produced from it can be relied on. All the results so far presented were computed to show whether the results produced in testing the hypothesises are statistically sound or not. Collectively the results suggest the hypothesis results are statistically sound. The results of the hypotheses testing are presented in Section 6.7.

Table 6.12: HC-VBE-TAM-provider model fit results

Overall Fit Index		Computed Value	Recommended Value
CMIN/DF		1.460	Between 1 and 3
CFI	Comparative fit index (baseline comparison)	0.914	CFI ≥ 0.90
TLI	Tucker Lewis Index (baseline comparison)	0.903	TLI ≥ 0.90
IFI	Incremental fit index (base line comparison)	0.916	IFI ≥ 0.90
RMSEA	Root Mean Square Error of Approximation (Absolute fit indices)	0.080	RMSEA ≤ 0.08
SRMR	(Standardized) Root Mean Square Residual	0.063	SRMR ≤ 0.08

6.6.2 HC-VBE-Requester Evaluation Results

This section presents healthcare requesters acceptance evaluation results and discussions for the HC-VBE-F. The results produced using the data collected during the survey and analysed using Structural Equation Modelling in AMOS software. The SEM model developed based on the HC-VBE-TAM-Requester is pictured in Figure 4.17 and described in Section 4.3.7.3.

6.6.2.1 Overall Data Analysis Results

This section reports on Mean, Standard deviation, Factor loading, Significance value and Intermeasurement Correlation values which are computed for the data collected using the questionnaire designed for healthcare requesters and can be found in appendix C. Mean is the average of all values given to an observed item by surveyed participants. The Mean results for the observed items are between 5.02 and 5.63 which indicate agreeability of participants with the measuring statements in the questionnaire. The results indicate that the concepts developed in the HC-VBE-F and demonstrated through the developed mobile application prototype are acceptable by healthcare requesters.

Standard deviation measures the deviation of answers from the mean and the smaller the better. The standard deviation values computed are between 1.059 and 1.478 which indicates that the answers given by research participants were close to each other since the standard deviation values are not too large. This result shows that research participants views about the concepts behind the mobile application protype were fairly consistent. The result of individual item factor loading indicates strong link between observed items and their unobserved variable with values between 0.751 and 0.907 which are all above the acceptable cut-off value 0.5 [241]. Significance *p* value is computed to measure relations between the unobserved variables and their observed items.

Significance test is necessary in SEM to ensure that the result is not produced by chance and it is widely accepted that the acceptable significance value is when $(p<0.05)$ [205]. Significance computed values are indicated as *** in AMOS analysis results output which indicates that $p<0.001$. The result of all items is significant which suggests a high probability that the results are not produced by chance. Table 6.13 summarises the overall data analysis results for the HC-VBE-F acceptability evaluation from healthcare requesters perspective. The table shows statistical results for each questionnaire item within the context of their unobserved variables.

Table 6.13: HC-VBE-TAM-Requester overall analysis results which includes Mean, Standard deviation, Factor loading and Significance value

Unobserved Variable	Observed Variable	Mean	Std. Deviation	Factor Loading	$p < 0.05$ (Significance)
Perceived healthcare availability (PHA)	PHA1	5.12	1.335	0.818	$p<0.001$
	Using the HC-VBE application facilitate fair access to healthcare.				
	PHA2	5.28	1.478	0.751	$p<0.001$
	Using the HC-VBE application provides anytime anywhere access to healthcare.				
	PHA3	5.13	1.338	0.858	$p<0.001$
	Using the HC-VBE application makes more varieties of healthcare available.				
	PHA4	5.29	1.409	0.863	$p<0.001$
	Using the HC-VBE application makes more specialist healthcare provider available				
Perceived Healthcare Quality (PHQ)	PHQ1	5.12	1.437	0.889	$p<0.001$
	Using the HC-VBE helps me find the right healthcare provider.				
	PHQ2	5.21	1.336	0.884	$p<0.001$
	Using the HC-VBE application helps me find healthcare respectful of and responsive to my preferences and needs.				
	PHQ3	5.24	1.357	0.802	$p<0.001$
	Using the HC-VBE application helps me find the right healthcare for reasonable price				
	PHQ4	5.33	1.393	0.875	$p<0.001$
	Using the HC-VBE application helps me find the right healthcare in a reasonable time.				
	PHQ5	5.42	1.319	0.818	$p<0.001$
	Using the HC-VBE application helps me find the right healthcare from a location of my choice.				

Unobserved Variable	Observed Variable	Mean	Std. Deviation	Factor Loading	$p < 0.05$ (Significance)
Perceived Usefulness (PU)	PU1	5.21	1.274	0.777	$p<0.001$
	Using the HC-VBE application improves my chance to get on demand healthcare.				
	PU2	5.51	1.367	0.832	$p<0.001$
	Using the HC-VBE application saves me effort and time to find needed healthcare.				
	PU3	5.02	1.378	0.803	$p<0.001$
	Using the HC-VBE application would be more convenient than visiting healthcare institutions.				
	PU4	5.23	1.325	0.822	$p<0.001$
	Overall, I find the HC-VBE application useful in receiving healthcare.				
Perceived ease of use (PEU)	PEU1	5.18	1.466	0.867	$p<0.001$
	Learning to use the HC-VBE application would be easy for me.				
	PEU2	5.22	1.323	0.807	$p<0.001$
	I would find it easy to receive care using the HC-VBE application.				
	PEU3	5.47	1.359	0.846	$p<0.001$
	It would be easy for me to become skilful at using the HC-VBE application.				
	PEU4	5.30	1.382	0.893	$p<0.001$
	I would find the HC-VBE application easy to use.				
Attitude towards using (AU)	AU1	5.63	1.338	0.907	$p<0.001$
	Using the HC-VBE application would be a good idea.				
	AU2	5.31	1.361	0.836	$p<0.001$
	Using the HC-VBE application makes receiving healthcare more interesting.				
	AU3	5.34	1.157	0.812	$p<0.001$
	Using the HC-VBE application would be a pleasant experience.				

Unobserved Variable	Observed Variable	Mean	Std. Deviation	Factor Loading	*p*< 0.05 (Significance)
	AU4	5.59	1.164	0.794	*p*<0.001
	I would like to use the HC-VBE application				
Intention to use (IU)	IU1	5.49	1.040	0.833	*p*<0.001
	I intend to use the HC-VBE application.				
	IU2	5.36	1.142	0.864	*p*<0.001
	It is likely that I will use the HC-VBE application.				
	IU3	5.50	1.059	0.860	*p*<0.001
	I expect to use the HC-VBE application.				
	IU4	5.63	1.143	0.839	*p*<0.001
	I am willing to recommend other people to use the HC-VBE application.				

6.6.2.2 Intermeasurement Correlation

Intermeasurement correlation shows the relationship between all observed items, Table 6.14 shows the analysis result of intermeasurement correlations for the questionnaire items examining the HC-VBE-TAM-Requester. There are 25 measurement items in the questionnaire. Each questionnaire item is correlated to all other questionnaire items in a questionnaire including itself. A perfect correlation value which is 1 is produced when a questionnaire item is correlated to itself, but the values would be less than 1 in all other cases. The intermeasurement results are between 0.30 and 0.82 which are within or above the acceptable cut-off point of 0.3. The results indicate strong correlation between them, which means, research participants shared similar opinions on measurement items. Intermeasurement values provide a detail map of the scores given to individual items in a questionnaire. If the majority of correlation values are above 0.3 that indicates that the questionnaire items have adequately captured users view of the technology being tested in this context.

Table 6.14: HC-VBE-TAM-Requester intermeasurement correlations

	PHA1	PHA2	PHA3	PHA4	PU1	PU2	PU3	PU4	PEU1	PEU2	PEU3	PEU4	PHQ1	PHQ2	PHQ3	PHQ4	PHQ5	AU1	AU2	AU3	AU4	IU1	IU2	IU3	IU4
PHA1	1.00																								
PHA2	0.63	1.00																							
PHA3	0.72	0.66	1.00																						
PHA4	0.68	0.70	0.76	1.00																					
PU1	0.62	0.50	0.58	0.61	1.00																				
PU2	0.65	0.66	0.64	0.71	0.76	1.00																			
PU3	0.60	0.48	0.68	0.64	0.62	0.67	1.00																		
PU4	0.61	0.49	0.64	0.71	0.63	0.63	0.72	1.00																	
PEU1	0.52	0.48	0.52	0.51	0.53	0.55	0.53	0.45	1.00																
PEU2	0.63	0.64	0.68	0.59	0.61	0.73	0.56	0.57	0.69	1.00															
PEU3	0.54	0.55	0.56	0.60	0.54	0.58	0.48	0.62	0.72	0.68	1.00														
PEU4	0.54	0.43	0.53	0.55	0.52	0.57	0.52	0.53	0.82	0.68	0.75	1.00													
PHQ1	0.65	0.56	0.67	0.62	0.65	0.70	0.63	0.66	0.51	0.75	0.59	0.54	1.00												
PHQ2	0.65	0.50	0.60	0.61	0.70	0.70	0.62	0.67	0.47	0.68	0.55	0.53	0.82	1.00											
PHQ3	0.58	0.57	0.64	0.59	0.49	0.58	0.50	0.62	0.50	0.65	0.56	0.51	0.68	0.66	1.00										
PHQ4	0.67	0.53	0.65	0.62	0.61	0.65	0.54	0.59	0.58	0.67	0.65	0.66	0.75	0.79	0.74	1.00									
PHQ5	0.61	0.57	0.64	0.62	0.54	0.63	0.52	0.57	0.59	0.70	0.63	0.57	0.71	0.69	0.74	0.72	1.00								
AU1	0.70	0.59	0.72	0.72	0.56	0.62	0.71	0.70	0.64	0.70	0.70	0.69	0.72	0.65	0.64	0.74	0.66	1.00							
AU2	0.62	0.50	0.64	0.63	0.55	0.59	0.62	0.73	0.50	0.59	0.64	0.58	0.72	0.62	0.60	0.69	0.59	0.76	1.00						
AU3	0.61	0.45	0.67	0.68	0.58	0.62	0.66	0.63	0.55	0.58	0.57	0.57	0.66	0.61	0.54	0.66	0.62	0.74	0.73	1.00					
AU4	0.45	0.47	0.53	0.56	0.48	0.53	0.57	0.61	0.55	0.57	0.63	0.64	0.60	0.58	0.56	0.63	0.51	0.73	0.69	0.58	1.00				
IU1	0.51	0.40	0.46	0.53	0.44	0.44	0.51	0.50	0.55	0.54	0.49	0.54	0.57	0.49	0.45	0.48	0.45	0.62	0.51	0.56	0.63	1.00			
IU2	0.30	0.32	0.29	0.44	0.46	0.46	0.46	0.47	0.46	0.44	0.46	0.46	0.56	0.51	0.41	0.43	0.40	0.52	0.50	0.50	0.64	0.72	1.00		
IU3	0.36	0.39	0.37	0.48	0.44	0.44	0.41	0.42	0.49	0.50	0.40	0.48	0.51	0.52	0.41	0.44	0.41	0.58	0.44	0.48	0.66	0.69	0.79	1.00	
IU4	0.39	0.41	0.41	0.53	0.48	0.60	0.52	0.54	0.53	0.57	0.46	0.60	0.62	0.60	0.47	0.51	0.52	0.60	0.50	0.56	0.67	0.71	0.71	0.71	1.00

6.6.2.3 Characteristics of Construct

At construct level, the results suggest strong acceptability by healthcare requesters for the concepts developed in the HC-VBE-F. The mean value for each construct variable computed as an average value for all observed item of a particular construct is above 5 with standard deviation between 0.97 and 1.23. Table 6.15 shows the result for all constructs tested. The result suggests that on construct level (each construct tests an aspect of the technology being tested) the survey participants' acceptance attitude towards the HC-VBE-F were positive since the values are above 5 which are equals to "Agree" in Likert-Style measures. The result also suggests that on construct level the answers were similar since the standard deviation values are not too large.

Table 6.15: HC-VBE-TAM-Requester construct characteristics results

Item Statistics				
Constructs	**Observed Items**	**Mean**	**Std. Deviation**	**N**
Perceived Healthcare Availability (PHA)	4	5.21	1.22	100
Perceived Healthcare Quality (PHQ)	5	5.26	1.21	100
Perceived Usefulness (PU)	4	5.24	1.16	100
Perceived Ease of Use (PEU)	4	5.29	1.23	100
Attitude Towards Using (AU)	4	5.47	1.11	100
Intention to Use (IU)	4	5.50	0.97	100

6.6.2.4 Data Validity and Reliability

In Sections 4.3.8.(6,7,8 and 9) the importance of measurement validity and reliability as well as the most common statistical methods are already explained. Here, the statistical data validity and reliability values computed for the data collected from healthcare requesters through the survey questionnaire designed for HC-VBE-TAM-Requester are presented. The acceptable value for *AVE* is 0.5 or above and the value computed for all constructs in this part of the study are above the cut off value starting from 0.679. These results suggest that the amount of variance produced as a result of correct data collected for each construct is much higher than the amount of variance which may have been produced as a result of errors in the data collected. The suggestion supports strong data reliability which is vital for validating the technology acceptance claims made with regard to the modelling framework developed in this thesis.

CR acceptable value is 0.7 or above, the result for all constructs are above the value starting from 0.894. The acceptable value for Cronbach's Alpha is 0.7 again the result for all constructs are above the value starting at 0.890 and the overall Cronbach's Alpha value is 0.972. These results suggest strong data validity and reliability. To ensure sampling adequacy Kaiser-Meyer-Olkin Measure of sampling adequacy was computed and the result is 0.939 which indicates that the sample used in the study is adequate as values above 8 is considered excellent [242]. The adequacy of the sample data is important to be proven statistically which in turn increases the findings made as result of analysing the sample data.

The Individual construct factor loading indicate strong connections between the construct and its measured questionnaire item as all values are above 0.7 is much higher than the 0.5 acceptable value. The correlations between the constructs in the model as values start with the correlation between IU and PHA being the lowest (0.526) which is much higher than the 0.3 acceptable value. The strong correlation between the constructs supports the validity of the model which in turn support the empirical conclusions made with regard to the acceptability of the modelling framework. Table 6.16 shows the summary of results obtained for the collected data reliability and validity.

Table 6.16: HC-VBE-TAM-requester data reliability and validity results

Latent Variables	AVE >0.5	CR>0.7	Cronbach's Alpha> *0.7*	Factor Loading	PHA	PHQ	PU	PEU	AU	IU	Whole Cronbach's Alpha> *0.7*	Kaiser-Meyer-Olkin Measure
Perceived Healthcare Availability (PHA)	0.679	0.894	0.898	0.877	1						0.972	0.939
Perceived Healthcare Quality (PHQ)	0.717	0.927	0.931	0.907	0.781	1						
Perceived Usefulness (PU)	0.702	0.904	0.890	0.904	0.808	0.794	1					
Perceived Ease of Use (PEU)	0.687	0.898	0.913	0.870	0.707	0.751	0.718	1				
Attitude Towards Using (AU)	0.719	0.911	0.904	0.926	0.773	0.807	0.800	0.772	1			
Intention to Use (IU)	0.715	0.909	0.911	0.770	0.526	0.620	0.616	0.628	0.710	1		

6.6.2.5 HC-VBE-TAM-Requester Model Fit

Model fit values indicate that the results generated from the model can be reproduced and the model is statistically acceptable. As stated already the most recommended fit indices are Chi Square (CMIN in AMOS), CFI, TLI, IFI, RMSEA [214] [215] [213]. The model fit indices computed for the HC-VBE-TAM-Requester are summarised in Table 6.17.

Chi Square is a measure of badness of fit, a value that is not significant ($p>0.05$) indicates model acceptability. The recommended Chi Square value is between 1 and 3 for a model to be acceptable; the computed Chi Square value for the model is 1.774 which indicates that the model and the data are a good fit. This means that the covariance matrix calculated based on the collected data is similar to the predicted covariance matrix by the model. CFI compares the fit value of the model with a fit value of a base model (alternative model) with value closer to 1 indicates an acceptable fit. In this case the Chi Square value suggest that the model designed to test the acceptability of the framework is acceptable and is fit for the intended purpose.

The CFI value computed is 0.911 which has exceeded the recommended 0.90 cut-of value and hence indicates a good fit. These results suggest that the model used to test the acceptability of the framework is closer to ideal, hence indicate the fitness of the model. TLI and IFI are both comparative fit indices similar to CFI with computed values of 0.900 and 0.913 respectively which are above the values are within the 0.9 cut-off value. Both results indicate that the model fits wells with the data and it is acceptable. RMSEA calculates the difference between covariance matrix value for the same observed item in both the tested and predicted model. The recommended value is 0.08 or smaller, the value computed for the HC-VBE-TAM-Provider is 0.088.

The final fit measure is SRMR which measures the standardised difference between measured and predicted covariance matrix with a recommended value is 0.08 or smaller. The computed SRMR value for the model specified is 0.064 which is smaller than 0.08 which indicates that the model is a good fit.

The model fit values collectively support the fitness of the model to test the acceptability of the framework by prospective users and the results produced from it can be relied on. All the results for far presented were computed to show whether the results produced in testing the hypothesises are statistically sound or not. Collectively the results suggest the hypothesis results are statistically sound. The results of the hypotheses testing are presented in the next section.

Table 6.17: HC-VBE-TAM-Requester model fit results

Overall Fit Index		Computed Value	Recommended Value
CMIN/DF		1.774	Between 1 and 3
CFI	Comparative fit index (baseline comparison)	0.911	CFI ≥ 0.90
TLI	Tucker Lewis Index (baseline comparison)	0.900	TLI ≥ 0.90
IFI	Incremental fit index (base line comparison)	0.913	IFI ≥ 0.90
RMSEA	Root Mean Square Error of Approximation (Absolute fit indices)	0.088	RMSEA ≤ 0.08
SRMR	(Standardized) Root Mean Square Residual	0.064	SRMR ≤ 0.08

6.7 HC-VBE-F Discussions

Governments and healthcare providers are in continuous search to find new technology-based platforms to provide on time and affordable healthcare [290]. Healthcare is complex and there is always a high demand for up-to-date knowledge and skills in the field. To cope with the demand, healthcare professionals and institutions are encouraged to collaborate and share resources, and for this, virtual care technologies are gaining importance [291]. Forms of virtual care have existed for some times as telemedicine and telehealth. However, the overall concept of virtual care which is defined as "*the* *convergence of digital media, health technology, mobile devices, text messaging, digital voice assistants, and decision support tools powered by artificial intelligence and augmented/virtual reality to create a continuous connection between patients, physicians, and other caregivers*" is yet to be realised in a manageable and organised settings [23].

