IMAP-CAMPUS: A THEORETICAL FRAMEWORK TO MEASURE USER'S BEHAVIOURAL INTENTION IN AUGMENTED REALITY

By

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A thesis submitted in partial fulfilment of the requirements for the degree of Master of Research

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STATEMENT OF CANDIDATE

I certify that this thesis entitled ***iMAP-CampUS: A Theoretical Framework to Measure User's Behavioural Intention in Augmented Reality*** has not been previously submitted for a higher degree to any other university or institution other than Macquarie University.

The research presented in this thesis was approved by the Human Research Ethics Committee, Macquarie University with reference number: 5201600796

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ABSTRACT

As technology penetrates into our lives, the vital need for institutions to provide rapid access to information has grown. Recently, Augmented Reality (AR) has emerged as a technology for educational institutions to enhance users' experience by overlaying computational information into their reality. iMAP_CampUS is a mobile AR application showing campus-related information superimposed on a map of Macquarie University. Using iMAP_CampUS app, our goal is to investigate the factors influencing the acceptance of a typical mobile AR system. The thesis proposes a theoretical framework with 14 research hypotheses based on UTAUT, IS success factors and Motivation theory. This framework is empirically examined using web-based survey data from a sample of 86 users. We use Structural Equation Modeling (SEM) and Partial Least Squares (PLS) to evaluate the acceptance and behavioural intention to use iMAP-CampUS app. The results indicate that ten research hypotheses have been significantly supported, while four have been rejected. The findings state that perceived enjoyment and user's satisfaction are important determinants for the use of iMap-CampUS. However, performance expectancy has not demonstrated any significant impacts on behavioural intention to use the app. We believe this research has both practical and theoretical implications on the design of future mobile AR apps.

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PUBLICATIONS RELATED TO THE TOPIC OF THE THESIS

- Alqahtani, H., Kavakli, M., 2017: iMAP-CampUS: an Intelligent Mobile Augmented Reality Program on Campus as a Ubiquitous System, 9th International Conference on Computer and Automation Engineering (ICCAE 2017), Sydney, Australia, February 18-21, 2017, 1-5

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- Alqahtani, H., Kavakli, M., 2017: A Theoretical Model to Measure User's Behavioural Intention to Use iMAP-CampUS App, 2017 12th IEEE Conference on Industrial Electronics and Applications (ICIEA), June 18-20, 2017, Siem Reap, Cambodia **(ERA A)**

THESIS STRUCTURE

Below is a brief overview of this thesis. The Thesis is organized into six chapters:

Chapter 1 Introduction presents the main concepts as well as the motivation and aims of the study. Also, it presents the research problem and the research questions.

Chapter 2 Background is divided into two parts:

- Part 1 provides a detailed and comprehensive Literature Review on Augmented Reality.
- Part 2 gives an overview of the theories and models used in the study.

Chapter 3 presents the development of iMAP-CampUS app.

Chapter 4 is divided into two parts:

- Part 1 presents the proposed research framework, related factors and the hypotheses drawn to evaluate user acceptance of technology.
- Part 2 describes the experimental procedures for the evaluation of the app.

Chapter 5 is separated into two parts:

- Part 1describes analysis, validity and reliability of the proposed framework.
- Part 2 presents the results of the analysis followed by a discussion.

Chapter 6 explains the implications, future research and limitations of this study followed by references and Appendices.

LIST OF ABBREVIATION

AR	Augmented Reality
AVE	Average Variance Extracted
BI	Behavioural Intention
BIW	Brief Information Widget
C- TAM-TPB	A combination of TAM and TPB
D&M	DeLone and McLean Model
DoF	Degree of Freedom
EE	Effort Expectancy
FC	Facilitating Condition
GPS	Global Positioning System
HMD	Head-Mounted Display
HTTP	Hypertext Transfer Protocol
IDT	Innovation diffusion theory
iMAP-CampUS	an Intelligent Mobile Augmented Reality Program on Campus as A Ubiquitous System
IP	Indoor positioning
IQ	Information Quality
IS	Information System
ISMAR	International Symposium on Mixed and Augmented Reality
ITU	Intention to Use
JSON	JavaScript Object Notation
LV	Latent variables
MAR	Mobile Augmented Reality
MARS	Mobile Augmented Reality System
MM	Motivation Model

MPCU	The model of PC utilization
MQ	Macquarie University
PE	Performance Expectancy
PENJ	Perceived Enjoyment
PEOU	Perceived Ease of Use
PI	Personal Innovativeness
PLS	Partial Least Squares
POI	Points of Interest
PU	Perceived Usefulness
QR	Quick Response
SAR	Spatial Augmented Reality
SAT	Satisfaction
SCT	Social cognitive theory
SEM	Structural Equation Modeling
SLAM	Simultaneous Tracking and Mapping
SQ	System Quality
TAM	Technology Acceptance Model
TPB	Theory of Planned Behavior
TRA	Theory of Reasoned Action
UTAUT	Unified Theory of Acceptance and Use of Technology
VISOR	Virtual and Interactive Simulations of Reality
VQ	Visual Quality
VR	Virtual Reality