In Section 1.3, three research questions were stated to be answered for healthcare virtual collaboration; here the researched answers to each of the questions are discussed.

RQ3: How to manage and organise virtual collaboration for healthcare?

To answer this question a healthcare virtual collaboration framework (HC-VBE-F) is developed based on the modelling framework described in Chapter 5. The framework facilitates both the organisation and management of virtual collaboration for healthcare. The HC-VBE-F consists of a number of components each having a specific function in organising and managing virtual collaboration in healthcare. The framework working steps are clearly outlined and explained. To demonstrate the feasibility of the concepts developed in the framework, a mobile application prototype is developed that implements the main functionalities and working steps in the framework. The results of the acceptance evaluation show that the framework concepts and mechanisms have passed the user acceptance test which is a vital first step in developing a virtual collaboration system for healthcare.

RQ4: How to select, verify and validate virtual healthcare providers?

To answer the first part of the question, with regard to provider selection, a member selection mechanism is developed and presented in Section 6.3. Ensuring the right member is selected to join a given healthcare virtual collaboration, increases trust in both the service provided and between the members that collaborate. As for the second part of the question, a user validation and verification mechanism which is described in Section 6.4 is developed. The mechanism uses blockchain technology as a theoretical base to verify and validate healthcare providers that wish to provide a service in HC-VBE collaborations. The mechanism provides a detailed step by step guide as to how healthcare service providers are going to be verified and validated and it is designed to increase trust between participants of a given virtual collaboration. The mechanism is conceptual and the author has not attempted to provide any technical implementation details as it requires a separate research, however the backbone of the mechanism is blockchain technology which has already been implemented for various purposes such as crypto currency.

RQ5: How to regulate virtual collaboration for healthcare?

To answer RQ5, an SLA management mechanism is developed. The mechanism manages the life-cycle of SLA which is formation, deployment, enforcement and termination [87] and it is described in Section 6.2. The mechanism is specific to VBE and VO based healthcare virtual collaboration. Having an electronic contract between collaborating parties in virtual collaboration is one of the methods suggested by researchers to address the issue of trust.

To facilitate the implementation of the SLA mechanism, a set of SLA templates are defined in Section 6.5 that embodies the necessary details for contracts to be approved by parties in a given virtual collaboration. The templates are text-based human readable which are designed to increase transparency and separation of rights and responsibilities of the contract approvers. A mechanism is also suggested to convert the text-based contracts into machine readable OWL. The basic concepts of the templates are implemented as a mobile application prototype and are evaluated by prospective users. The results show that prospective users believe that the templates can contribute to the formalisation and regulation of SLA in healthcare virtual collaboration.

To examine the user acceptance of the concepts developed in the HC-VBE-F, it was implemented in a form of a mobile application prototype and examined using Technology Acceptance Model [34]. One of the mechanisms to investigate the suitability of a technology in a sector is to examine users' acceptance of the technology. The importance of studying the acceptance of users towards a healthcare information technology has been recognised by researchers [101].

TAM is one of the most widely used models used to examine users' acceptance of a new technology. In evaluating the acceptability of the HC-VBE-F, in Section 4.3.2, the original TAM is extended with four new constructs to develop two new TAMs (HC-VBE-TAM-Provider and HC-VBE-TAM-Requester). The results of the acceptance examinations are discussed in the next two sections.

This study also empirically evaluated four new technology acceptance factors specific to healthcare virtual collaboration system which are PCE, PHG, PHQ and PHA. The factors have not been evaluated in previous studies in the context of healthcare information technology systems and statistical results show that they are significant healthcare technology acceptance indicators. This result is an important contribution to the list of latent variables that have been validated previously through extending TAM for healthcare information technology systems.

6.7.1 HC-VBE-TAM-Provider Discussion

To investigate the healthcare providers acceptance of technologies developed in the HC-VBE-F for healthcare virtual collaboration based on the HC-VBE-TAM-Provider, nine hypotheses were defined in Section 4.3.2.2. Here, the result of testing those hypotheses based on the data analysis carried out in AMOS are presented and discussed. The authors of [109] state that significant path coefficient is a good tool to empirically accept or reject a hypothesis in TAMs and the recommend acceptance statistical significance value is equal or less than 0.05.

The evaluation results show that H_1a is accepted with a significance *p* value of less than 0.001 indicated by *** in AMOS; which means PHG has a significant effect on PCE. The result provides empirical proof that research participants believe a globally accessed healthcare virtual collaboration system will affect positively on its clinical effectiveness. A possible explanation for this could be the fact that a system that allows healthcare providers around the world to provide care will have more resources to be effective and provide a timely service. H_1b which hypothesises the causal effect of PHG on PEU is also accepted indicated by a significance value of less than 0.001. It means that healthcare providers think that a healthcare system which can be accessed globally will be easier to use. This is because “anytime anywhere” attribute of a system that can be used on a timely and on demand base increases system availability which makes it easier to use.

H_1c which hypothesises the causal effect of PHG on PU is rejected with a significance value of 0.390 which is more than 0.05. The result contradicts with expectation since one would expect that if a healthcare system can be used globally it would be more useful as more people can benefit from using it. H_2 which hypothesises the causal effect of PCE on PU is accepted with a significance value of less than 0.001. This result indicates that healthcare providers believe that clinical effectiveness of a virtual healthcare system will influence its usefulness. The causal effect of PEU on PU hypothesised in H_3a is rejected with a significance value of 0.232; which suggests that healthcare provides don’t think that if a system is easy to use it means it is also useful. H_3b hypothesises the causal effect of PU on AU is accepted with a significance value of less than 0.001. The result suggests that healthcare providers believe that the usefulness of a virtual healthcare system will influence their attitude towards using that system. H_4a is accepted as the computed significance value is 0.004. H_4a hypothesises the causal effect of PEU on AU; which indicates that healthcare providers attitude towards using healthcare systems developed based on the HC-VBE framework is affected by how easy they think the system is to use. The causal effect of AU on IU is accepted by healthcare providers which is hypothesised in H_4b. The acceptance of this hypothesis indicates that healthcare providers intention to use a virtual healthcare system developed based on the HC-VBE concept will lead them to heightened intention to use it. The causal effect of PU on IU which is hypothesised in H_5 is rejected with a significance value of 0.379. This result is also one of the unexpected ones since if a system is useful it would be expected to be used.

Overall, these results show that the participants were positive about the contribution that the HC-VBE-F can make to virtual collaboration for healthcare. Table 6.18 summarises the hypotheses test results and Figure 6.25 shows the accepted causal paths indicated by bold lines.

Table 6.18: HC-VBE-TAM-provider hypotheses testing results

Hypotheses	Evaluated Causal Effect			Sig.Level at $p<0.05$	Acceptance
H_1a	Perceived clinical effectiveness	<---	Perceived healthcare globalisation	$p<0.001$	Accepted
H_1b	Perceived ease of use	<---	Perceived healthcare globalisation	$p<0.001$	Accepted
H_1c	Perceived usefulness	<---	Perceived healthcare globalisation	0.390	Not Accepted
H_2	Perceived usefulness	<---	Perceived clinical effectiveness	$p<0.001$	Accepted
H_3a	Perceived usefulness	<---	Perceived ease of use	0.232	Not Accepted
H_3b	Attitude towards using	<---	Perceived usefulness	$p<0.001$	Accepted
H_4a	Attitude towards using	<---	Perceived ease of use	0.004	Accepted
H_4b	Intention to use	<---	Attitude towards using	0.002	Accepted
H_5	Intention to use	<---	Perceived usefulness	0.379	Not Accepted

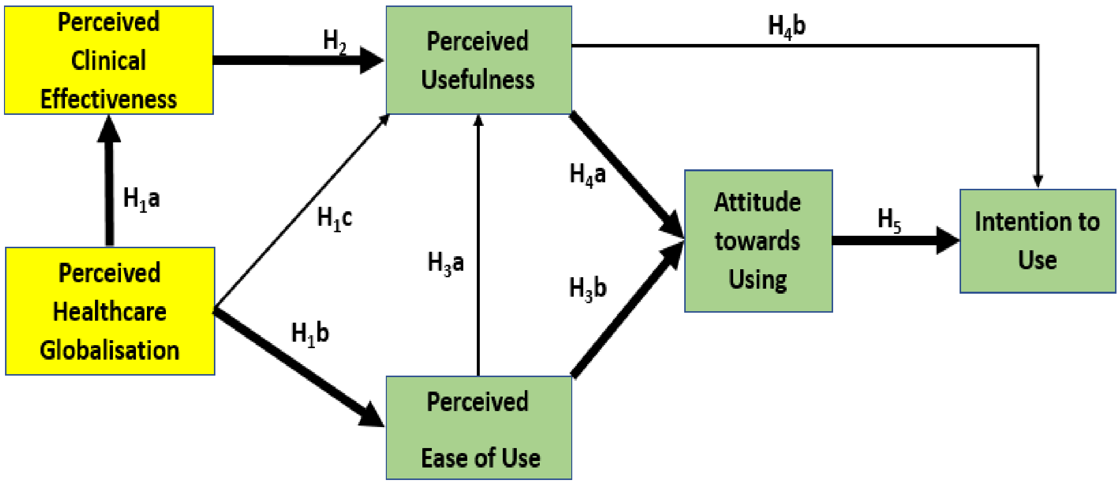


Figure 6.25: HC-VBE-TAM-provider accepted hypotheses results with bold lines indicating the accepted hypotheses.

6.7.2 HC-VBE-TAM-Requester Discussion

To investigate the healthcare requesters acceptance of technologies developed in the HC-VBE-F for healthcare virtual collaboration, based on the HC-VBE-TAM-Requester, nine hypotheses were defined in Section 4.3.2.3. Here, the result of testing those hypotheses are discussed based on the data analysis carried out in AMOS software.

The evaluation results show that H_1a is accepted with a significance value of less than 0.001 indicated by *** in AMOS; which means PHA has a significant effect on PHQ. The result indicates that healthcare requesters believe that a virtual healthcare system availability will influence the quality of services provided through it. H_1b which hypothesises the causal effect of PHA on PEU is accepted which is indicated by a significance value of less than 0.001. This means that healthcare requesters perceive that the availability of a virtual healthcare system will influence its easiness to use. H_1c which hypothesises the causal effect of PHA on PU is accepted with a significance value of less than 0.001. This is in line with expectation that a virtual healthcare system that is available to be used when needed will heighten its usefulness.

H_2 which hypothesises the causal effect of PHQ on PU is accepted with a significance value of 0.014. This result indicates that healthcare requesters believe that the quality of services provided in applications developed based on the HC-VBE-F will be a contributing factor in its usefulness. The causal effect of PEU on PU hypothesised in H_3a is rejected with a significance value of 0.737; which suggests that healthcare requesters don't believe that if a system is easy to use means it is also useful. H_3b hypothesises the causal effect of PEU on AU is accepted with a significance value of less than 0.001. The result suggests that healthcare requesters believe that the usefulness of a virtual healthcare system will influence their attitude towards using that system.

H_4a is accepted as the computed significance value is less than 0.001. H_4a hypothesises the causal effect of PU on AU; which indicates that healthcare requesters attitude towards using healthcare systems developed based on the HC-VBE framework is affected by how useful they think the system is. The causal effect of PU on IU which is hypothesised in H_4b is rejected with a significance value of 0.444. This result is unexpected since if a system is useful it would be expected to be used. The causal effect of AU on IU is accepted by healthcare requesters which is hypothesised in H_5. The acceptance of this hypothesis indicates that healthcare requesters intention to use a virtual healthcare system developed based on the HC-VBE concept will lead them to heightened intention to use it. Table 6.19 shows the hypotheses testing results and Figure 6.26 shows the accepted paths.

Table 6.19: HC-VBE-TAM-requester hypotheses testing results

Hypotheses	**Evaluated Causal Effect**			**Sig.Level at *p*<0.05**	**Acceptance**
H_1a	Perceived healthcare quality	<---	Perceived healthcare availability	$p<0.001$	Accepted
H_1b	Perceived ease of use	<---	Perceived healthcare availability	$p<0.001$	Accepted
H_1c	Perceived usefulness	<---	Perceived healthcare availability	$p<0.001$	Accepted
H_2	Perceived usefulness	<---	Perceived healthcare quality	0.014	Accepted

Hypotheses	Evaluated Causal Effect			Sig.Level at p<0.05	Acceptance
H_3a	Perceived usefulness	<---	Perceived ease of use	0.737	Not Accepted
H_3b	Attitude towards using	<---	Perceived ease of use	p<0.001	Accepted
H_4a	Attitude towards using	<---	Perceived usefulness	p<0.001	Accepted
H_4b	Intention to use	<---	Perceived usefulness	0.444	Not Accepted
H_5	Intention to use	<---	Attitude towards using	p<0.001	Accepted

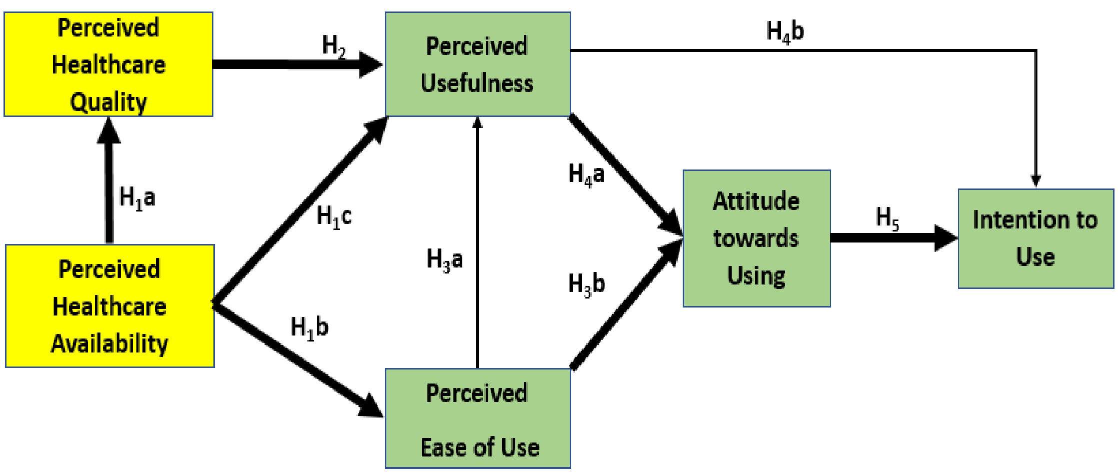


Figure 6.26: HC-VBE-TAM-requester accepted hypotheses with bold lines indicating the accepted hypotheses

6.7.3 HC-VBE-TAM Providers and Requester Comparison

The mobile application prototype developed based on the HC-VBE-F was evaluated by both healthcare providers and requesters. Each was tested with a slightly different TAMs, however the framework they were examining was the same. Therefore, it is important to compare the hypotheses testing results for both groups and discuss similarities and differences between them.

In both cases the extended TAM was comprised of 6 constructs two of which were newly added to examine relevant acceptability factors. Since the newly added constructs are examining different factors from different perspectives (Healthcare providers and healthcare requesters) their results cannot be compared. However, the TAMs have four original constructs (PEU, PU, AU and IU) and five hypotheses (H_3a, H_3b, H_4a, H_4b and H_5) in common, which allows their results and findings to be compared and discussed.

Table 6.20 shows the results of the comparison and perhaps not surprisingly both healthcare providers and requesters are the same in terms of accepting and rejecting hypotheses. Both users have accepted hypotheses H_3b, H_4a, H_4b and have rejected hypotheses H_3a and H_5. From the comparison result one can conclude that the developed virtual collaboration framework for healthcare was received equally by both healthcare providers and receivers and their intension to use systems that are going to be developed based on the HC-VBE-F is positive.

Table 6.20: Comparison between HC-VBE-TAM-provider and requester hypotheses testing results

Hypotheses	**Evaluated Causal Effect**			**Healthcare Providers Hypotheses Result**		**Healthcare Requesters Hypotheses Result**	
				Sig.Level at *p*<0.05	**Acceptance**	**Sig.Level at *p*<0.05**	**Acceptance**
H_3a	Perceived usefulness	<---	Perceived ease of use	0.232	Not Accepted	0.737	Not Accepted
H_3b	Attitude towards using	<---	Perceived usefulness	*p*<0.001	Accepted	*p*<0.001	Accepted

Hypotheses	Evaluated Causal Effect			Healthcare Providers Hypotheses Result		Healthcare Requesters Hypotheses Result	
				Sig.Level at $p<0.05$	Acceptance	Sig.Level at $p<0.05$	Acceptance
H_4a	Attitude towards using	<---	Perceived ease of use	0.004	Accepted	$p<0.001$	Accepted
H_4b	Intention to use	<---	Attitude towards using	0.002	Accepted	$p<0.001$	Accepted
H_5	Intention to use	<---	Perceived usefulness	0.379	Not Accepted	0.444	Not Accepted

6.7.4 HC-VBE Framework Limitations

This study was carried out on a local level which may not reflect the globalised view of the HC-VBE framework. The research would have carried more credit if participants were recruited from different regions and countries to provide feedback on the developed concept and prototype. However, because the framework needed to be presented and explained to prospective users before the prototype demonstration, it would have been difficult to gather and engage users beyond the local area. Another limitation is that the mobile application protype was developed in English but evaluated in a none-English speaking country, this posed a limitation on researchers to only invite those who had some basics of English. This may have affected the sample study representativeness of the local population negatively. To dilute the effect of this limitation the questionnaires used in the surveys were translated into the local language and the author answered questions and concerns during meetings held for data collection.

6.8 Chapter 6 Summary

This chapter presented a Healthcare Virtual Collaboration Framework (HC-VBE-F) that consists of a conceptual description, a member selection mechanism, a healthcare provider verification and validation mechanism and a set of SLA templates. The content of the chapter is summarised in the following points:

1- The HC-VBE-F is described on conceptual level which includes the components required to provide the use cases that facilitate the initiation, negotiation, creation, monitoring and archiving life-cycle of a given healthcare virtual collaboration. The framework working steps are explained in detail which spans over 16 steps.