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Chapter 1: Introduction

The potential benefits of using augmented reality (AR) in educational institutions have been recognised by a number of universities [1]. For instance, Columbia University, University of Exeter, National Taiwan University and Fu-Jen University have installed smartphone apps for campus navigation to allow students and visitors' access to campus-related information via self-guided devices[1]. Yet, despite the popularity of AR applications and user acceptance of GPS-based AR technology, only a limited number of researchers have investigated users' acceptance of AR applications. The aim of this thesis is to examine the factors influencing acceptance of the iMAP_CampUS system, a mobile Augmented Reality (AR) application that shows campus-related information superimposed on a map of Macquarie University, Sydney. This chapter describes the research problem, aims, and significance of the study, defines the key terms and concepts, explains the motivation for the study and presents the research question.

1.1 Research Problem

Throughout the world, enhanced mobile and smartphone capabilities have changed how university students and visitors find their way around the campus. Traditionally, orientation was supported by tour guides, signage, online maps or paper-based tour maps. Paper-based tour maps are among the most widely utilised sources of campus information. These, however, contain static images, provide little information, and lack interactive visualisation and accurate navigation facilities. Moreover, it is difficult to update paper-based maps regularly, since printing and distribution are costly. These considerations underpinned our proposal to develop a mobile tour guide utilising AR technology, called iMAP-CampUS.

Recently, attention has been drawn to the power of augmented reality (AR) to change students' views of their campus [1]. AR combines digital information with the student's campus in real time. Unlike virtual reality, which builds a fully artificial environment, AR utilises the existing environment and superimposes new information on top of it. The popularity of smartphones with built-in cameras, GPS and Internet connections has increased the availability of AR applications that allow context-aware tour experiences [4]. AR is especially valuable for educational institutions since it can create an interactive campus in which students and visitors with little knowledge of the site can realistically experience unfamiliar buildings. To date, however, this potential has been under-researched.

1.2 Significance of the Study

Macquarie University (MQ) is a public research university in the suburb of Macquarie Park, Sydney, Australia. Founded in 1964 by the New South Wales Government, it was the third university to be established in the metropolitan area of Sydney. Macquarie has five faculties as well as the Macquarie University Hospital and the Macquarie Graduate School of Management, all of which are located on the university's main campus in suburban Sydney. Despite its relative youth, Macquarie has established a strong local and international reputation [2]. Macquarie campus, which brings together 40,000 students and 2,000 staff, is set on more than 126-hectares and has numerous interconnected buildings [3]. As a result of this dispersed architectural layout, first-year students and visitors experience difficulty locating departments, lecture theatres and other destinations. Being a student at MQ, like many other students and visitors, I initially found it difficult to find my way around the campus, as I knew nothing about the history and purpose of the various buildings.

Over the last few years, educational institutions have increasingly utilised mobile technologies. As mentioned earlier, several universities have recently developed Mobile Augmented Reality (MAR) applications to provide campus-related information. Numerous studies have investigated the adoption of smartphones for these kinds of applications. User acceptance of technology has been a topic of interest to researchers and practitioners for decades. A number of studies have examined the acceptance of mobile applications and services [e.g, 5, 6]. At least one study investigated the acceptance of MAR applications in general [7]. Yet very few studies have addressed users' willingness to use such applications to obtain campus-related information.

Relevant research in the field of IT mostly employs the technology acceptance model (TAM), originally developed by Davis in 1986, and the IS success factors model [8]. It has been suggested, however, that TAM is an incomplete model, requiring additional constructs to improve its predictive ability. Therefore, TAM has modified versions such as the Unified Theory of Acceptance and Use of Technology (UTAUT) to improve its predictive ability [8-10]. The focus of this study is to use this theoretical foundation to examine the factors that influence the acceptance of such systems.

1.3 Goal

The goal of this project is to develop a research framework for the acceptance of a mobile AR app by examining the factors that influence the behavioural intention of students and visitors to use this application. To accomplish this goal, a mobile augmented reality application, iMAP-CampUS, was designed to present campus-related information on specific GPS location.

The focus of the study is users' behavioural intention to use iMAP-CampUS. Specific objectives are to:

(i) identify the factors that influence students' and visitors' intention to use iMAP-CampUS; and

(ii) determine the underlying relationships among the factors.

The expected outcome is that understanding the factors that affect students' and visitors' intention to use iMAP-CampUS can inform the future development and acceptance of mobile AR systems.

To this end, the study employs a combination of the Unified Theory of Acceptance and Use of Technology (UTAUT), IS success factors and motivation theory as a model to predict students' and visitors' behavioral intention to use iMAP-CampUS in higher education institutions (MQ). Our model includes three success measures (information quality, system quality and user satisfaction), three acceptance constructs (performance expectancy, facilitating conditions and behavioural intention), as well as perceived enjoyment and visual quality.

1.4 Research Question

The study addresses the following primary research question (RQ) with two secondary questions:

> **RQ 1:** Can a theoretical model be developed and used to predict the acceptance of a typical mobile AR app (iMAP-CampUS) by determining the correlations between the proposed constructs in the existing models for user acceptance?
>
> This knowledge can help to make this type of application more acceptable to users. More specifically, we investigate the following secondary research questions:
>
> > **RQ 1.1:** What are the factors that influence students' and visitors' behavioural intention to use iMAP-CampUS?
> >
> > **RQ 1.2:** What are the correlations between these factors?

1.5 Contributions of the Study

- The development of a mobile AR application as a ubiquitous system (iMAP-CampUS) that can show university campus-related information on specific GPS location when needed.
- The development of a research framework for the acceptance of a mobile AR app (iMAP-CampUS) that integrates important constructs from different theories and models.
- The identification of the most important factors influencing the acceptance of a mobile AR app (iMAP-CampUS) that can be used to extend TAM.

Chapter 2: Literature Review

The chapter presents a comprehensive review of relevant literature. The first part provides an overview of the history and characteristics of augmented reality (AR). The second part explains the theoretical foundation of the technology acceptance model that was employed in this study.

2.1 Augmented Reality

2.1.1 Definition and Taxonomy

Augmented Reality (AR) and Virtual Reality (VR) appear at the opposite ends of the reality-virtuality continuum (Figure 2.1). In VR technology, users are totally immersed in an artificial environment and cannot see the real world around them. In contrast, AR permits the user to see the real world, with virtual objects superimposed upon or composited with the reality. Thus, AR supplements reality, instead of entirely replacing it [11].

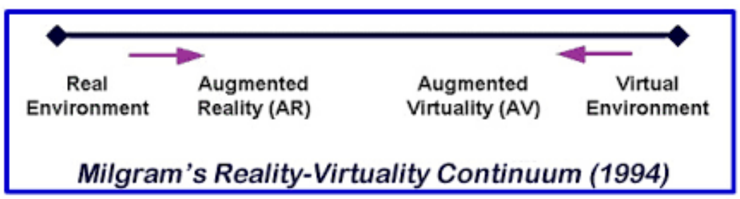

Figure 2.1 Virtual and augmented reality concepts

The concept of the reality-virtuality continuum was introduced by Milgram and Kishino to describe the diversity of environments that are connected with virtual reality [12]. In Figure 2.2, the real environment includes only real objects, while virtual reality, at the opposite end of the continuum, contains only virtual objects. Mixed reality, between the real environment and virtual reality, consists of real world and virtual world objects presented together within a single display [12]. In augmented virtuality, the primary world is the virtual world augmented by real objects. In augmented reality, the primary world is the real world augmented by virtual objects.

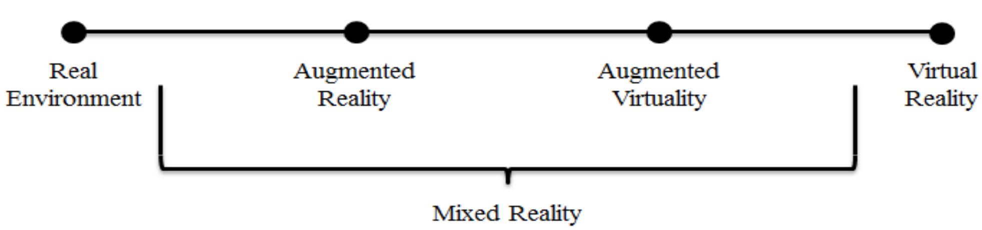

Figure 2.2 Reality-virtuality continuum

One of the most commonly used definitions of AR proposes that AR technology should integrate real and virtual content, be interactive in real time and be registered in 3D [13]. Most users, however, accept a less stringent definition in which the virtual area can contain only 2D objects including text, icons and images [14]. This thesis adopts the latter perspective.

Given that it is permissible to use 2D representations in AR, there are two options for displaying image overlays: by displaying the images as 3D objects in the scene; or by displaying the images as flat 2D overlays over the scene. At first glance, displaying the images as flat 2D overlays might seem simple. Hence, successful AR applications described in the literature have employed the first option[14]. Aligning images with 'reality' in 3D view can end up being just a gimmick instead of a useful feature. Given the technical difficulties such as information delay in graphics processing or correct alignment of real and virtual object, in developing an application with 3D objects and the problems associated with its use, the second approach was adopted to display photographs as flat 2D overlays in the MQ Tour Guide app.