2- A Member Selection Mechanism (HC-VBE-MSM) is developed that facilitates the selection process of suitable healthcare virtual collaboration participants. The mechanism is made up of a seven steps process. The applicability of the mechanism is demonstrated by applying it to a simple healthcare virtual collaboration case study.

3- A Healthcare Virtual Collaboration Provider Verification and Validation Mechanism (HC-VBE-PVVM) is developed using blockchain technology as a theoretical base. The mechanism presents a step by step guide as to how to verify and validate a healthcare provider who offers to provide a service to a requester. The applicability of the mechanism is demonstrated by applying it to a simple case study.

4- To standardise the terms and conditions of a healthcare virtual collaboration service and to regulate the rights and responsibilities of participants, a set of SLA templates are developed. The templates are text-based and human readable; designed to speed up the negotiation process between service requesters and service providers. The content of each clause of the SLA templates are explained in detail.

5- The HC-VBE-F evaluation results show that the framework is acceptable by healthcare service providers and requesters and their intension to use systems developed based on the framework is positive.

The research is concluded in the next chapter which contains research achievements and future works.

Chapter 7 : Conclusion and Future Works

This chapter concludes the research in Section 7.1, outline the main achievements in Section 7.2, presents publications in Section 7.3 and presents future works in Section 7.4.

7.1 Conclusion

Literatures in the field of healthcare show that the demand for healthcare is rising and the current model of healthcare provision which relies on centralised healthcare organisations such as hospitals are not coping well. The demand for healthcare is partly because of the rinse in population numbers and partly because of an aging population that is becoming a phenomenon in many countries such as Japan. The rise in demand has increased cost and affected resource availability in care institutions. To reduce cost and increase resource availability, virtual collaboration is seen as an answer for healthcare. However, the modelling, organisation and management of virtual collaboration for healthcare presents many challenges such as, role and service classification, member selection mechanisms and SLAs which are yet to be addressed.

The aim of this research was to model and develop virtual collaboration frameworks for healthcare. At the initial stage of the research, a number of challenges regarding the use of virtual collaboration in healthcare were presented from which 5 research questions were formulated. How to model and describe service provision in virtual collaboration for healthcare and how to organise and manage healthcare virtual collaboration are some of the questions researched in this thesis. System developers use models to simplify complex scenarios, in this thesis, a modelling framework to model healthcare virtual collaboration is developed. Based on the modelling framework, a healthcare virtual collaboration framework is developed to address the organisation and management aspects of virtual care provision.

Both frameworks are implemented and evaluated empirically using Technology Acceptance Modelling (TAM) as a theoretical evaluation framework and Structural Equation Modelling (SEM) is used as a statistical analysis technique to analyse the data collected during the evaluation process. AMOS is used as tool to compute statistical results based on the SEM models and the data collected for each of the developed frameworks.

The results of the evaluations show that both frameworks are received positively by prospective users (system developers in the case of the modelling framework and healthcare requesters and providers in the case of the collaboration framework). The contributions of this thesis are the modelling and collaboration frameworks for healthcare virtual collaboration. The main achievments of the thesis is summarised in the next section.

7.2 Research Achievements

The main achievements of this research can be summarised in the following points:

1. A comprehensive literature review has been carried out for healthcare sector in general and as a result the main roles and services in healthcare have been classified. This is considered as a noticeable achievement because it simplifies the structure of healthcare to a point that specialists and non-specialists can understand it.

2. A simple and generic service and participant classification mechanism (SPCM) has been developed for VBE and VO based healthcare virtual collaboration. The mechanism provides a conceptual classification of roles and services in healthcare which facilitate in simplifying complex virtual collaboration scenarios for the sector. It also helps healthcare system developers and professionals to plan ahead and identify requirements for a given virtual collaboration.

3. To provide a modelling capability specific to healthcare virtual collaboration, UML use case notations are extended to develop a domain specific modelling language (DSML) using the profiling technique provided by Object Management Group. The DSML is simple to understand and use, which can be used to model all HC-VBE and HC-VO collaboration scenarios.

4. A healthcare virtual collaboration service orchestration mechanism that is capable of modelling service workflows has been developed. The orchestration mechanism covers the scope and processes needed to show the steps of healthcare service provision virtually. It consists of a textual description language which has been developed to describe the orchestration mechanism. The language has a sentence structure and a set of vocabularies to standardise the description.

5. A general conceptual healthcare virtual collaboration framework that describes how collaborations are organised and managed has been developed. The framework is described in detail in terms of the number of components that make up the framework and how it works step by step.

6. A healthcare virtual collaboration member selection mechanism has been developed which is simple and effective. The mechanism has been described in detail and a step by step selection process is presented. The mechanism is developed in line with the other part of the research for ease of integration later in one package.

7. A healthcare provider verification and validation mechanism based on blockchain technology has been developed. The mechanism is feasible and effective if implemented and has the potential to address the issue of trust between healthcare stakeholders which is one of the most outstanding issue in healthcare and it is yet to be completely addressed by researchers.

8. A set of healthcare virtual collaboration SLA templates have been developed to regulate contracts between participants during HC-VBE collaborations. The templates are simple and generic which are capable of documenting all possible virtual collaboration agreements. The templates provide a base for all SLAs that might be created during a

healthcare virtual collaboration setting. The templates facilitate faster agreements between the collaborating participants and they are presented with fine details and possible implementation mechanisms. The templates are both human and machine readable.

9- Technology Acceptance Model (TAM) is extended and validated with 5 new constructs. Perceived Ability to Model (PAM) was added to the original TAM to evaluate the modelling framework by system developers. To evaluate the HC-VBE-F, Perceived Healthcare Araciality (PHA) and Perceived Healthcare Quality (PHQ) were added to the original TAM to evaluate healthcare requesters acceptance. Perceived Clinical Effectiveness (PCE) and Perceived Healthcare Globalisation (PHG) were added to the original TAM to evaluate the HC-VBE-F by healthcare providers. The outcome of this part of the research contributes towards further expanding and validating the applicability of TAM to evaluate new healthcare technologies. The new constructs have not been used in previous studies as user acceptance factors. The new constructs further develop TAM as a theoretical evaluation framework for healthcare technologies which is an achievement.

7.3 Published and Planned Publications

1. Published papers

A. H. Mahmud, M. Mohammadi, N. Ali, T. A. R. Khan, N. K. Al-Salihi, R. M. D. Omer, and J. Lu, "Technologies in medical information processing," Advances in Telemedicine for Health Monitoring: Technologies, Design and Applications, p. 31, 2020.

I was the main author of this book chapter in which we present a number of technologies in use in the field of medical information processing. The chapter in general is relevant to this thesis but in Section 1.6 we present a specific framework that is based on VBE and VO concept for healthcare information interpretation.

B. H. Mahmud, J. Lu and Q. Xu, "A Blockchain-based Service Provider Validation and Verification Framework for Healthcare Virtual Organization," *UHD Journal of Science and Technology*, vol. 2, no. 2, pp. 24–31, 2018.

I was the main author of this paper in which we have presented a healthcare service provider verification and validation framework for healthcare virtual collaboration. The paper is based on the framework described in Section 6.4.

C. H. Mahmud, “Modeling Virtual Organization for Home Healthcare Using UML,” Int. J. Comput. Sci. Eng, vol. 4, pp. 22–31, 2016.

I was the sole author of this paper in which I explain the limitation of UML modelling language in modelling healthcare virtual collaboration. The paper evaluates UML, based on a number of modelling criterions and discuss UML limitations. The paper was written as part of justification for developing the DSML for healthcare virtual collaboration.

D. H. Mahmud and J. Lu, “A GENERIC VOBE FRAMEWORK TO MANAGE HOME HEALTHCARE COLLABORATION,” *Journal of Theoretical and Applied Information Technology*, vol. 80, no. 2, p. 362, 2015.

I was the main author of this paper in which we present and describe a framework to classify roles and services for home healthcare based on VBE and VO concept. This paper is part of the SPCM described in Section 5.2.

2- Planed papers to be published in the future

A. A Healthcare Virtual Collaboration Framework: Evaluating Users’ Acceptance Using Technology Acceptance Model.

B. A Generic SLA template for VBE- based Healthcare Virtual Collaborations.

C. The Role of Robot in VBE-based Healthcare Virtual Collaborations.

D. A Member Selection Mechanism for VBE-based healthcare Virtual Collaborations.

E. An Orchestration Mechanism for VBE-based healthcare Virtual Collaborations.

F. A Domain Specific Modelling Language for VBE-based healthcare Virtual collaborations

G. An OWL-based Model for Healthcare Virtual Collaboration Service Level Agreement

7.4 Future Works

Healthcare virtual collaboration is multi-faceted and requires much more research to address challenges and issues in realising it. This section presents a number of future works that would extend the implications and contributions of this thesis.

1. **Cultural differences during HC-VBE-based collaborations**

Culture may be an influential factor in the usability and acceptability of virtual healthcare as people are directed to use an electronic medium to explain their health issues rather that a face to face method. In some cultures, due to religious beliefs or cultural boundaries it may not be acceptable for people to use an online virtual method to speak to someone they meet for the first time. The frameworks developed in this research encourage such encounters and healthcare providers can be recruited from anywhere in the world. It would be interesting and useful to study the influence of culture in healthcare virtual collaborations.

Language is another important factor in the success of systems developed based on the HC-VBE framework. Healthcare requesters and providers may not be able to communicate directly with each other but through an interpreter since they may be from different countries. Tackling this challenge would also be an interesting topic to research. Therefore, culture and language barriers are two new electronic healthcare system acceptability variables that can be investigated in future studies.

2. **HC-VBEs visibility**

The concepts presented in this thesis are global where many HC-VBEs can be created around the world to provide services, collaborate and share resources. The globalised concept of HC-VBE presents a visibility challenge. The question here is how to make HC-VBEs visible in order for them to be discoverable to each other. This is an area of virtual collaboration for healthcare that can be researched in the future.

3. Service orchestration simulation and validation

The service orchestration mechanism presented in this thesis is theoretical and text based with no simulation and validation mechanism. Simulation can provide the facility to visualise healthcare virtual collaboration service provision in action. Service orchestration validation is crucial to check the soundness of the flow of activities to achieve a goal before its implementation. Developing a mechanism to simulate and validate the service orchestration in healthcare is a future work that offers theoretical and technical challenges to future researchers.

4. Healthcare requester data security and privacy

The issue of data security and privacy of users is well recognised and the importance of the topic is well researched. However, the theoretical mechanism and the technical implementation varies depending on the purpose of a system. Healthcare virtual collaborations based on the HC-VBE-F presented in this thesis surely present its own unique security and privacy challenges which can be researched in the future.

5. SLA enforcement and monitoring mechanism

One of the most obvious challenge presented in the HC-VBE-F is to do with SLA monitoring. After an SLA is agreed between healthcare requesters and providers, a robust mechanism is required for the SLA enforcement and monitoring. The mechanism could involve artificial intelligence and smart decision support systems to cope with the dynamic nature of healthcare virtual collaboration. Developing a mechanism to carry out SLA enforcement and monitoring is a research challenge which can be researched in the future.

6. SLA dispute management

Service in HC-VBE based system are provided based on SLA which defines the terms and conditions of the service. The question is, if there is a dispute regarding the extend of observed terms and conditions by one of the signatory parties of the contract how the dispute is managed as communication is virtual. This suggests the need for a simple and effective dispute management mechanism which is a future research opportunity.

7. HC-BE-PVVM development and implementation

The healthcare provider verification and validation mechanism outlined in Section 6.4 is a conceptual one and requires further research and implementation. The mechanism is based on blockchain technology which is a fairly new technology that offers a number of conceptual and implementational challenges that can be researched in the future.

8. Member selection mechanism development and implementation

The HC-VBE-MSM described in Section 6.3 is a conceptual one that is described in an abstract level which may need further research and implementation to make it usable in real systems. Despite the fact that it has been described in a step by step process but it lacks implementation details which offers development challenges that can be addressed by further research in the future.

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Appendices

Below a brief introduction to each of the appendices included in this thesis is provided:

Appendix A

During data collection a consent form was given to each survey participants along with the relevant questionnaire to fill in, appendix A is the consent from.

Appendix B

The appendix is composed of two parts, B1 which is an image of the questionnaire which was given to healthcare providers to fill in for the HC-VBE-F mobile application acceptance testing and appendix B2 which is the Kurdish translation of the questionnaire.

Appendix C

The appendix is composed of two parts, C1 which is an image of the questionnaire which was given to healthcare requesters to fill in for the HC-VBE-F mobile application acceptance testing and appendix C2 which is the Kurdish translation of the questionnaire.

Appendix D

The appendix is composed of two parts, D1 which is an image of the questionnaire which was given to system developers to fill in for the HC-VBE-M-F java application acceptance testing and appendix D2 which is the Kurdish translation of the questionnaire.

Appendix E

This appendix contains examples of official permission letters obtained to conduct part of the research at certain healthcare authorities and institution.

Appendix F

The appendix provides images of all the data collected from survey participants of the HC-VBE-M-F java application.

Appendix G

The appendix provides images of all the data collected from healthcare providers during the HC-VBE-F mobile application evaluation.

Appendix H

The appendix provides images of all the data collected from healthcare requesters during the HC-VBE-F mobile application evaluation.

Appendix I

The appendix is a number of tables with the HC-VBE-F mobile application screenshots and explanations.

Appendix J

This appendix is an example of AMOS data analysis output from which a selection has been used for evaluation purpose in this thesis. The analysis output is for the HC-VBE-F-Provider acceptance .data collected from healthcare providers.

Appendix A: Research survey consent form

RESEARCH CONSENT FORM

Research Details
Full Name of Researcher: Hoger Hussen Mahmud
Student Number: u1450239
Title of Research: Modelling and Investigating Virtual Collaboration for Healthcare
Research Description: The aim of this research is to develop modelling and collaboration concepts for healthcare virtual collaboration, based on Virtual Breeding Environment (VBE) and Virtual Organisation (VO) concepts. The developed concepts then will be evaluated using Technology Acceptance Model (TAM) mechanism to establish the level of acceptability of the developed concepts amongst healthcare providers, healthcare receivers and virtual system developers.
Research mode: PhD in Computer Science and informatics
Department: Computer Science
School: School of Computing & Engineering
University: Huddersfield - UK

Participant Details
Full Name of Participant:
Age: 15-20 ☐ 20-30 ☐ 30-40 ☐ 40-50 ☐ 50-60 ☐ Above 60 ☐
Sex: Male ☐ Female ☐
Contact Number:
Email Address:
Education: Secondary School ☐ High School ☐ Graduate ☐ Post-Graduate ☐
Profession:
Place of Work:

Please read and tick the boxes as appropriate and sign and date the declaration at the end. Please ask if you want more clarification on any of the points.

- The research has been explained to me in verbal and / or written form by the researcher. **Yes** ☐ **No** ☐
- I understand that the research will involve filling in a number of questionnaires regarding concepts being developed for this research. **Yes** ☐ **No** ☐
- I understand that the research involves using personal mobile phones to test a software prototype developed for the research. **Yes** ☐ **No** ☐

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- I understand that the research process takes 45 minutes to complete. **Yes** ☐ **No** ☐
- I understand that I may withdraw from this study at any time without having to give an explanation. **Yes** ☐ **No** ☐
- I understand that all information about me will be treated in strict confidence and that I will not be named in any written work arising from this study. **Yes** ☐ **No** ☐
- I understand that any recordings of me (Video, sound and image) will be used for research purposes only and I give my consent to their uses. **Yes** ☐ **No** ☐

I freely give my consent to participate in this research study and I have been given a copy of this form for my own information.

Signature: ……………………………………………………………………………………

Date: ……………………………………………………………………………………………

Appendix B: HC-VBE-F healthcare professionals survey questionnaire

Appendix B1

Questionnaire 1

Questionnaire 1 (Healthcare professionals)

The purpose of this questionnaire is to examine Technology Acceptance Model of developed VOBE-based concepts for healthcare virtual collaboration by healthcare professionals.

Keys: 1= Strongly Disagree 2= Quite Disagree 3= Slightly Disagree 4= Neutral 5= Slightly Agree 6= Quite Agree 7= Strongly Agree

1. Expected healthcare globalization	**Strongly Disagree**			**Neutral**			**Strongly Agree**
1. Using the HC-VOBE application enhances healthcare providers collaboration.	1	2	3	4	5	6	7
2. Using the HC-VOBE application helps making healthcare more widely available.	1	2	3	4	5	6	7
3. Using the HC-VOBE application provides the opportunity to serve healthcare seekers around the world.	1	2	3	4	5	6	7
4. Using the HC-VOBE application would be instrumental in globalizing healthcare.	1	2	3	4	5	6	7

2. Expected usefulness (convenience)	**Strongly Disagree**			**Neutral**			**Strongly Agree**
1. Using the HC-VOBE application improves my performance in providing care.	1	2	3	4	5	6	7
2. Using the HC-VOBE application improves my availability to provide care.	1	2	3	4	5	6	7
3. Using the HC-VOBE application improves my patient management tasks.	1	2	3	4	5	6	7
4. Overall, I find the HC-VOBE application useful in providing healthcare.	1	2	3	4	5	6	7

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3. Expected ease of use	Strongly Disagree			Neutral			Strongly Agree
1. Learning to use the HC-VOBE application would be easy for me.	1	2	3	4	5	6	7
2. I would find it easy to provide care using the HC-VOBE application.	1	2	3	4	5	6	7
3. It would be easy for me to become skilful at using the HC-VOBE application.	1	2	3	4	5	6	7
4. I would find the HC-VOBE application easy to use.	1	2	3	4	5	6	7

4. Expected Clinical effectiveness	Strongly Disagree			Neutral			Strongly Agree
1. Using the HC-VOBE application would facilitate providing the right care through making patient history available.	1	2	3	4	5	6	7
2. Using the HC-VOBE application would facilitate providing the right care through recruiting specialist care provider.	1	2	3	4	5	6	7
3. Using the HC-VOBE application would facilitate providing timely care through anytime collaboration capability.	1	2	3	4	5	6	7
4. Using the HC-VOBE application would facilitate providing care in the right place through anywhere collaboration capability.	1	2	3	4	5	6	7

5. Attitude towards using	Strongly Disagree			Neutral			Strongly Agree
1. Using the HC-VOBE application would be a good idea.	1	2	3	4	5	6	7
2. Using the HC-VOBE application make providing healthcare more interesting.	1	2	3	4	5	6	7
3. Using the HC-VOBE application would be a pleasant experience.	1	2	3	4	5	6	7
4. I would like to use the HC-VOBE application.	1	2	3	4	5	6	7

6. Intention to use	Strongly Disagree			Neutral			Strongly Agree
1. I intend to use the HC-VOBE application.	1	2	3	4	5	6	7
2. It is likely that I will use the HC-VOBE application.	1	2	3	4	5	6	7
3. I expect to use the HC-VOBE application.	1	2	3	4	5	6	7
4. I am willing to recommend other people to use the HC-VOBE application.	1	2	3	4	5	6	7

Thank you for completing this questionnaire

If you have any questions regarding this questionnaire please email: hoger.mahmud@hud.ac.uk

Appendix B2

Questionnaire 1

Questionnaire 1 (Healthcare professionals)

The purpose of this questionnaire is to examine Technology Acceptance Model of developed VOBE-based concepts for healthcare virtual collaboration by healthcare professionals.