2.1.2 Historical Development

The origin of AR can be traced back to 1957, when Morton Heilig added visuals, sound, vibration and smell to movies [15]. In 1968, Sutherland invented the first head-mounted display (HMD), which comprised two types of head sensors - a mechanical sensor and an ultrasonic sensor. In 1992, the term 'augmented reality' was coined by Caudell and Mizell [15] to describe a digital display they developed at Boeing to provide wiring instructions for aircraft assembly. At the U.S. Air Force's Armstrong Laboratory in 1993, Rosenberg developed one of the first AR systems, Virtual Fixtures, in which he manipulated tasks from a distance using an overlay of augmented sensory information [16]. Also in 1993, KARMA (Knowledge-based Augmented Reality for Maintenance Assistance) was developed by [17]to allow the user to implement a maintenance task on a laser printer. The first AR theatre production (Dancing in Cyberspace) was produced in 1994 [18]. Rekimoto developed one of the first marker systems that allowed camera tracking with six degrees of freedom (6DoF)[18] .

In 1997, the first mobile AR system (MARS), the Touring Machine, was introduced[17] . Its unit provides campus information through a see-through head-worn display with an integral orientation tracker. Kato and Billinghurst in [19] developed ARToolkit in 1999. In 2000, the authors developed AR-Quake, an AR extension to the desktop game Quake[20] . AR-Quake was based on a 6DoF vision-based tracking system that used fiducial markers, GPS and a digital compass.

The first see-through AR system for tracking 3D markers on the phone was developed by Mathias Möhring et al. [21] . In 2008, Wikitude, the first Android smartphone, was launched by Mobilizy. This application merges GPS and compass data with entries from Wikipedia. Also in 2008, Metaio developed a mobile AR museum guide that used technologies such as markerless tracking and hybrid tracking [22]. In 2009, ARToolkit developed the open-source SDK to the web browser which is FLARToolkit. With various advances in technology, by 2011, AR had gradually begun to change from marker-based to markerless systems, and mobile context-aware AR apps became available for mobile devices [23]. In 2013, Volkswagen developed MARTA, a service support app that provides a virtual step-by-step repair guide [23]. In the ensuing years, Google Glass and Pokemon became widespread.

2.1.3 Mobile Augmented Reality (MAR)

Over the past few decades, augmented reality apps have been widely used on mobile devices to enhance our experience with our surroundings and help us deal with it in creative and engaging ways. Mobile AR (MAR) is defined as "AR created and accessed with mobile devices in cellular contexts of use" [24]. Mobile AR systems provide similar services to traditional AR systems without forcing the user to choose a particular location [25]. According to[13], mobile AR is one of the fastest growing research topics in the field of AR due to the prevalence of smartphones that provide powerful mobile platforms. Current smartphones and tablets combine a fast processor with graphics hardware, a touch screen and relevant embedded sensors such as camera, GPS and Wifi for indoor positioning [4]. They also accommodate in-built sensors such as a gyroscope and accelerometer for both indoor and outdoor AR.

Recent technological developments in mobile computing, wireless sensors and computer graphics have stimulated the rapid growth of AR applications on smartphones[26]. AR applications are currently seen in various fields such as education, medical science and architecture[1, 26]. Relatively less explored, however, are mobile AR applications for self-guided tours, such as campus navigation systems[1]. The use of AR in self-guided tours is practical and has the advantage of providing natural mapping between information and real locations. Therefore, it can help students and visitors better understand their environment.

AR technology has been utilised in mobile devices for self-guided tours in universities throughout the world. In the US, mobile AR campus navigation system development began in 1996 at Columbia University [27] and, in 2010, a smartphone campus tour system was introduced to allow visitors to experience campus history [28]. In the UK, the University of Exeter developed a dynamic landscape of flora and fauna in AR [1]. Employing AR, the campus became an accessible learning resource for both formal and informal curricula. In Taiwan, National Taiwan University developed a mobile AR campus touring system and Fu-Jen University (FJU) enabled its students to experience the history of the campus using MAR in 2012 [1].

Instead of a head-mounted display, the system used GPS-based AR; for positioning, it relied on GPS coordinates [1]. The AR application was developed on top of Layar, an AR app for smartphones that supports both Android and iPhone/iOS. Layar visualises Points Of Interest (POI) as markers on top of the live camera feed from the smartphone. It processes the positioning and rendering of information on the smartphone and allows the app developers to concentrate on constructing a web service with the information they want to cover.

The CityViewAR system is an example of city-based mobile AR [29]. Students and international visitors can use this mobile phone application to learn more about the architecture in the city of Christchurch, New Zealand, as it was before the 2011 earthquake. In [30], a mobile app uses AR technology to explain the history and architecture of a real building. Kavakli in [31] proposed a generic framework (4Any) for people-centric mobile AR systems to leverage the application system design and implementation. The 4Any framework was used in ArcHIVE 4Any in Chalon sur Saone, France and Anzac Cove, Gallipoli, Turkey to display heritage-related architectural information.

Tokusho and Feiner [32] developed the "AR street view" app which provided an attractive means of accessing geo-information for navigation. When users walked down a street, the street name, virtual paths and current location were overlaid on the real world to provide an enjoyable view of surrounding sites. Marimon et al. [33] developed an app called MobiAR for tourist information based on AR. MobiAR provides users with information and multimedia content about a city on their smartphones. Liu and Tsai in [34] developed an AR app fo that allows students to access information in English about nearby locations.

Overall, mobile AR technology creates outstanding opportunities for situated learning. Research, however, has tended to focus on applications for indoor rather than outdoor learning. Situated Learning focuses on the relationship between learning and the social situation in which it occurs. Rather than considering learning as the acquisition of knowledge, situated learning posits that learning is unintentional, and situated within authentic activity, context and culture. One goal of this project was to develop an iMAP-CampUS app to support situated learning for students and visitors. The app development is described in more detail in Chapter 3.

While AR is a valuable tool to provide content and enhance university visitors' experience, it can also be a reason for visiting universities to experience innovative technologies.

2.1.4 AR Hardware Technology

Currently, AR systems require both hardware and software to provide a compelling AR experience. This section describes display technologies that integrate the real and virtual worlds and the sensors and tracking devices that provide information about user position and orientation.

2.1.4.1 Display

Three main types of display are used in AR: head-mounted displays (HMD), handheld displays and spatial displays.

HMDs are worn on the head or as part of a helmet. A HMD places images of both the real and virtual environment over the user's view of the world. There are two types of HMDs: video-see-through and optical-see-through. HMDs can have a monocular or binocular display optic. Video-see-through systems require users to wear two cameras on their head, both of which must be processed to provide the real part of the augmented scene and the virtual objects. Optical-see-through, by contrast, uses a half-silver mirror technology to allow views of the physical world to pass through the lens and graphically overlay information to be reflected in the user's eyes.

Handheld displays use tiny computing devices with a screen that can be held in the hand. They employ video-see-through techniques to overlay graphics onto the real world and use digital sensors, including compasses and GPS units, for their 6DoF tracking sensors, fiducial marker systems and computer vision methods. This type of display was most appropriate for the present study for several reasons: it makes our app simple and easy to use, it does not require expensive equipment (other than a mobile phone) or training on new equipment. Handheld displays are the most efficient choice given the fact that HMDs cause delay in graphics processing of real scene and hence, misalignments spatio-temporal in information processing.

Spatial Augmented Reality (SAR) employs video-projectors, holograms, optical elements, radio frequency tags and other tracking technologies to present graphical information directly onto physical objects with no need for the user to wear or carry the display. SAR allows for collaboration between users. Accessibility of SAR is limited for the end user and therefore, the thesis targets only handheld display.

2.1.4.2 Tracking

Tracking is an essential technology for AR. The position of the user must be known so that the virtual information can be precisely overlaid over the real. This section describes some of the common tracking techniques that are suitable for use in AR devices, with particular focus on sensor-based and vision-based techniques. Hybrid techniques integrate elements from each of these to provide a more robust result.

2.1.4.2.1 Sensor-based tracking

Sensor-based tracking techniques use acoustic, magnetic, inertial, GPS or optical sensors to determine the position of the viewer.

Acoustic tracking employs ultrasonic signal emitters and receivers. The receiver can calculate the distance to the emitter by measuring the time taken for the signal to travel through the air. At least three emitters are needed to estimate all 6 DoF.

Magnetic tracking requires a source creating an electro-magnetic field and one or more sensors placed within the field. This system allows for stable and accurate tracking in all DoF as long as the sensors are located in the field.

Optical tracking is often based on the infrared spectrum. One object is equipped with markers, which either reflect or emit light. The light is gathered by one or several cameras placed in a known location, and then the location of the tracked object is figured by combining data from each camera.

Inertial tracking estimates orientation with the help of accelerometers, gyroscopes and magnetometers.

GPS tracking is often used in MAR systems to obtain a basic geographic location from the GPS sensor on the device. This is augmented by Wi-Fi and cell tower locations. Global positioning satellite (GPS) systems are usually used for outdoor mobile device tracking. GPS does not function well indoors because of the requirement for an active link to the satellites. Indoor positioning (IP) uses wireless technologies to locate the device inside buildings. GPS tracking was the most appropriate system for our purposes because it does not require the installation of any extra equipment.

2.1.4.2.2 Vision-based tracking

Vision-based tracking has attracted far more research attention than sensor-based techniques, with nearly 80% of tracking-related papers submitted to the ISMAR conference (primary venue for AR papers) employing computer-vision methods [35]. Vision-based methods use image processing of camera images to define the camera's pose in relation to real-world objects. There are two types of vision-based tracking techniques: marker-based and marker-less approaches.

The marker-based approach requires that the app to recognise an artificial fiduciary marker located at any place or on objects in the real world in order to bring up the correct information. Marker-based approaches often utilise a 2D image or QR code to be identified by a mobile device equipped with a suitable software application [35, 36].

The marker-less approach relies on natural feature detection to read real world objects, such as posters or landmarks that have no artificial makers to facilitate object recognition [14]. Many recent techniques are either feature-based or model-based.

Feature-based techniques are "the first attempt to find a correspondence between features in the 2D image and their world frame coordinates in 3D space. This is typically done by exploiting prior knowledge of the geometry of the scene and camera lens" [37]. Feature-based techniques use either fiducial marker-based tracking or natural feature tracking.