Keys: 1= Strongly Disagree 2= Quite Disagree 3= Slightly Disagree 4= Neutral 5= Slightly Agree 6= Quite Agree 7= Strongly Agree

1. Expected healthcare globalization	**وەرگێڕاو بۆ کوردی**
1. Using the HC-VOBE application enhances healthcare providers collaboration.	1.بەکارهێنانی ئەپلیکەیشنی HC-VOBE هەماهەنگی لە نێوان دابینکەرانی خزمەتگوزاری تەندروستی باشتر دەکات.
2. Using the HC-VOBE application helps making healthcare more widely available.	2.بەکارهێنانی ئەپلیکەیشنی HC-VOBE هاوکارە لە دابینکردنی خزمەتگوزاری تەندروستی بە شێوەیەکی فراوانتر.
3. Using the HC-VOBE application provides the opportunity to serve healthcare seekers around the world.	3.بەکارهێنانی ئەپلیکەیشنی HC-VOBE دەرفەت دەرەخسێنێت کە خزمەتی داواکارانی خزمەتگوزاری تەندروستی بکرێت لە هەرشوێنێک بن لە دونیا.
4. Using the HC-VOBE application would be instrumental in globalizing healthcare.	4.بەکارهێنانی ئەپلیکەیشنی HC-VOBE هاوکارە لە بەجیهانیکردنی خزمەتگوزاری تەندروستی

2. Expected usefulness (convenience)	**وەرگێڕاو بۆ کوردی**
1. Using the HC-VOBE application improves my performance in providing care.	1.بەکارهێنانی ئەپلیکەیشنی HC-VOBE توانای دابینکردنی خزمەتگوزاری تەندروستیم باشتردەکات.
2. Using the HC-VOBE application improves my availability to provide care.	2.بەکارهێنانی ئەپلیکەیشنی HC-VOBE بەردەست بوونم بۆ دابینکردنی خزمەتگوزاری تەندروستی زیاتر دەکات.
3. Using the HC-VOBE application improves my patient management tasks.	3.بەکارهێنانی ئەپلیکەیشنی HC-VOBE توانای بەڕێوەبردنی نەخۆشەکانم باشتر دەکات.
4. Overall, I find the HC-VOBE application useful in providing healthcare.	4.بەشێوەیەکی گشتی پێم وایە بەکارهێنانی ئەپلیکەیشنی HC-VOBE بە سودە بۆ دابینکردنی خزمەتگەزاری تەندروستی.

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Questionnaire 1

3. **Expected ease of use**	**وەرگێڕاو بۆ کوردی**
1. Learning to use HC-VOBE application would be easy for me.	1.فێربوونی بەکارهێنانی ئەپلیکەیشنی HC-VOBE ئاسان دەبێت بۆ من.
2. I would find it easy to provide care using the HC-VOBE application.	2.بەلامەوە ئاسان دەبێت کە خزمەتگوزاری تەندروستی دابین بکەم لە ڕێگەی بەکارهێنانی ئەپلیکەیشنی HC-VOBE.
3. I would be easy for me to become skilful at using the HC-VOBE application.	3.بۆ من ئاسان دەبێت کە شارەزابم لە بەکارهێنانی ئەپلیکەیشنی HC-VOBE .
4. I would find HC-VOBE application easy to use.	4.بەکارهێنانی ئەپلیکەیشنی HC-VOBE بۆ من ئاسان دەبێت

4. **Expected Clinical effectiveness**	**وەرگێڕاو بۆ کوردی**
1. Using the HC-VOBE application would facilitate providing the right care through making patient history available.	1.بەکارهێنانی ئەپلیکەیشنی HC-VOBE ئاسانکاری دەکات لە دابینکردنی خزمەتگوزاری دروست لە ڕێگەی بەردەستکردنی مێژووی نەخۆشەکە.
2. Using the HC-VOBE application would facilitate providing the right care through recruiting specialist care provider.	2.بەکارهێنانی ئەپلیکەیشنی HC-VOBE ئاسانکاری دەکات لە دابینکردنی خزمەتگوزاری تەندروستی دروست لە ڕێگەی دۆزینەوەی کەسی پسپۆڕ.
3. Using the HC-VOBE application would facilitate providing timely care through anytime collaboration capability.	3.بەکارهێنانی ئەپلیکەیشنی HC-VOBE ئاسانکاری دەکات لە دابینکردنی خزمەتگوزاری کاتی لەڕێگەی دابینکردنی توانای هەماهەنگی کاتی.
4. Using the HC-VOBE application would facilitate providing care in the right place through anywhere collaboration capability.	4.بەکارهێنانی ئەپلیکەیشنی HC-VOBE ئاسانکاری دەکات لە دابینکردنی خزمەتگوزاری شوێنی لەڕێگەی دابینکردنی توانای هەماهەنگی شوێنی.

Questionnaire 1

5. Attitude towards using	وەرگێڕاو بۆ کوردی
1. Using the HC-VOBE application would be a good idea.	1.بەکارهێنانی ئەپلیکەیشنی HC-VOBE بیرۆکەیەکی باش دەبێت.
2. Using the HC-VOBE application make providing healthcare more interesting.	2.بەکارهێنانی ئەپلیکەیشنی HC-VOBE دابینکردنی خزمەتگوزاری تەندروستی ئارەزوومەند تر دەکات.
3. Using the HC-VOBE application would be a pleasant experience.	3.بەکارهێنانی ئەپلیکەیشنی HC-VOBE ئەجروبەیەکی ئاسودە بەخش دەبێت.
4. I would like to use the HC-VOBE application	4.ئارەزووم هەیە بۆ بەکارهێنانی ئەپلیکەیشنی HC-VOBE.

6. Intention to use	وەرگێڕاو بۆ کوردی
1. I intend to use the HC_VOBE application.	1.من ئامادەیم ئیایە بۆ بەکارهێنانی ئەپلیکەیشنی HC-VOBE.
2. It is likely that I will use the HC_VOBE application.	2.ئەگەری هەیە کە من ئەپلیکەیشنی HC-VOBE بەکاربهێنم.
3. I expect to use the HC_VOBE application.	3.پێشبینی دەکەم دەکەم کە من ئەپلیکەیشنی HC-VOBE بەکاربهێنم.
4. I am willing to recommend other people to use the HC_VOBE application.	4.من ئامادەیم ئیایە پێشنیاری بەکارهێنای ئەپلیکەیشنی HC-VOBE بۆ کاسانی تر بکەم.

زۆر سوپاس بۆ هاوکاریت

Appendix C: HC-VBE-F healthcare requesters survey questionnaire

Appendix C1

Questionnaire 2

Questionnaire 2 (Prospective Patients)

The purpose of this questionnaire is to examine Technology Acceptance Model of developed VOBE-based concepts for healthcare virtual collaboration by prospective patients.

Keys: 1= Strongly Disagree 2= Quite Disagree 3= Slightly Disagree 4= Neutral 5= Slightly Agree 6= Quite Agree 7= Strongly Agree

1. Expected healthcare availability	Strongly Disagree			Neutral			Strongly Agree
1. Using the HC-VOBE application facilitate fair access to healthcare.	1	2	3	4	5	6	7
2. Using the HC-VOBE application provides anytime anywhere access to healthcare.	1	2	3	4	5	6	7
3. Using the HC-VOBE application makes more varieties of healthcare available.	1	2	3	4	5	6	7
4. Using the HC-VOBE application makes more specialist healthcare provider available.	1	2	3	4	5	6	7

2. Expected usefulness (convenience)	Strongly Disagree			Neutral			Strongly Agree
1. Using the HC-VOBE application improves my chance to get on demand healthcare.	1	2	3	4	5	6	7
2. Using the HC-VOBE application saves me effort and time to find needed healthcare.	1	2	3	4	5	6	7
3. Using the HC-VOBE application would be more convenient than visiting healthcare institutions.	1	2	3	4	5	6	7
4. Overall, I find the HC-VOBE application useful in receiving healthcare.	1	2	3	4	5	6	7

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3. Expected ease of use	Strongly Disagree			Neutral			Strongly Agree
1. Learning to use the HC-VOBE application would be easy for me.	1	2	3	4	5	6	7
2. I would find it easy to receive care using the HC-VOBE application.	1	2	3	4	5	6	7
3. It would be easy for me to become skilful at using the HC-VOBE application.	1	2	3	4	5	6	7
4. I would find the HC-VOBE application easy to use.	1	2	3	4	5	6	7

4. Expected healthcare quality	Strongly Disagree			Neutral			Strongly Agree
1. Using the HC-VOBE helps me find the right healthcare provider.	1	2	3	4	5	6	7
2. Using the HC-VOBE application helps me find healthcare respectful of and responsive to my preferences and needs.	1	2	3	4	5	6	7
3. Using the HC-VOBE application helps me find the right healthcare for reasonable price.	1	2	3	4	5	6	7
4. Using the HC-VOBE application helps me find the right healthcare in a reasonable time.	1	2	3	4	5	6	7
5. Using the HC-VOBE application helps me find the right healthcare from a location of my choice.	1	2	3	4	5	6	7

Questionnaire 2

5. Attitude towards using	Strongly Disagree			Neutral			Strongly Agree
1. Using the HC-VOBE application would be a good idea.	1	2	3	4	5	6	7
2. Using the HC-VOBE application makes receiving healthcare more interesting.	1	2	3	4	5	6	7
3. Using the HC-VOBE application would be a pleasant experience.	1	2	3	4	5	6	7
4. I would like to use the HC-VOBE application.	1	2	3	4	5	6	7

6. Intention to use	Strongly Disagree			Neutral			Strongly Agree
1. I intend to use the HC-VOBE application.	1	2	3	4	5	6	7
2. It is likely that I will use the HC-VOBE application.	1	2	3	4	5	6	7
3. I expect to use the HC-VOBE application.	1	2	3	4	5	6	7
4. I am willing to recommend other people to use the HC-VOBE application.	1	2	3	4	5	6	7

Thank you for completing this questionnaire

If you have any questions regarding this questionnaire please email: hoger.mahmud@hud.ac.uk

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Appendix C2

Questionnaire 2

Questionnaire 2 (Prospective Patients)

The purpose of this questionnaire is to examine Technology Acceptance Model of developed VOBE-based concepts for healthcare virtual collaboration by prospective patients.

Keys: 1= Strongly Disagree 2= Quite Disagree 3= Slightly Disagree 4= Neutral 5= Slightly Agree 6= Quite Agree 7= Strongly Agree

1. Expected healthcare availability	**وەرگێردراو بۆ کوردی**
1. Using the HC-VOBE application facilitate fair access to healthcare.	1.بەکارهێنانی ئەپلیکەیشنی HC-VOBE ئاسانکاری دەکات لە بەردەستکردنی دادپەروەرانەی خزمەتگوزاری تەندروستی.
2. Using the HC-VOBE application provides anytime anywhere access to healthcare.	2.بەکارهێنانی ئەپلیکەیشنی HC-VOBE خزمەتگوزاری تەندروستی ئانی و شوێنی بەردەست دەکات.
3. Using the HC-VOBE application makes more varieties of healthcare available.	3.بەکارهێنانی ئەپلیکەیشنی HC-VOBE جۆری زیاتر لە خزمەتگوزاری تەندروستی بەردەست دەکات.
4. Using the HC-VOBE application makes more specialist healthcare provider available.	4.بەکارهێنانی ئەپلیکەیشنی HC-VOBE جۆری زیاتر لە پسپۆری تەندروستی بەردەست دەکات.

2. Expected usefulness (convenience)	**وەرگێردراو بۆ کوردی**
1. Using the HC-VOBE application improves my chance to get on demand healthcare.	1.بەکارهێنانی ئەپلیکەیشنی HC-VOBE ئەگەری دەستکەوتنی خزمەتگوزاری تەندروستی پێویستم زیاتر دەکات.
2. Using the HC-VOBE application saves me effort and time to find needed healthcare	2.بەکارهێنانی ئەپلیکەیشنی HC-VOBE کات و هەوڵم بۆ دەگێڕێتەوە لە دۆزینەوەی خزمەتگوزاری تەندروستی پێویست.
3. Using the HC-VOBE application would be more convenient than visiting healthcare institutions.	3.بەکارهێنانی ئەپلیکەیشنی HC-VOBE لەبارتر دەبێت تا سەردانیکردنی دامەزراوە تەندروستی یەکان.

Page **1** of **3**

Questionnaire 2

4. Overall, I find the HC-VOBE application useful in receiving healthcare.	4.بەشێوەیەکی گشتی بەکارهێنانی ئەپلیکەیشنی HC-VOBE بە بەسود دەبینم لە بەدەست هێنانی خزمەتگوزاری تەندروستی.

3. Expected ease of use	**وەرگێڕدراو بۆ کوردی**
1. Learning to use the HC-VOBE application would be easy for me.	1.فێربوونی بەکارهێنانی ئەپلیکەیشنی HC-VOBE بۆ من ئاسان دەبێت.
2. I would find it easy to receive care using the HC-VOBE application.	2.من با ئاسانی دەبینیم خزمەتگوزاری تەندروستیم پێبگات لە ڕێگەی بەکارهێنانی ئەپلیکەیشنی HC-VOBE.
3. I would be easy for me to become skilful at using the HC-VOBE application.	3.ئاسان دەبێت کە من شارەزابم لە بەکارهێنانی ئەپلیکەیشنی HC-VOBE.
4. I would find the HC-VOBE application easy to use.	4.بەکارهێنانی ئەپلیکەیشنی HC-VOBE بە ئاسان دەبینم.

4. Expected healthcare quality	**وەرگێڕدراو بۆ کوردی**
1. Using the HC-VOBE helps me find the right healthcare provider.	1.بەکارهێنانی ئەپلیکەیشنی HC-VOBE هاوکارم دەبێت لە دۆزینەوەی پسپۆڕی تەندروستی دروست.
2. Using the HC-VOBE application helps me find healthcare respectful of and responsive to my preferences and needs.	2.بەکارهێنانی ئەپلیکەیشنی HC-VOBE هاوکارم دەبێت لە دۆزینەوەی خزمەتگوزاری تەندروستی بە پێی داواکاری و پێویستی خۆم.
3. Using the HC-VOBE application helps me find the right healthcare for reasonable price.	3.بەکارهێنانی ئەپلیکەیشنی HC-VOBE هاوکارم دەبێت لە دۆزینەوەی خزمەتگوزاری تەندروستی بە نرخێکی گونجاو.
4. Using the HC-VOBE application helps me find the right healthcare in a reasonable time	4.بەکارهێنانی ئەپلیکەیشنی HC-VOBE هاوکارم دەبێت لە دۆزینەوەی خزمەتگوزاری تەندروستی بە کاتێکی گونجاو.

Questionnaire 2

5. Using the HC-VOBE application helps me find the right healthcare from a location of my choice.	5.بەکارهێنانی ئەپلیکەیشنی HC-VOBE هاوکارم دەبێت لە دۆزینەوەی خزمەتگوزاری تەندروستی لە شوێنی هەڵبژاردەی خۆم.

5. Attitude towards using	وەرگێردراو بۆ کوردی
1. Using the HC-VOBE application would be a good idea.	1. بەکارهێنانی ئەپلیکەیشنی HC-VOBE بیرۆکەیەکی باش دەبێت.
2. Using the HC-VOBE application makes receiving healthcare more interesting.	2.بەکارهێنانی ئەپلیکەیشنی HC-VOBE بایینکردنی خزمەتگوزاری تەندروستی ئارەزوومەند تر دەکات.
3. Using the HC-VOBE application would be a pleasant experience.	3.بەکارهێنانی ئەپلیکەیشنی HC-VOBE ئەجروبەیەکی ئاسودە بەخش دەبێت.
4. I would like to use the HC-VOBE application	4.ئارەزووم هەیە بۆ بەکارهێنانی ئەپلیکەیشنی HC-VOBE.

6. Intention to use	وەرگێردراو بۆ کوردی
1. I intend to use the HC-VOBE application.	1.من ئامادەیم ئیایە بۆ بەکارهێنانی ئەپلیکەیشنی HC-VOBE.
2. It is likely that I will use the HC-VOBE application.	2.ئەگەری هەیە کە من ئەپلیکەیشنی HC-VOBE بەکاربهێنم.
3. I expect to use the HC-VOBE application.	3.پێشبینی دەکەم کە من ئەپلیکەیشنی HC-VOBE بەکاربهێنم.
4. I am willing to recommend other people to use the HC-VOBE application.	4.من ئامادەیم ئیایە پێشنیاری بەکارهێنای ئەپلیکەیشنی HC-VOBE بۆ کەسانی تر بکەم.

زۆر سوپاس بۆ هاوکاریت

Appendix D: HC-VBE-M-F System Developer Questionnaire

Appendix D1

Questionnaire 4

Questionnaire 4 (System Developers)

The purpose of this questionnaire is to examine Technology Acceptance Model of the modelling language and the orchestration mechanism developed for healthcare virtual collaboration based on VOBE concept by system developers.