Fiducial marker based tracking is the most commonly used technique to achieve AR. Fiducial markers with a known size and shape are placed within a scene. This type of tracking system is popular in AR due to easy recognition and high contrast in the field of view. Further, it does not only relate to points in space, but can also calculate the user's distance and angle of vision. Typical markers used in fiducial marker-based tracking are black and white squares with geometric figures. It is essential to remember the marker's position and refresh its position according to the movement of the device.

Natural feature tracking allows the use of objects in the real environment as markers by recognising their natural features. It does not require any objects to be added to the environment and is commonly used when no engineering of the outdoor environment is possible. Natural features refer to points, edges, lines or textures that might be displayed in the camera image [37].

Model-based tracking. The development of vision-based tracking methods has recently begun to focus on model-based tracking. Model-based systems track the camera by trying to fit a known 3D model to the camera image. The 3D model can either be a hand-created model or one that is generated at runtime through a process called simultaneous tracking and mapping (SLAM), which usually needs much more processing power.

2.1.4.3 Hybrid tracking

As noted earlier, all techniques have their shortcomings. To address these, hybrid tracking merges two or more data sources (e.g. GPS, compass, accelerometer) to calculate actual position and orientation. The GPS, for instance, allows the current position of the device to be defined; with this information, users can find objects in their area that are to be augmented.

Overall, vision-based tracking techniques are slow and fragile, particularly in natural outdoor settings. In marker-based AR, the markers are placed in the real world; this can be a time-consuming process, seeks a certain amount of control of the environment, and requires permission for the developers to hang the markers. Although it does not require the same control of the environment as marker-less AR, it is susceptible to small changes in lighting and in surrounding objects.

In summary, vision-based tracking techniques offer a simple solution for institutions that are looking for a means of developing an indoor AR application [38]. For the purposes of the present study, a hybrid, sensor-based based tracking approach is appropriate, since iMAP-CampUS is an outdoor application that covers a limited geographical area.

2.2 User Acceptance

An important part of implementing a new technology in educational institutions is to assess its likely adoption by students. Numerous studies evaluated the factors that influence IT acceptance and use [5, 6]. AR, however, is not widely utilised and, as a new phenomenon, it has been investigated more slowly than expected [39]. Existing research has primarily focused on its technological features and developmental phases [29, 31, 33].

Yusoff and Ahmad [40] used a number of constructs to determine acceptance of mixed reality technology. These included personal innovativeness (PI), perceived enjoyment (PENJ), perceived ease of use (PEOU), perceived usefulness (PU), and intention to use (ITU). Results from simple correlation analyses showed positive linear correlations between the constructs. Findings from regression analysis, however, suggested that perceived usefulness was the most important factor determining users' intention to use mixed reality technology [40].

Studies have put forward various explanations for IT acceptance or rejection [41-43]. Students may develop a positive behavioural intention if the AR system is easy to use, attractive, available, informative and fast. Numerous studies have identified behavioural intention as a significant predictor of the acceptance of new technology[44, 45].

For this project, we developed a theoretical model for understanding students' and visitors' behavioural intention to use mobile AR systems in a higher-education setting. The comprehensive model combines the Unified Theory of Acceptance and Use of Technology (UTAUT), the Information System (IS) Success Model and motivation theory. Each of these is discussed in more detail below. This integration generated three success measures (information quality, system quality and user satisfaction) and two acceptance constructs (effort expectancy and facilitating conditions). Motivation theory was also introduced since perceived enjoyment is believed to influence students' and visitors' behavioural intentions. Most previous studies indicated that perceived enjoyment is affected by visual quality. Therefore, visual quality is one of the external factors in our model.

Acceptance of technology is defined as "the demonstrable willingness within a user group to employ information technology for the tasks it is designed to support" [46]. This can be assessed in relation to recently developed technologies and to technologies which have not yet been implemented. AR acceptance models have attracted significant research attention over the last two decades. Eight models that explain human behaviour and predict AR acceptance have been identified [47]:

- The theory of reasoned action (TRA) [48].
- The technology acceptance model (TAM), developed from TRA by Davis [8].
- The theory of planned behavior (TPB) [49].
- The motivational model (MM) [50].
- Social cognitive theory (SCT) [51].
- A combination of TAM and TPB (C- TAM-TPB) [52].
- The model of PC utilisation (MPCU) [53].
- Innovation diffusion theory (IDT) [54].

2.2.1 Technology Acceptance Model (TAM)

The theory of reasoned action (TRA) proposes that behaviour and intention are affected by two main constructs: attitude about behaviour and subjective norms [48]. From this, TAM was developed to understand users' acceptance and usage of a given technology [8].

TAM, a simple theory in the field of information systems (IS) research, has been widely used to demonstrate the role of intentions in individual behavior [8]. TAM identifies the key determinants of behavioural intention as perceived usefulness and perceived ease of use (see Figure 2.3). Perceived usefulness (PU) is defined as "the degree to which a person believes using a particular system would enhance his or her job performance", and "perceived ease of use" (PEOU) is defined as "the degree to which a person believes that using a particular system would be free of effort" [8]. In the original model, Davis proposed that perceived ease of use indirectly affects behavioural intentions via attitude [8]. Davis later rejected this view because of the weak mediation effect of attitude and his subsequent work confirmed that PU and PEOU, were directly associated with behavioural intention [50]. In this model, the external variables such as system design features, personal characteristics and the like, are fully mediated by PEOU and PU. In fact, external variables gave a better understanding of what affects PEOU and PU.

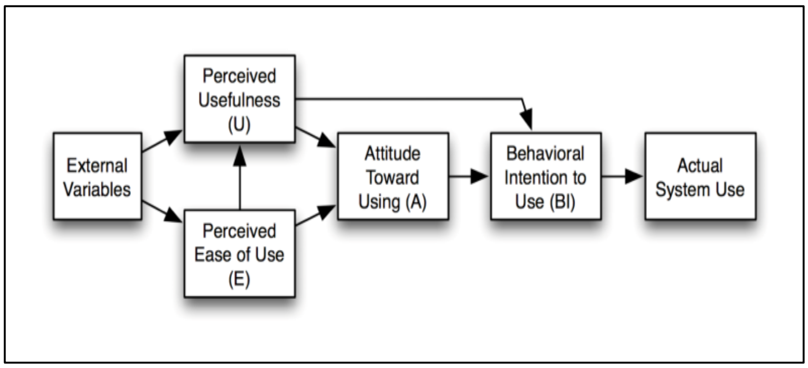

Figure 2.3 Technology Acceptance Model

Although a number of theories explained AR adoption or behavioural intention, they did not simultaneously consider utilitarian significance and hedonic significance. As a result, Van der Heijden extended the original TAM by adding the hedonic factor of perceived enjoyment, explaining that hedonic value is a key determinant of intention [55].

Since TAM does not explain post-adoption behaviour, Bhattacherjee developed an expectation-confirmation model (ECM) to explain the behavioural intention to use AR. User satisfaction, in the form of an overall evaluation of an AR app, was found to be a crucial determining factor [56].

Based on research conducted by Davis, the extended TAM, known as the Unified Theory of Acceptance and Use of Technology (UTAUT), was introduced. UTAUT constructs are derived from the eight models mentioned above [47] in 2.2 section.

2.2.2 Unified Theory of Acceptance and Use of Technology

TAM has since been extended by combining factors from different theories to enhance understanding of key acceptance constructs [57]. AR research has used TAM and expanded versions of TAM to investigate new technology concepts [58]. The unified theory of acceptance and use of technology (UTAUT) developed by Davis sought to address identified shortcomings in previous theories. UTAUT, as shown in Figure 2.4, proposes four core constructs - performance expectancy, effort expectancy, social factors, and facilitating conditions that affect users' behavioural intention and use behaviour. The behavioural intention construct refers to the possibility of using of the iMAP-CampUS app in our case.. Four other factors (gender, age, experience and voluntariness of use) are seen to moderate users' adoption of an IS. Age and gender have received very little attention in the literature but the results from studies using UTAUT show that they moderate all of the key relationships in the model.

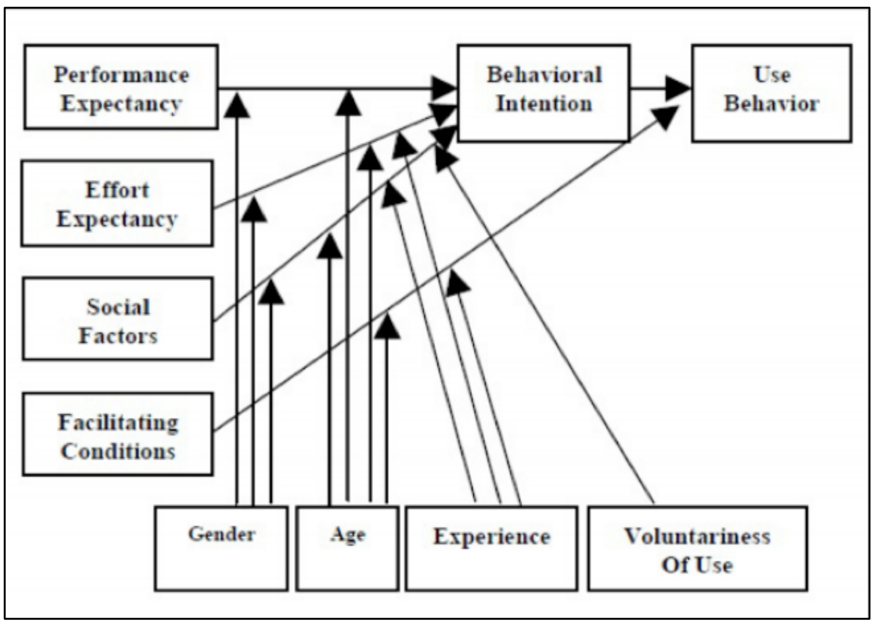

Figure 2.4 Unified Theory of Acceptance and Use of Technology Model

The literature shows that these eight determinants can explain roughly 70% of technology acceptance behaviour[10, 59]. The UTAUT model has been empirically validated and it has been successfully applied in the field of mobile technology adoption, which is similar to the framework proposed in this study [60] (see Figure 2.3). The initial TAM proposed that acceptance or rejection of AR is based on two beliefs: perceived usefulness and perceived ease of use. These are similar to performance expectancy (PE) and effort expectancy (EE), respectively, in the UTAUT model. The other constructs are social factors, which affects behavioural intention, and facilitating conditions, which directly affect use behaviour.