Keys: 1= Strongly Disagree 2= Quite Disagree 3= Slightly Disagree 4= Neutral 5= Slightly Agree 6= Quite Agree 7= Strongly Agree

1. Expected ability to illustrate	Strongly Disagree			Neutral			Strongly Agree
1. Models produced using HC-VOBE modelling package represents virtual collaboration in healthcare.	1	2	3	4	5	6	7
2. Models produced using HC-VOBE modelling package simplifies complex healthcare virtual collaboration scenarios.	1	2	3	4	5	6	7
3. Models produced using HC-VOBE modelling package represent roles of virtual healthcare stakeholders.	1	2	3	4	5	6	7
4. Models produced using HC-VOBE modelling package describes the collaboration process between virtual healthcare stakeholders.	1	2	3	4	5	6	7

2. Expected usefulness	Strongly Disagree			Neutral			Strongly Agree
1. Using the HC-VOBE modelling package improves my healthcare virtual system development process.	1	2	3	4	5	6	7
2. Using the HC-VOBE modelling package saves me effort and time to understand a healthcare virtual collaboration scenario.	1	2	3	4	5	6	7

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3. Using the HC-VOBE modelling package would be more effective to use for modelling healthcare virtual collaboration systems than other modelling languages.	1	2	3	4	5	6	7
4. Overall, I find the HC-VOBE modelling package useful for modelling healthcare virtual collaboration systems.	1	2	3	4	5	6	7

3. Expected ease of use	Strongly Disagree			Neutral			Strongly Agree
1. Learning to use HC-VOBE modelling package would be easy for me.	1	2	3	4	5	6	7
2. I would find it easy to model healthcare virtual collaboration systems using the HC-VOBE modelling package.	1	2	3	4	5	6	7
3. It would be easy for me to become skilful at using the HC-VOBE modelling package.	1	2	3	4	5	6	7
4. I would find the HC-VOBE modelling package easy to use.	1	2	3	4	5	6	7

4. Attitude towards using	Strongly Disagree			Neutral			Strongly Agree
1. Using the HC-VOBE modelling package would be a good idea.	1	2	3	4	5	6	7
2. Using the HC-VOBE modelling package makes modelling healthcare systems more interesting.	1	2	3	4	5	6	7
3. Using the HC-VOBE modelling package would be a pleasant experience.	1	2	3	4	5	6	7

Questionnaire 4

4. I would like to use the HC-VOBE modelling package.	1 2 3 4 5 6 7

5. Intention to use	Strongly Disagree			Neutral			Strongly Agree
1. I intend to use the HC-VOBE modelling package.	1	2	3	4	5	6	7
2. It is likely that I will use the HC-VOBE modelling package.	1	2	3	4	5	6	7
3. I expect to use the HC-VOBE modelling package.	1	2	3	4	5	6	7
4. I am willing to recommend other people to use the HC-VOBE modelling package.	1	2	3	4	5	6	7

Thank you for completing this questionnaire

If you have any questions regarding this questionnaire please email: hoger.mahmud@hud.ac.uk

Page 3 of 3

Appendix D2

Questionnaire 4

Questionnaire 4 (System Developers)

The purpose of this questionnaire is to examine Technology Acceptance Model of the modelling language and the orchestration mechanism developed for healthcare virtual collaboration based on VOBE concept by system developers.

Keys: 1= Strongly Disagree 2= Quite Disagree 3= Slightly Disagree 4= Neutral 5= Slightly Agree 6= Quite Agree 7= Strongly Agree

1. Expected ability to illustrate	وەرگێڕاو بۆ کوردی
1. Models produced using HC-VOBE modelling package represents virtual collaboration in healthcare.	1.وێنای بەرهەم هاتوو لە ڕێگەی بەکارهێنانی پاکێجی HC-VOBE بۆ وێنا کردن وێنەی هەمانگی نابەرجەستە لە خزمەتگوزاری تەندروستی دەکات.
2. Models produced using HC-VOBE modelling package simplifies complex healthcare virtual collaboration scenarios.	2.وێنای بەرهەم هاتوو لە ڕێگەی بەکارهێنانی پاکێجی HC-VOBE بۆ وێنا کردن سیناریۆی ئاڵۆز لە هەمانگی نابەرجەستە لە خزمەتگوزاری تەندروستی سادە دەکات.
3. Models produced using HC-VOBE modelling package represent roles of virtual healthcare stakeholders.	3.وێنای بەرهەم هاتوو لە ڕێگەی بەکارهێنانی پاکێجی HC-VOBE بۆ وێنا کردن وێنای دەوری بەشداربوانی نابەرجەستەی خزمەتگوزاری تەندروستی دەکات.
4. Models produced using HC-VOBE modelling package describes the collaboration process between virtual healthcare stakeholders.	4.وێنای بەرهەم هاتوو لە ڕێگەی بەکارهێنانی پاکێجی HC-VOBE بۆ وێنا کردن پرۆسەی هەماهەنگی لە نێوان بەشداربوانی نابەرجەستەی خزمەتگوزاری تەندروستی ڕوندەکاتەوە.

2. Expected usefulness	وەرگێڕاو بۆ کوردی
1. Using the HC-VOBE modelling package improves my healthcare virtual system development process.	1.بەکارهێنانی پاکێجی HC-VOBE بۆ وێنا کردن کاری پەرەپێدانی سیستەمی نابەرجەستەی خزمەتگوزاری تەندروستی باشتر دەکات.
2. Using the HC-VOBE modelling package saves me effort and time to understand a healthcare virtual collaboration scenario.	2.بەکارهێنانی پاکێجی HC-VOBE بۆ وێناکردن هەوڵ و کاتم بۆ دەگێڕێتەوە لە تێگەشتنی سیناریۆی خزمەتگوزاری تەندروستی نابەرجەستە.

3. Using the HC-VOBE modelling package would be more effective to use for modelling healthcare virtual collaboration systems than other modelling languages.	3.بەکارهێنانی پاکێجی HC-VOBE بۆ وێنا کردن کاریگەرترە لە ئامرازەکانی تر بۆ دروستکردنی وێنای سیستەمی نابەرجەستەی خزمەتگوزاری تەندروستی.
4. Overall, I find the HC-VOBE modelling package useful for modelling healthcare virtual collaboration systems.	4.بەشێوەیەکی گشتی من پاکێجی HC-VOBE بۆ وێنا کردنم بەلاوە بە سوودە بۆ سیستەمی نابەرجەستەی خزمەتگوزاری تەندروستی.

3. Expected ease of use	**وەرگێڕاو بۆ کوردی**
1. Learning to use HC-VOBE modelling package would be easy for me.	1.فێربوونی بەکارهێنانی پاکێجی HC-VOBE بۆ وێنا کردن بۆ من ئاسان دەبێت.
2. I would find it easy to model healthcare virtual collaboration systems using the HC-VOBE modelling package.	2.من بە ئاسانی ئەبینم کە وێنای سیستەمی نابەرجەستەی خزمەتگوزاری تەندروستی بکێشم لە ڕێگەی بەکارهێنانی پاکێجی HC-VOBE بۆ وێنا کردن.
3. It would be easy for me to become skilful at using the HC-VOBE modelling package.	3.ئاسان دەبێت بۆ من کە شارەزابم لە باکارهێنانی پاکێجی HC-VOBE بۆ وێنا کردن.
4. I would find the HC-VOBE modelling package easy to use.	4.من بەکارهێنانی پاکێجی HC-VOBE بۆ وێنا کردن با ئاسان دەبینم .

4. Attitude towards using	**وەرگێڕاو بۆ کوردی**
1. Using the HC-VOBE modelling package would be a good idea.	1.بەکارهێنانی پاکێجی HC-VOBE بۆ وێنا کردن بیرۆکەیەکی باش دەبێت.
2. Using the HC-VOBE modelling package makes modelling healthcare systems more interesting.	2.بەکارهێنانی پاکێجی HC-VOBE بۆ وێنا کردن وێناکردنی سیستەمی نابەرجەستەی خزمەتگوزاری تەندروستی ئارەزووبەند تر دەکات.
3. Using the HC-VOBE modelling package would be a pleasant experience.	3.بەکارهێنانی پاکێجی HC-VOBE بۆ وێنا کردن ئەجروبەیەکی ئاسودە بەخش دەبێت.

Questionnaire 4

4. I would like to use the HC-VOBE modelling package	4.ئارەزووم هەیە بۆ بەکارهێنانی پاکێجی HC-VOBE بۆ وێنا کردن.

5. Intention use	**وەرگێڕاو بۆ کوردی**
1. I intend to use the HC-VOBE modelling package	1.من ئامادەیم ئیایە بۆ بەکارهێنانی پاکێجی HC-VOBE بۆ وێنا کردن.
2. It is likely that I will use the HC-VOBE modelling package	2.ئەگەری هەیە کە من پاکێجی HC-VOBE بۆ وێنا کردن بەکاربهێنم.
3. I expect to use the HC-VOBE modelling package.	3.پێشبینی دەکەم کە من پاکێجی HC-VOBE بۆ وێنا کردن بەکاربهێنم.
4. I am willing to recommend other people to use the HC-VOBE modelling package.	4.من ئامادەیم ئیایە پێشنیاری بەکارهێنانی پاکێجی HC-VOBE بۆ وێنا کردن بۆ کەسانی تر بکەم.

زۆر سوپاس بۆ هاوکاریت

Appendix E: Official permissions obtained to conduct research

اقليم كردستان العراق
مجلس وزراء
وزارة الصحة
المديرية العامة لصحة حلبجة
الاعلام

هەرێمی کوردستانی عێراق
ئەنجومەنی وەزیران
وەزارەتی تەندروستی
بەڕێوەبەرایەتی گشتی تەندروستی هەڵەبجە
ڕاگەیاندن

Date:30/04/2019

To: Huddersfield University - UK

This is to confirm that (Hoger Mahmud) who is a PhD student has conducted part of his research in our health institutes. He is working on a research entitled (Modelling and Investigating Virtual Collaboration for Healthcare).

Should you require further information Please do not hesitate to contact us.

Yours Faithfully

Honar Omar Wali.

حکومة اقليم كوردستان
رئاسة مجلس الوزراء
وزارة الصحه
المديريه العامة لصحة گرميان
مستشفى كلار العام
﴿ الاداره ﴾

Kurdistan Regional Government
Ministry of Health
Kalar General Hospital

حکومەتی هەرێمی کوردستان
سەرۆکایەتی ئەنجومەنی وەزیران
- وەزارەتی تەندروستی
بەڕێوەبەرایەتی گشتی تەندروستی گەرمیان
نەخۆشخانەی گشتی کەلار
﴿ کارگێری ﴾

ژمارە: ٥٦٤
بەروار: ٢/ ٥ /٢٠١٩

[redacted]

٤٢٧١٨/ /

(پێشمەرگە سومبولی نەتەوەیی و پارێزەری کوردستانە)

پیشە : مامۆستا لەزانکۆی گەشەپێدانی مرۆیی

To : Huddersfield University _ UK

This is to confirm that (Hoger Mahmud) who is a PhhD student has conducted part of his research in our health institues . He is working on research entitled (Modelling and Investigating Collaboration for Healthcare).

Should you require further information please [redacted] contact us .

+9647701066609

Yours Faithfully

د.هاوار وشيار ابراهيم
بەرێوەبەری نەخۆشخانەی گشتی کەلار
٢/ ٥ /٢٠١٩

وێنەیەک بۆ : بەشی کارگێری
*دۆسیەی گشتی

ناونیشان کەلار ریگای گشتی ت/٠٧٤٨٠١٩٢١٧٩

Appendix F: All data collected for the HC-VBE-M-F

1	PAM1	PAM2	PAM3	PAM4	PU1	PU2	PU3	PU4	PEU1	PEU2	PEU3	PEU4	AU1	AU2	AU3	AU4	IU1	IU2	IU3	IU4
2	5	6	7	6	5	7	5	6	7	6	6	7	7	6	7	6	7	6	6	6
3	5	5	5	5	6	6	6	6	5	4	5	5	6	6	6	5	6	5	5	5
4	6	6	7	4	6	6	4	5	6	6	6	6	7	5	5	6	6	6	6	6
5	5	7	6	5	7	7	6	6	7	5	6	7	5	6	7	5	5	6	6	7
6	5	5	6	4	5	7	6	6	7	6	5	5	6	6	6	6	5	5	6	5
7	5	7	6	5	7	6	7	5	7	5	7	7	7	5	7	6	5	5	6	7
8	7	7	7	6	6	7	6	5	6	5	7	7	7	6	6	5	5	5	5	7
9	6	7	5	6	7	6	6	5	5	6	5	6	7	6	5	6	5	6	5	4
10	6	5	6	6	5	6	6	5	6	6	6	6	6	5	6	6	6	6	5	6
11	5	4	5	5	4	5	5	4	5	5	7	7	5	5	6	5	5	6	5	5
12	7	6	7	7	7	7	7	7	7	6	7	7	7	7	7	5	6	4	5	7
13	3	2	4	5	5	5	5	4	4	4	4	4	5	5	5	5	4	5	4	5
14	7	7	5	6	7	6	6	7	6	6	6	6	7	7	6	6	6	6	6	7
15	6	6	6	6	5	6	6	6	7	6	7	7	7	6	6	5	5	5	6	6
16	5	5	6	6	5	5	4	6	5	5	6	6	5	5	5	5	5	5	5	5
17	6	6	7	6	6	6	6	6	5	6	5	5	6	5	6	6	6	5	5	5
18	6	4	6	6	5	6	3	4	4	5	5	4	6	5	6	6	5	6	6	5
19	6	5	6	5	5	6	5	6	5	6	5	6	6	6	6	6	5	6	5	6
20	3	4	3	3	3	3	4	3	4	3	4	3	3	3	3	4	4	4	4	4
21	6	5	5	5	5	5	5	5	5	4	5	4	5	4	4	5	5	5	5	5
22	3	4	3	4	3	3	4	4	2	3	4	3	4	3	4	3	4	3	4	3
23	3	3	4	3	4	4	4	3	4	4	4	3	2	3	2	3	4	3	4	3
24	3	4	3	4	3	4	3	4	4	4	3	3	3	4	3	3	4	4	3	4
25	4	3	3	4	5	5	5	4	3	4	3	4	3	4	3	4	3	3	4	3
26	3	2	3	2	3	4	3	2	3	4	3	4	4	5	3	5	4	3	4	3
27	2	3	2	2	3	2	3	3	3	3	2	2	2	3	3	2	4	5	4	4
28	3	4	4	3	4	4	3	4	3	3	4	3	3	3	2	3	3	4	3	4
29	3	3	2	3	3	3	3	4	4	4	5	5	3	3	3	3	4	3	3	3

Appendix G: All data collected for the HC-VBE-F from healthcare professionals

1	PHG1	PHG2	PHG3	PHG4	PU1	PU2	PU3	PU4	PEU1	PEU2	PEU3	PEU4	PCE1	PCE2	PCE3	PCE4	AU1	AU2	AU3	AU4	IU1	IU2	IU3	IU4
2	6	7	7	5	5	7	6	6	5	6	6	6	7	7	6	6	6	6	7	6	6	5	4	5
3	5	6	6	7	4	6	6	7	4	5	5	5	6	6	5	6	7	7	5	6	6	6	6	6
4	5	3	5	5	7	7	6	7	4	4	5	3	4	4	4	5	7	6	7	5	6	5	5	6
5	7	6	6	7	7	7	6	7	5	6	5	7	6	7	7	6	6	7	4	5	6	7	7	6
6	2	1	1	2	2	1	1	1	7	6	6	6	3	2	2	2	3	3	2	4	5	5	4	5
7	5	6	7	6	3	4	3	5	3	4	3	5	3	4	3	5	7	6	5	4	5	6	4	6
8	6	5	5	5	4	6	5	6	5	6	5	4	4	5	6	5	5	6	4	4	5	5	6	5
9	6	5	7	7	6	6	5	7	5	6	4	3	5	6	4	6	7	6	5	7	7	6	7	6
10	6	7	6	6	5	6	6	6	6	6	5	7	5	7	6	5	7	6	7	7	7	7	7	7
11	6	7	7	6	7	6	6	7	5	5	6	6	7	7	6	7	7	6	6	7	6	7	7	7
12	6	5	4	6	5	7	6	5	5	6	5	6	6	7	4	6	7	6	7	7	6	7	6	7
13	6	6	4	6	6	6	7	7	5	7	6	7	7	7	6	7	7	6	7	7	7	6	6	7
14	6	7	6	7	7	7	6	7	7	6	7	7	7	7	7	7	7	7	6	7	5	6	6	6
15	7	7	7	7	7	7	7	7	6	7	7	7	7	7	7	6	7	7	7	5	6	7	7	6
16	6	6	6	7	4	6	5	6	4	4	5	5	6	5	5	4	6	5	6	6	7	5	5	5
17	7	7	7	7	7	7	7	7	5	5	7	6	7	7	7	7	6	6	6	6	6	7	6	7
18	7	7	7	7	7	7	7	7	5	6	6	7	6	7	7	6	7	6	7	7	6	6	7	6
19	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
20	6	5	6	7	5	6	6	7	7	6	7	7	5	6	7	6	7	6	7	7	7	7	7	7
21	4	5	6	7	6	5	7	7	7	6	7	7	6	7	6	7	7	7	6	7	7	7	7	7
22	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
23	7	7	7	7	7	7	7	7	5	7	7	6	7	7	7	7	7	7	7	7	7	7	7	7
24	7	7	7	7	7	7	7	7	5	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
25	6	7	7	7	4	5	6	6	7	6	6	6	7	7	6	6	7	6	6	6	5	6	6	5
26	7	7	6	6	6	6	6	5	5	4	5	5	7	6	4	7	5	7	6	7	7	7	7	7
27	7	6	7	7	7	7	7	7	6	7	7	7	6	7	7	7	7	7	7	7	7	7	6	7
28	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	6
29	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
30	5	7	7	6	7	7	7	7	5	6	5	5	7	7	7	7	7	7	7	6	5	6	7	6
31	5	6	7	6	7	6	6	5	2	5	4	6	6	7	5	6	7	6	6	6	6	5	5	6
32	7	7	7	7	7	7	7	7	5	6	6	6	7	7	7	7	7	7	7	7	7	7	7	7
33	7	7	7	6	7	7	6	7	7	7	7	6	7	7	7	6	7	6	7	7	7	7	7	6
34	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
35	6	7	5	6	4	5	7	7	4	4	6	5	7	7	7	7	6	7	6	4	7	7	7	7
36	6	5	4	7	7	5	6	7	6	6	7	5	7	6	5	5	6	5	7	5	5	5	6	6

37	7	5	6	5	6	5	6	6	4	5	5	5	6	6	5	6	6	6	5	5	5	5	6	6
38	7	7	7	7	6	7	5	7	7	6	7	7	7	7	7	7	7	7	6	7	7	7	7	6
39	6	5	6	7	6	7	6	5	4	5	5	6	5	6	5	6	6	5	5	6	4	5	5	6
40	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
41	7	7	6	7	7	7	7	7	6	6	7	7	7	6	7	7	7	7	7	7	7	7	7	7
42	7	7	6	7	7	7	7	7	7	7	6	7	7	6	6	7	7	7	6	6	7	7	7	7
43	7	7	7	7	7	7	7	7	6	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
44	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
45	4	5	5	4	4	3	4	5	3	4	6	6	5	6	5	5	6	5	5	4	5	7	6	5
46	5	6	7	6	6	5	6	6	3	5	5	4	6	7	6	5	5	6	7	6	6	7	6	7
47	6	6	5	6	4	6	3	4	6	4	7	7	6	7	6	6	4	5	6	5	5	4	4	5
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49	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
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52	6	7	5	7	5	6	6	7	7	5	7	6	7	6	5	7	7	5	6	6	7	6	6	7
53	7	7	7	7	7	6	6	7	6	6	6	6	6	5	5	6	7	7	7	6	6	5	6	6
54	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
55	7	7	7	6	7	7	7	7	7	7	7	7	7	7	7	7	7	6	6	6	7	7	7	6
56	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	6	7	7	7	6	6
57	5	5	5	6	5	5	5	4	6	6	5	4	6	6	6	7	7	7	7	7	7	7	7	7
58	7	7	7	7	7	7	7	5	6	6	6	7	7	6	7	7	7	7	6	5	7	7	7	7
59	7	7	7	7	6	6	7	7	7	7	7	6	7	7	6	7	7	6	6	7	7	6	6	7
60	7	7	7	7	7	7	6	6	7	7	6	7	7	7	7	7	7	7	7	7	7	6	6	7
61	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
62	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
63	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	3	3	3	3	4	4	4	4
64	7	7	6	5	6	7	6	6	7	7	7	7	7	6	7	5	7	6	5	6	7	6	6	7
65	6	7	7	6	5	6	6	7	7	7	7	7	6	7	6	7	7	7	7	6	6	6	6	6
66	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	5	5	5	5
67	7	7	7	7	7	7	7	7	7	5	7	4	6	6	6	7	6	5	6	6	7	7	7	7
68	7	7	7	7	7	7	7	7	7	7	7	7	7	7	6	7	7	7	7	6	6	7	7	7
69	5	7	7	7	5	7	6	4	7	6	7	7	7	7	7	6	7	6	7	7	7	6	5	6
70	5	5	6	6	7	7	6	7	4	4	3	3	7	6	7	7	6	6	7	7	5	7	5	7
71	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
72	3	6	6	7	6	7	7	7	5	7	5	7	6	7	7	7	6	5	6	7	7	7	7	6
73	7	6	7	7	4	5	6	7	7	6	7	7	5	4	7	7	7	6	7	7	7	7	7	6
74	7	7	7	7	7	7	7	6	7	7	7	7	7	7	6	7	7	7	6	7	7	6	7	6
75	7	7	7	6	7	7	7	7	7	7	7	7	7	7	5	7	7	7	7	7	7	7	7	7
76	7	7	7	7	7	7	7	7	7	7	7	6	7	7	6	7	7	7	7	7	7	6	7	7
77	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
78	7	7	7	7	7	7	7	7	7	7	6	7	7	7	7	7	6	7	7	7	7	7	6	7
79	7	7	6	6	7	7	7	7	7	5	6	7	7	7	7	6	6	7	7	6	5	5	6	7
80	7	7	7	7	6	6	7	7	7	7	7	5	7	7	7	6	6	7	6	7	7	7	7	7
81	7	7	7	7	7	7	7	7	6	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
82	6	7	5	7	4	5	5	6	6	5	6	5	6	4	6	5	6	6	6	5	5	5	4	4
83	7	7	7	6	5	5	6	6	6	6	6	4	6	5	6	6	6	6	6	6	6	5	6	6
84	7	7	7	7	7	7	6	7	7	7	7	7	7	7	6	7	7	7	7	7	7	7	7	7
85	7	7	7	6	5	6	6	4	6	5	7	4	7	6	5	6	7	6	6	5	3	7	5	5
86	7	6	7	5	7	6	7	7	7	5	7	7	7	7	6	7	7	6	7	7	7	3	7	7
87	7	7	7	7	7	7	7	7	7	7	7	5	6	7	7	7	7	7	7	7	7	7	7	7
88	5	7	5	7	5	6	7	7	6	6	6	6	7	7	6	7	7	7	6	7	7	6	7	6
89	6	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
90	7	7	7	6	7	7	7	7	7	7	6	6	7	7	7	7	7	7	7	7	7	7	7	7
91	7	7	7	7	7	7	7	7	7	7	7	7	7	6	6	7	7	7	7	7	7	6	7	7
92	7	7	7	7	7	7	7	7	7	7	7	6	7	7	5	7	7	7	7	7	7	7	7	7
93	7	7	7	7	7	6	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
94	6	7	7	7	6	6	7	7	6	6	5	6	6	7	6	5	6	6	5	7	5	4	5	5
95	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
96	7	7	7	7	7	7	6	7	6	6	7	7	7	6	5	7	7	7	6	7	6	7	7	7
97	7	7	7	7	7	6	7	7	7	7	7	7	7	7	7	7	7	7	7	6	7	6	7	7
98	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	5	6	6	6
99	6	7	7	7	7	6	6	7	6	6	7	6	6	7	6	6	6	7	6	6	6	5	6	6
100	6	7	7	7	6	7	7	7	7	7	7	7	7	7	6	7	6	6	6	7	7	7	7	7
101	7	6	7	6	7	7	7	7	5	5	6	6	7	7	7	7	7	7	7	5	5	5	5	5

Appendix H: All data collected for the HC-VBE-F from healthcare requesters

1	PHA1	PHA2	PHA3	PHA4	PU1	PU2	PU3	PU4	PEU1	PEU2	PEU3	PEU4	PHQ1	PHQ2	PHQ3	PHQ4	PHQ5	AU1	AU2	AU3	AU4	IU1	IU2	IU3	IU4
2	7	7	5	5	4	5	5	4	5	4	5	4	4	5	5	5	5	5	5	5	5	6	4	5	5
3	6	5	5	5	6	7	4	5	4	7	7	6	7	6	6	6	5	6	5	5	6	6	7	6	6
4	5	4	5	3	6	5	5	4	6	4	5	5	6	5	4	5	5	4	5	5	6	4	4	5	5
5	5	6	6	7	4	5	4	4	4	4	5	4	5	4	4	5	6	6	6	6	5	5	5	5	5
6	7	6	6	7	7	7	6	7	5	7	6	6	7	7	6	7	6	7	6	7	7	5	6	7	7
7	7	7	6	5	6	7	7	4	7	7	4	6	7	6	7	7	7	7	7	6	6	5	7	7	7
8	5	5	4	5	6	5	4	3	7	6	5	6	5	5	6	6	7	4	3	4	5	6	5	5	5
9	4	6	7	7	6	7	7	5	4	7	4	3	7	7	6	7	7	6	5	6	6	5	4	5	6
10	4	7	3	6	6	6	5	4	7	6	7	7	4	4	4	5	5	5	4	5	5	5	5	5	5
11	5	7	4	6	4	6	3	5	5	6	7	5	6	5	6	6	6	6	6	4	6	5	5	5	6
12	5	4	5	5	4	4	3	3	4	4	4	5	4	4	5	4	4	4	4	5	4	4	3	4	4
13	6	7	7	5	7	6	7	5	7	7	7	6	6	6	5	5	6	7	6	5	6	6	6	6	5
14	4	6	6	5	4	6	6	5	6	6	6	4	5	3	5	4	4	5	6	5	5	5	5	5	4
15	5	6	5	6	5	6	6	6	5	5	6	7	5	5	5	6	6	7	6	6	6	5	6	6	7
16	5	5	6	5	6	6	5	5	6	6	5	6	5	5	5	5	5	6	5	5	5	5	5	6	6
17	7	7	6	7	5	6	6	6	4	4	5	5	4	6	6	6	7	5	5	5	5	5	4	4	3
18	7	6	6	6	7	7	6	6	4	5	6	4	5	6	6	6	7	5	5	5	5	5	4	4	5
19	5	7	6	6	6	7	4	5	5	5	6	6	6	6	6	7	6	6	5	5	5	4	5	5	5
20	4	5	5	6	5	5	4	5	6	5	5	6	4	5	4	6	4	6	5	4	6	5	6	6	6
21	4	2	4	4	5	5	4	4	3	3	5	5	4	5	5	5	4	4	5	5	6	5	6	6	6
22	5	4	6	5	5	5	5	5	5	5	5	5	6	6	6	6	6	6	6	6	6	5	5	5	5
23	5	6	6	7	6	6	6	6	7	6	7	7	6	6	5	6	6	6	6	6	6	6	6	6	6
24	5	2	3	6	7	6	7	7	7	4	7	7	5	6	2	5	4	7	7	7	7	7	7	6	7
25	4	5	5	5	5	5	4	4	3	3	4	3	5	5	5	6	5	4	6	6	5	4	5	4	4
26	5	5	6	6	6	6	6	7	6	6	7	7	6	7	7	7	7	7	7	7	7	6	7	7	7
27	6	4	4	4	6	4	5	5	4	5	4	5	5	6	4	6	3	6	5	4	5	6	4	6	4
28	6	6	7	7	6	7	7	7	7	6	7	7	6	5	7	7	7	7	7	7	6	5	4	4	7
29	6	7	6	6	7	6	4	6	5	5	6	5	4	6	7	7	6	6	7	6	7	6	5	6	6
30	5	7	6	7	7	7	4	5	7	7	7	7	5	4	6	4	7	6	5	4	6	7	6	6	7
31	5	6	6	6	6	5	5	6	6	5	6	5	5	6	6	6	6	6	5	5	6	5	5	6	5
32	5	5	5	5	5	6	4	5	5	5	6	6	5	4	4	4	5	6	5	6	6	5	5	5	6
33	6	6	5	6	5	7	6	5	6	6	6	5	5	6	5	6	6	6	5	5	7	6	6	6	6
34	5	1	3	2	4	4	4	3	5	5	4	5	5	4	4	5	6	6	5	5	5	6	5	5	5
35	2	3	3	2	4	4	3	4	5	5	4	4	4	4	5	3	5	3	4	4	4	4	3	4	5
36	7	7	6	7	7	7	7	7	7	7	6	7	7	6	7	6	7	7	7	7	7	7	7	6	7

37	5	6	4	5	5	6	5	4	7	5	5	6	3	5	6	5	7	7	5	6	5	5	6	7	6
38	7	7	7	7	4	5	6	6	7	7	7	7	7	6	6	6	6	7	7	7	7	7	7	7	6
39	6	5	6	7	6	6	7	7	6	5	5	6	6	7	5	6	5	6	7	7	7	7	7	6	7
40	5	3	3	4	6	4	3	5	4	3	5	3	5	5	4	5	6	4	5	5	4	5	6	5	4
41	6	7	6	7	6	7	6	6	7	6	7	7	6	6	6	7	6	7	6	7	7	7	7	7	7
42	4	5	6	6	4	4	5	4	3	4	6	4	4	4	5	5	5	6	6	5	5	4	4	4	4
43	6	6	6	5	5	5	6	5	4	6	7	4	6	6	5	5	5	7	6	5	6	5	5	5	4
44	5	5	6	6	6	6	7	7	6	6	7	7	7	7	7	7	7	7	6	6	7	7	7	7	7
45	6	7	5	7	7	6	7	7	6	4	6	6	6	6	5	6	6	7	7	6	7	6	7	7	7
46	6	7	7	7	7	7	7	7	6	6	6	6	7	7	7	7	7	7	7	6	7	7	7	7	6
47	5	2	6	5	3	2	5	6	7	4	7	7	2	2	7	6	5	7	6	6	7	6	4	4	4
48	5	6	6	6	7	7	6	6	7	7	7	7	7	6	7	7	7	7	7	7	6	6	6	6	6
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78	1	3	2	3	4	5	3	2	2	3	2	2	1	2	1	1	2	1	1	4	5	4	5	5	4
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82	7	7	7	7	4	4	5	5	4	5	4	4	5	4	4	5	6	7	4	7	4	7	4	6	6
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88	5	4	6	5	5	6	5	6	4	5	6	6	5	5	4	5	6	5	6	6	6	5	5	6	6
89	4	4	4	4	5	6	5	6	5	5	5	4	5	5	5	5	5	5	5	5	5	4	5	5	6
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93	3	5	4	4	3	4	6	6	4	4	6	4	4	3	5	3	6	6	6	5	6	5	6	5	5
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97	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4	5	5	5
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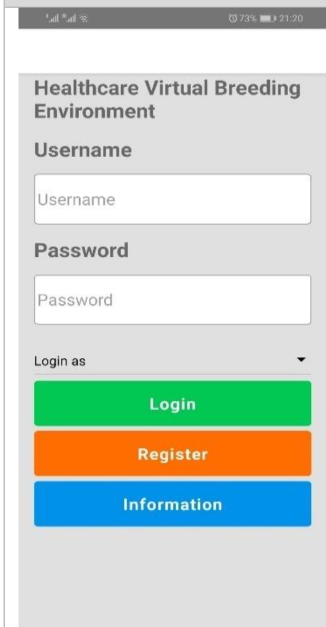
100	2	3	2	1	3	2	3	2	3	2	3	2	2	2	3	2	3	2	2	3	4	5	5	4	4
101	2	2	1	2	2	2	1	2	2	1	2	1	2	2	2	2	2	3	2	2	3	4	4	4	4

Appendix I: HC-VBE-F mobile application screenshots and explanations

1. Home Screen



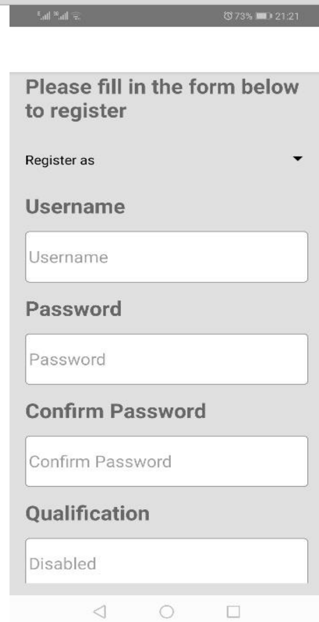
This is the home interface of the HC-VBE mobile application that includes the following functions:

1- Log in: This function lets users to login into the HC-VBE system.

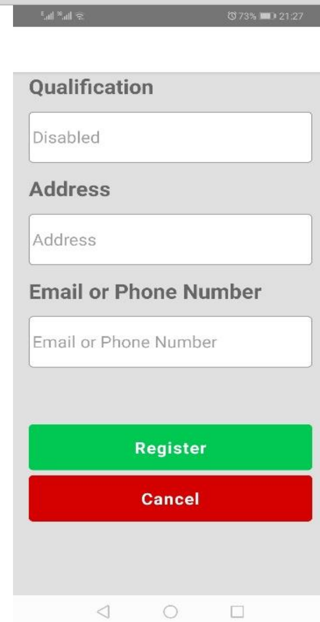
2- Register: This function allows new users to register to use the virtual environment.

3- Information: This function provides some basic information about the HC-VBE.

2.1 Register



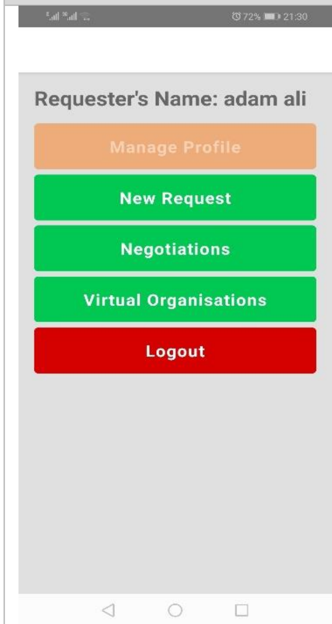
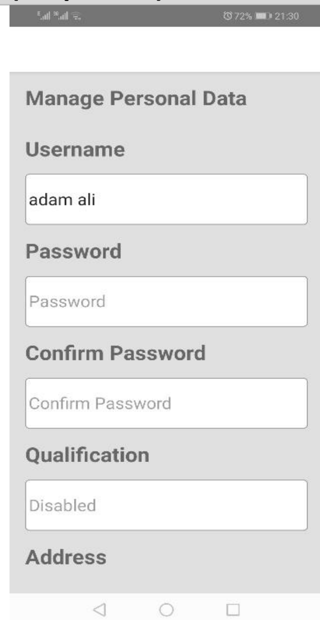
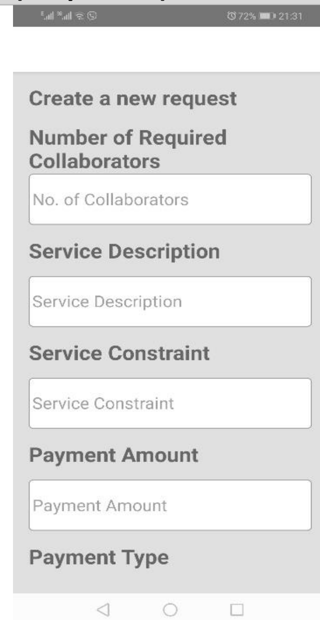
2.1 Register



This is the registration form of the HC-VBE mobile application that new users will have to fill in to register in the system and includes the following functions:

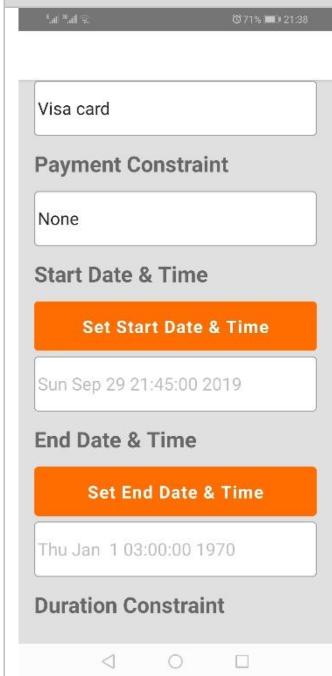
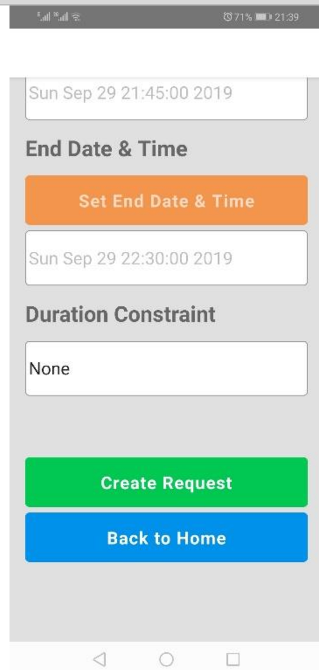
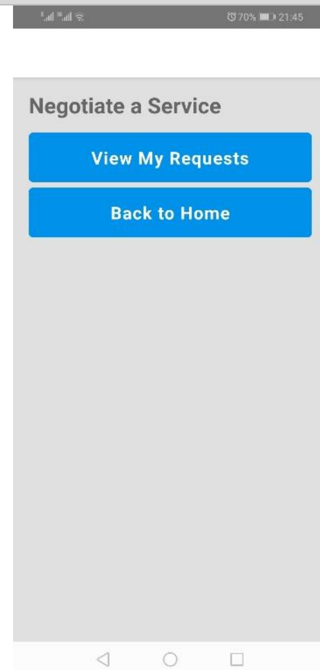
1- Register: This function lets users submit their details into the HC-VBE system for registration.

3- **Cancel**: This function allows users cancel registration if they wish to do so.

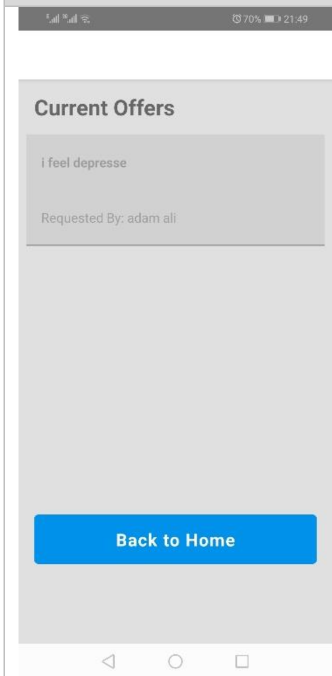
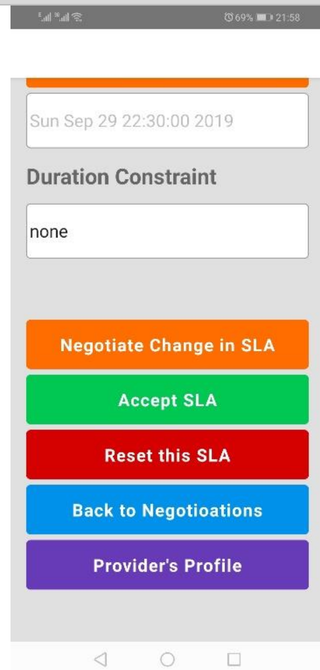
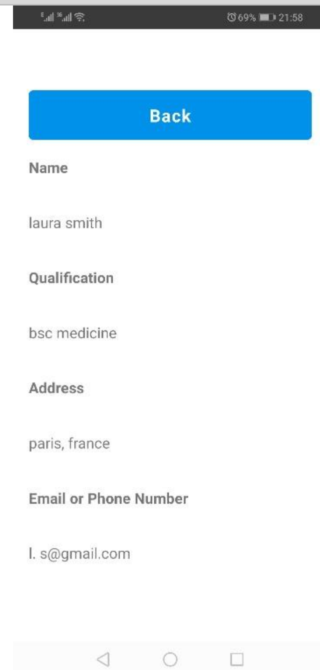
<table>
<tr>
<th>3. Requesters options</th>
<th>3.1 Manage Profile 1 (Requester)</th>
<th>3.2 New Request (Requester)</th>
</tr>
<tr>
<td>
</td>
<td>
</td>
<td>
</td>
</tr>
<tr>
<td>After a successful log in the APP will provide users with a number of optional functions as below:
1- Manage Profile: Allow users to make changes to their personal details in the HC-VBE system.
2- New request: This function allows requester users to request a new healthcare service.
3- Negotiation: Allow requesters to negotiate the offers sent to them by the HC-VBE.
4- Virtual Organisation: Allows users to view and progress the Created VOs for them.
5- Log out: Allows users to log out of the system</td>
<td>The “Manage Profile” function is used to make changes to the requester’s profiles. When triggered a form with relevant filled in detail of the requester opens where the requester can make changes and save the change.</td>
<td>To make a new healthcare requester will have to use the “New request” function. When clicked a request form will open for the requester to fill in. The form captures the details required to initiate an SLA and ultimately the VBE creates a VO based on this request.</td>
</tr>
</table>

<table>
<tr><th>3.2 New Request (Requester)</th><th>3.2 New request

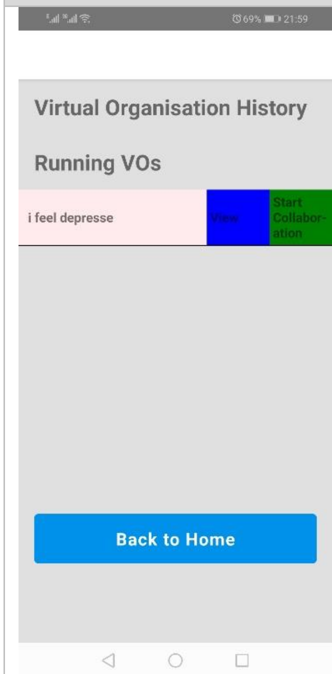
(Requester)</th><th>3.3 Negotiate

(Requester)</th></tr>
<tr><td>
</td><td>
</td><td>
</td></tr>
<tr><td>The screenshot above is a continuation of the request form</td><td>The screenshot above is a continuation of the request form where the process is finalised by clicking on the “Create Request” button. If no data is missing the request will be submitted to the HC-VBE system for processing.</td><td>The third function available to the requester is “Negotiation” when triggered two options will be presented to the requester as below:
1-View My Requests: This function enables the requester to view all the requests made by him/her to the system. It can all show all offers made by providers to provide the service.

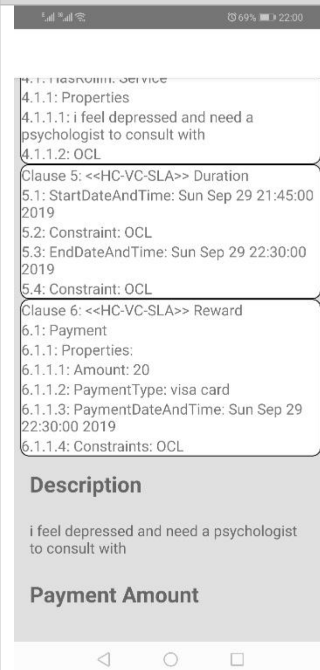
2- Back to Home: This function will the requester back to the main page of the application.</td></tr>
</table>

3.3.1 Offers made (Requester)	3.3.1 Offer details (Requester)	3.3.1 Offer details (Requester)
		
The requester will be notified of any offer made by a healthcare service provider. For more details about the offer the requester clicks on the offer**.**	When the offer is clicked several options as above will be displayed to the requester: **1- Negotiate Change in SLA:** Requester can use this option to propose a new offer after viewing the offer received by a provider. **2- Accept SLA:** This option enables the requester to accept the offer made by a provider without any change. **3-Reset this SLA:** This function enables the requester to make the	The screenshot above shows how the requester sees the provider profile detail as a result of "Provider's Profile" being clicked.

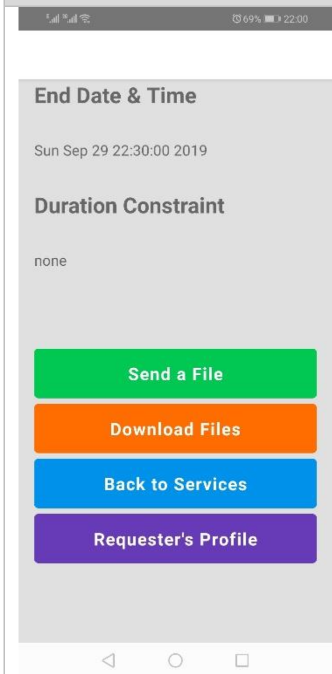
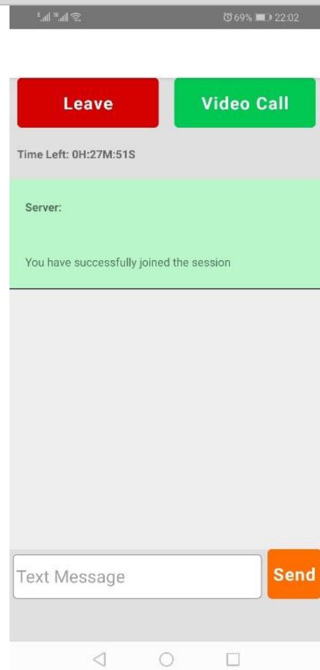
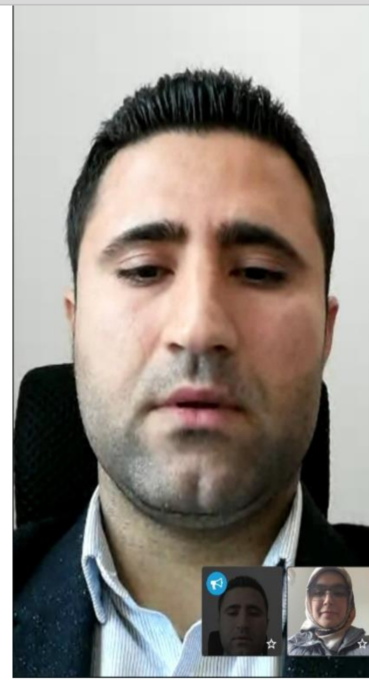
	available for offers by other healthcare providers and do not accept the current healthcare provider. **4- back to Negotiation:** Enables requesters to go back to the negotiation page where all offers can be viewed. **5- Provider profile:** Enables requester view the profile of the healthcare provider who has made the offer to provide the service**.**	

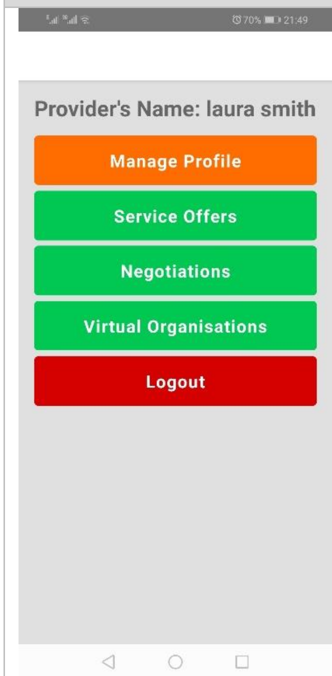
<table>
<tr><th>3.4 Virtual Organisations (Requester)</th><th>3.4.1 SLA View (Requester)</th><th>3.4.1 SLA View (Requester)</th></tr>
<tr><td>


</td><td>


</td><td>


</td></tr>
<tr><td>After an offer is accepted by the requester as a result of the negotiation process the function” Virtual Organisation” will enable the requester to view the VO created by the HC-VBE for the service as shown in the screenshot. Requesters can click the “View” option to view the SLA approved by the requester and provider. Or click on the “Start Collaboration” option to start the real-time VO.</td><td>The screenshot above is the SLA view that is created between the healthcare requester and provider based on which a VO has been created for the real-time collaboration.</td><td>SLA continued</td></tr>
</table>

3.4.1 View SLA (Requester)	3.4.2 Start Collaboration (Requester)	3.4.3 Real-time video and sound communication
		
At the end of the view of the SLA, several options are available to the requester before the real-time collaboration takes place as below: **1- Send a File**: Requesters can send a file to the provider for example an X-ray image. The file will be sent to the provider in the SLA. **2-Download files:** This option allows the requester to download any file that has been sent by the provider. **3- Back to Service:** This option will take the requester back to the Virtual Organisation page.	When the "Start Collaboration" is triggered the requester will be connected to a session which is basically a virtual room and ready to speak to the provider. The requester will have to trigger the Video call by pressing the "Video Call" option, or leave the session.	The screenshot above shows a real-time video call collaboration between the healthcare requester and provider after they both chose to start a video call.

<table>
<tr>
<th>1. Home Screen (Provider)</th>
<th>1.2 Current offers (Provider)</th>
<th>1.2.1 offer details (Provider)</th>
</tr>
<tr>
<td>
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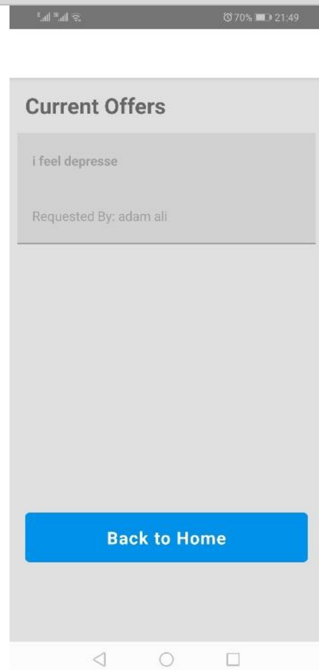
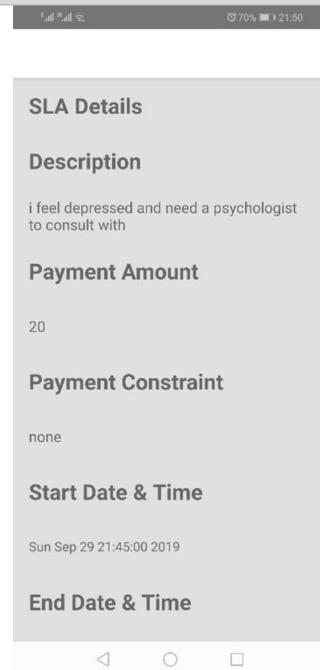
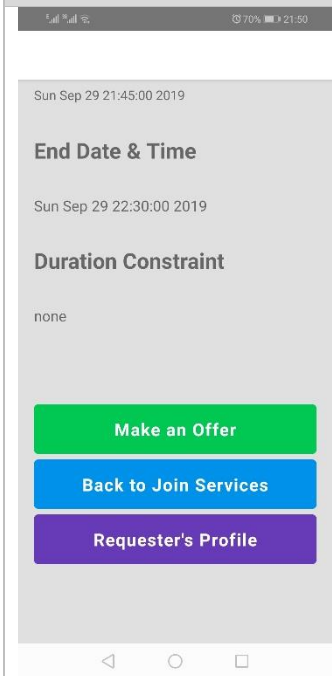
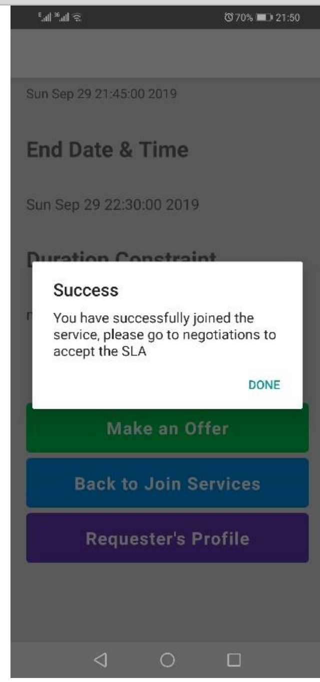
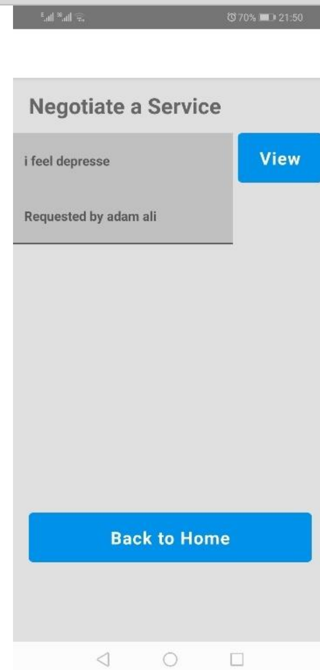
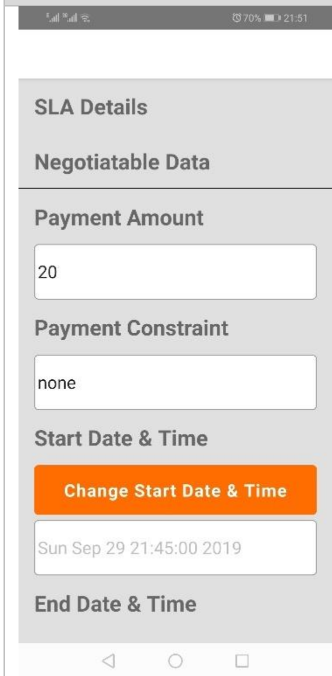
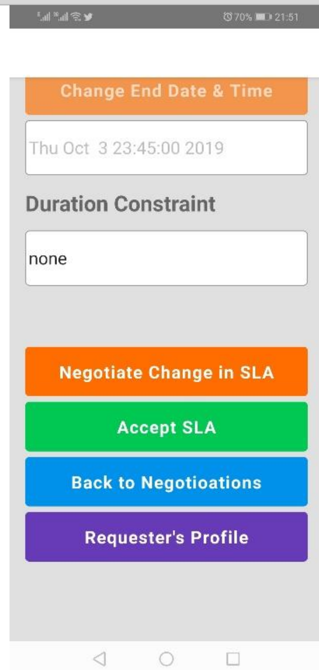
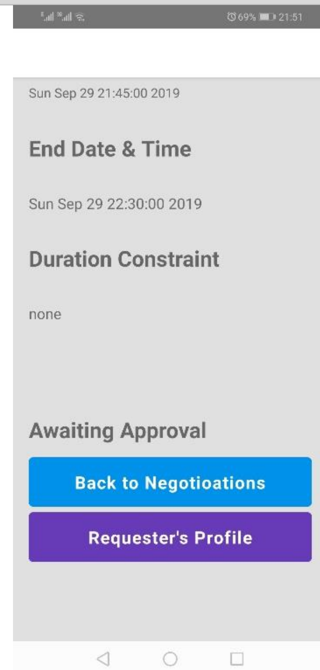
<td>
</td>
<td>
</td>
</tr>
<tr>
<td>After a successful log in the APP the healthcare provider will have a number of options as below:
1- Manage Profile: Allows provider to make changes to their personal details in the HC-VBE system.
2- Service Offers: Allows providers to view requests sent into the HC-VBE and choose to make an offer to provide a service.
3- Negotiation: Allow provider to negotiate the offers sent to the HC-VBE for a service by requesters.
4- Virtual Organisation: Allows providers to view and progress the Created VOs for them.
5- Log out: Allows providers to log out of the system</td>
<td>This is the view of the requests sent into the HC-VBE that can be seen after the “Service offer” function is triggered.</td>
<td>Providers can click on the offer to see the details of the request as shown above.</td>
</tr>
</table>

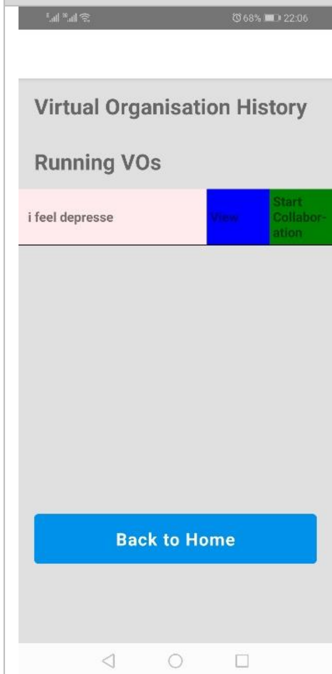
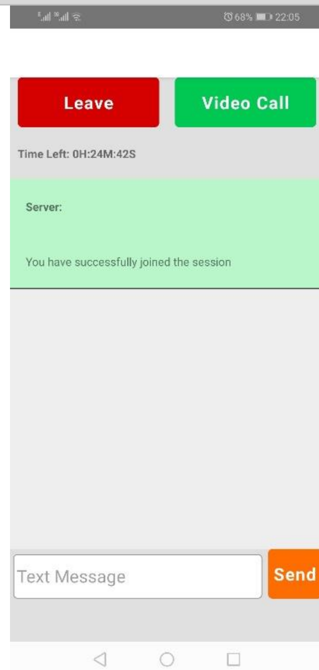
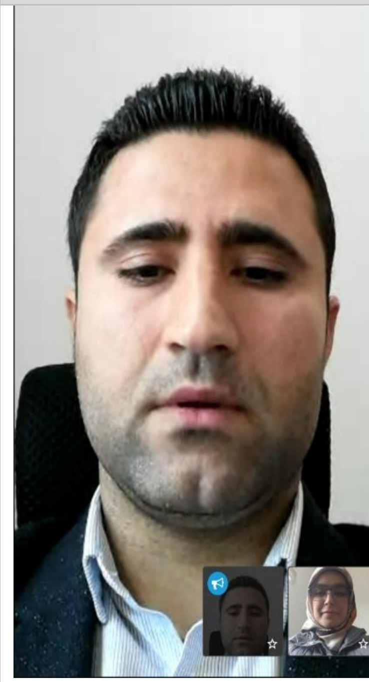
<table>
<tr><th>1.2.1 Offer details (Provider)</th><th>1.2.2 Make an Offer (Provider)</th><th>1.3.1 Negotiate (Provider)</th></tr>
<tr><td>
</td><td>
</td><td>
</td></tr>
<tr><td>This screenshot shows the continuation of request details where at the end three options are available to the Provider:

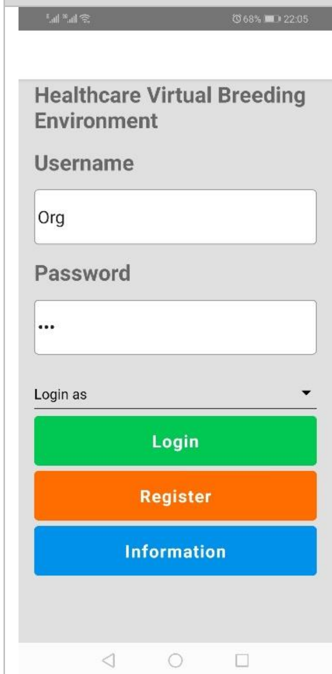
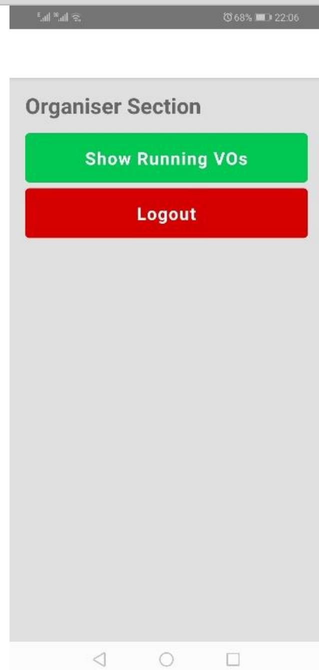
1- Make an Offer: Allows providers to make and offer to the requester who has made the request

2- Back to Join Services: Allows providers to be available again to offer services again and cancel the current intention to offer a service.

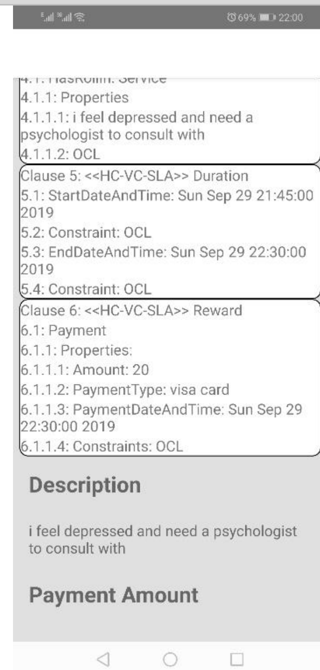
3- Requesters Profile: Allows the provider to view the profile of the requester.</td><td>The above screenshot shows the result of making an offer by the provider. The HC-VBE system notifies the provider that he has successfully joint with a requester to start service negotiation.</td><td>Once the healthcare provider triggered the “Negotiation” function he will be provided with a link to the offer he/she has made in the previous step. Now the provider has the option to view the details of the request and start negotiating its details.</td></tr>
</table>

1.3.2 Negotiate (Provider)	1.3.2 Negotiate (Provider)	1.3.3 Negotiate (Provider)
		
When the “View” is clicked the service request details will be displayed to be viewed.	At the end of viewing the request several options as above will be displayed to the requester: **1- Negotiate Change in SLA**: Requester can use this option to propose a new offer after viewing the offer received by a provider. **2- Accept SLA**: This option enables the requester to accept the offer made by a provider without any change. **3- back to Negotiation:** Enables requesters to go back to the negotiation page where all offers can be viewed. **4- Requester Profile:** Allows the provider to view the requesters profile	If the healthcare provider chooses to negotiation a different offer presented in the request, then necessary changes can be made to the request and be sent back to the requester using the “Negotiate Change in SLA” option. Once this is done the status will be changed to “Awaiting Approval” by requester.

1.3.4 VO creation (Provider)	1.3.5 VO triggered to start (Provider)	1.3.6 Video call started (Provider)
		
After an offer is accepted by the requester as a result of the negotiation process the function" Virtual Organisation" will enable the provider to view the VO created by the HC-VBE for the service as shown in this screenshot. providers can click the "View" option to view the SLA approved by the requester and provider. Or click on the "Start Collaboration" option to start the real-time VO. the SLA view will be the same as the ones detailed in the requester screenshots 3.4.1	When the "Start Collaboration" is triggered the provider will be connected to a session which is basically a virtual room and ready to speak to the requester. The provider will have to trigger the Video call by pressing the "Video Call" option, or leave the session.	The screenshot above shows a real-time video call collaboration between the healthcare requester and provider after they both chose to start a video call.

<table>
<tr><th>1. Organiser Log in</th><th>1.2 Show the Running VOs (Organiser)</th><th>1.2.1 List of Running VOs (Organiser)</th></tr>
<tr><td>
</td><td>
</td><td>
</td></tr>
<tr><td>This is the home interface of the HC-VBE mobile application that includes the following functions:

1- Log in: This function lets users to login into the HC-VBE system.
2- Register: This function allows new users to register to use the virtual environment.
3- Information: This function provides some basic information about the HC-VBE.</td><td>After a successful log in the APP will provide the Organisers of the HC-VBE to view the detail of all the currently running VO by choosing to show the running VOs.</td><td>Triggering the “Show running VO” will result in showing all the currently running VO and the ones that has ended. Organisers can view the master SLA agreement and the SLA of a particular VO by choosing to “View” the detail.</td></tr>
</table>

<table>
<tr><th>1.2.2 Master SLA of a VO (Organiser)</th><th>1.2.3 SLA of a VO (Organiser)</th><th>1.2.3 SLA of a VO (Organiser)</th></tr>
<tr><td>
</td>
<td>
</td>
<td>
</td></tr>
<tr><td>This is the view of the master SLA created for a particular VO.

Here the Organiser can view all the SLAs contained in the Master SLA by clicking the “View” button next to the request name.</td><td>View of SLA of the chosen request</td><td>View of SLA of the chosen request</td></tr>
</table>

Apendix J: HC-VBE-F-Provider AMOS Data Analysis Output

Notes for Group (Group number 1)

The model is recursive.

Sample size = 100

Variable Summary (Group number 1)

Your model contains the following variables (Group number 1)

Observed, endogenous variables

PHG4

PHG3

PHG2

PHG1

PCE4

PCE3

PCE2

PCE1

PU1

PU2

PU3

PU4

PEU4

PEU3

PEU2

PEU1

AU4

AU3

AU2

AU1

IU1

IU2

IU3

IU4

Unobserved, endogenous variables

Perceived_Clinical_Effectiveness

Perceived_Usefulness

Perceived_Ease_of_Use

Attitude_Towards_Using

Intention_to_Use

Unobserved, exogenous variables

Perceived_Healthcare_Globalisation

e1

e2

e3

e4

e5

e6

e7

e8

e9

e10

e11

e12

e13

e14

e15

e16

e17

e18

e19

e20

e21

e22

e23

e24

EUL1

ATL2

IUL4

PCEL3

PEU5

Variable counts (Group number 1)

Number of variables in your model: 59

Number of observed variables: 24

Number of unobserved variables: 35

Number of exogenous variables: 30

Number of endogenous variables: 29

Result (Default model)

Minimum was achieved

Chi-square = 398.70118

Degrees of freedom = 243

Probability level = .00000

Regression Weights: (Group number 1 - Default model)

			Estimate	S.E.	C.R.	P	Label
Perceived_Clinical_Effectiveness	<---	Perceived_Healthcare_Globalisation	1.07686	.13887	7.75437	***	par_26
Perceived_Ease_of_Use	<---	Perceived_Healthcare_Globalisation	.83731	.15013	5.57720	***	par_27
Perceived_Usefulness	<---	Perceived_Healthcare_Globalisation	.26083	.30335	.85984	.38988	par_19

			Estimate	S.E.	C.R.	P	Label
Perceived_Usefulness	<---	Perceived_Clinical_Effectiveness	1.05803	.25682	4.11978	***	par_20
Perceived_Usefulness	<---	Perceived_Ease_of_Use	-.10854	.09076	-1.19595	.23171	par_24
Attitude_Towards_Using	<---	Perceived_Usefulness	.50072	.06930	7.22551	***	par_21
Attitude_Towards_Using	<---	Perceived_Ease_of_Use	.15993	.05532	2.89074	.00384	par_22
Intention_to_Use	<---	Attitude_Towards_Using	1.22322	.39625	3.08696	.00202	par_23
Intention_to_Use	<---	Perceived_Usefulness	-.20126	.22853	-.88067	.37850	par_25
PHG4	<---	Perceived_Healthcare_Globalisation	1.00000				
PHG3	<---	Perceived_Healthcare_Globalisation	1.25343	.15560	8.05554	***	par_1
PHG2	<---	Perceived_Healthcare_Globalisation	1.37575	.15235	9.03024	***	par_2
PHG1	<---	Perceived_Healthcare_Globalisation	1.19950	.15514	7.73188	***	par_3

			Estimate	S.E.	C.R.	P	Label
PCE4	<---	Perceived_Clinical_Effectiveness	.99236	.09455	10.49573	***	par_4
PCE3	<---	Perceived_Clinical_Effectiveness	1.04639	.11709	8.93701	***	par_5
PCE2	<---	Perceived_Clinical_Effectiveness	.98594	.10088	9.77376	***	par_6
PCE1	<---	Perceived_Clinical_Effectiveness	1.00000				
PU1	<---	Perceived_Usefulness	1.00000				
PU2	<---	Perceived_Usefulness	.88265	.08945	9.86716	***	par_7
PU3	<---	Perceived_Usefulness	.97293	.08594	11.32076	***	par_8
PU4	<---	Perceived_Usefulness	.82839	.09162	9.04143	***	par_9
PEU4	<---	Perceived_Ease_of_Use	.93648	.12057	7.76739	***	par_10
PEU3	<---	Perceived_Ease_of_Use	1.00000				
PEU2	<---	Perceived_Ease_of_Use	.93412	.10493	8.90257	***	par_11

			Estimate	S.E.	C.R.	P	Label
PEU1	<---	Perceived_Ease_of_Use	1.24873	.12508	9.98378	***	par_12
AU4	<---	Attitude_Towards_Using	1.18548	.15202	7.79835	***	par_13
AU3	<---	Attitude_Towards_Using	1.20138	.14829	8.10148	***	par_14
AU2	<---	Attitude_Towards_Using	1.07963	.13001	8.30408	***	par_15
AU1	<---	Attitude_Towards_Using	1.00000				
IU1	<---	Intention_to_Use	1.00000				
IU2	<---	Intention_to_Use	.93414	.12545	7.44618	***	par_16
IU3	<---	Intention_to_Use	1.09384	.11919	9.17746	***	par_17
IU4	<---	Intention_to_Use	.89454	.10188	8.78009	***	par_18

Standardized Regression Weights: (Group number 1 - Default model)

			Estimate
Perceived_Clinical_Effectiveness	<---	Perceived_Healthcare_Globalisation	.89755
Perceived_Ease_of_Use	<---	Perceived_Healthcare_Globalisation	.63540
Perceived_Usefulness	<---	Perceived_Healthcare_Globalisation	.17187
Perceived_Usefulness	<---	Perceived_Clinical_Effectiveness	.83645
Perceived_Usefulness	<---	Perceived_Ease_of_Use	-.09425
Attitude_Towards_Using	<---	Perceived_Usefulness	.80107
Attitude_Towards_Using	<---	Perceived_Ease_of_Use	.22216
Intention_to_Use	<---	Attitude_Towards_Using	1.02106
Intention_to_Use	<---	Perceived_Usefulness	-.26876
PHG4	<---	Perceived_Healthcare_Globalisation	.75022
PHG3	<---	Perceived_Healthcare_Globalisation	.79234
PHG2	<---	Perceived_Healthcare_Globalisation	.87858
PHG1	<---	Perceived_Healthcare_Globalisation	.76378
PCE4	<---	Perceived_Clinical_Effectiveness	.84505
PCE3	<---	Perceived_Clinical_Effectiveness	.76204
PCE2	<---	Perceived_Clinical_Effectiveness	.80825
PCE1	<---	Perceived_Clinical_Effectiveness	.84028
PU1	<---	Perceived_Usefulness	.81504

			Estimate
PU2	<---	Perceived_Usefulness	.83360
PU3	<---	Perceived_Usefulness	.91167
PU4	<---	Perceived_Usefulness	.78483
PEU4	<---	Perceived_Ease_of_Use	.70967
PEU3	<---	Perceived_Ease_of_Use	.84552
PEU2	<---	Perceived_Ease_of_Use	.78430
PEU1	<---	Perceived_Ease_of_Use	.85545
AU4	<---	Attitude_Towards_Using	.75212
AU3	<---	Attitude_Towards_Using	.77697
AU2	<---	Attitude_Towards_Using	.79340
AU1	<---	Attitude_Towards_Using	.76555
IU1	<---	Intention_to_Use	.78496
IU2	<---	Intention_to_Use	.72183
IU3	<---	Intention_to_Use	.86332
IU4	<---	Intention_to_Use	.82925

Model Fit Summary

CMIN

Model	NPAR	CMIN	DF	P	CMIN/DF
Default model	57	398.70118	243	.00000	1.64075
Saturated model	300	.00000	0		
Independence model	24	2099.36512	276	.00000	7.60640

RMR, GFI

Model	RMR	GFI	AGFI	PGFI
Default model	.05892	.76948	.71541	.62328
Saturated model	.00000	1.00000		
Independence model	.44431	.14138	.06672	.13007

Baseline Comparisons

Model	NFI Delta1	RFI rho1	IFI Delta2	TLI rho2	CFI
Default model	.81008	.78429	.91613	.90301	.91461
Saturated model	1.00000		1.00000		1.00000
Independence model	.00000	.00000	.00000	.00000	.00000

Parsimony-Adjusted Measures

Model	PRATIO	PNFI	PCFI
Default model	.88043	.71323	.80525
Saturated model	.00000	.00000	.00000
Independence model	1.00000	.00000	.00000

NCP

Model	NCP	LO 90	HI 90
Default model	155.70118	104.84277	214.46261
Saturated model	.00000	.00000	.00000
Independence model	1823.36512	1681.33610	1972.81631

FMIN

Model	FMIN	F0	LO 90	HI 90
Default model	4.02728	1.57274	1.05902	2.16629
Saturated model	.00000	.00000	.00000	.00000
Independence model	21.20571	18.41783	16.98319	19.92744

RMSEA

Model	RMSEA	LO 90	HI 90	PCLOSE
Default model	.08045	.06602	.09442	.00055

Model	RMSEA	LO 90	HI 90	PCLOSE
Independence model	.25832	.24806	.26870	.00001

AIC

Model	AIC	BCC	BIC	CAIC
Default model	512.70118	551.21470	661.19589	718.19589
Saturated model	600.00000	802.70270	1381.55106	1681.55106
Independence model	2147.36512	2163.58133	2209.88920	2233.88920

ECVI

Model	ECVI	LO 90	HI 90	MECVI
Default model	5.17880	4.66508	5.77235	5.56783
Saturated model	6.06061	6.06061	6.06061	8.10811
Independence model	21.69056	20.25592	23.20016	21.85436

HOELTER

Model	HOELTER .05	HOELTER .01
Default model	70	74
Independence model	15	16