Social factors are omitted from the proposed model as they are not an immediate determinant of use behavior in the present study[61]. Age, gender experience, and voluntariness of use suggested by UTAUT are also removed because they are not meaningful since we target volunteers to test a generic AR app. Further, since the study goal is to measure students' and visitors' behavioural intention to use mobile AR, the use behaviour in UTAUT and use in the DeLone and McLean (D&M) model were also deleted [61-63]. Finally, in TAM, effort expectancy, a significant construct in UTAUT, is useful for explaining use behaviour in the first stage of adoption but not to explain behavioural intention in the last stage [56].

2.2.3 IS Success Model

Following a review of relevant literature, DeLone and McLean (D&M) suggested a model for measuring IS success [62, 63]. This multidimensional model contains six groups of success factors: system quality, information quality, use, user satisfaction, individual impact, and organization impact (see Figure 2.5).

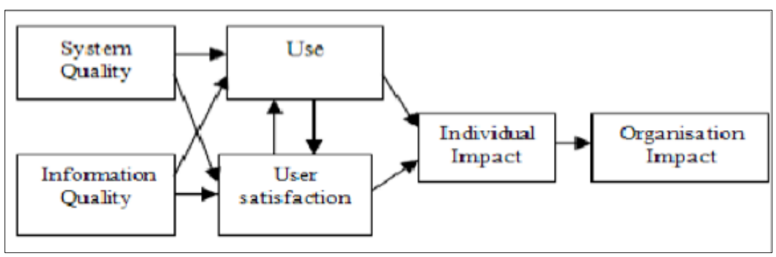

Figure 2.5 IS Success Factor Model

Both system quality and information quality influence use and user satisfaction. User satisfaction can be impacted by the amount of use and vice versa. Use and user satisfaction have a direct association with individual impact.

Success factors differ from one IS to another. Stockdale and Borovicka reported that success factors were affected by the type of system being examined. Thus, it is critical to link the context of the IS to the appropriate success measures [64]. In this study, information quality, system quality and user satisfaction are adapted from the model by DeLone and McLean. Ahn surveyed users of online retailing systems to examine the extended TAM model and showed empirically that system quality and information quality were positively associated with PE [65].

2.2.4 Motivation Theory

The motivational theory proposed by Deci explains behaviour in relation to extrinsic and intrinsic motivations. In the context of AR usage, extrinsic motivation relates to utilitarian aims such as expecting a reward or benefits [66, 67], whereas intrinsic motivation relates to hedonic goals such as the expectation of that interaction with the system itself will be a source of pleasure or satisfaction [55] . Performance expectancy (PE) focuses on extrinsic motivation whereas perceived enjoyment (PENJ) focuses on intrinsic motivation [68]. These two beliefs are the principal constructs used in UTAUT to predict behavioural intention [8, 55]. Thus, the present study investigates both extrinsic and intrinsic motivation influencing the behavioural intention to use AR at universities.

2.3 Summary

This chapter has presented an overview of AR, including its definition, history and technology, and has described the various theories and models that underpin the proposed model of the determinants of AR acceptance. The empirical validity of the proposed model was examined in the context of a higher-education institution, Macquarie University, using the iMAP-CampUS app. This is discussed in detail in the following chapter.

As stated in 2.2,

- we expect to find positive linear correlations between performance expectancy (PE), Perceived enjoyment(PENJ), user satisfaction (SAT) and behavioural intention (BI).
- Behavioural intention (BI) as the significant predictor of proposed research framework.
- Performance expectancy (PE), perceived enjoyment(PENJ) and user satisfaction (SAT) are directly correlated with behavioural intention (BI).
- Information Quality (IQ), system Quality (SQ), visual Quality (VQ) and Facilitating Condition (FC) are directly associated with performance expectancy (PE) and perceived enjoyment(PENJ).
- Performance expectancy (PE) as extrinsic motive and perceived enjoyment(PENJ) as intrinsic motive influence user satisfaction (SAT).
- Perceived enjoyment(PENJ) affect performance expectancy (PE).

Chapter 3: iMAP-CampUS

This chapter describes the development of iMAP-CampUS app to examine the relationship between a MAR application and the acceptance of such technology in a higher-education institution. iMAP-CampUS is a location-aware mobile AR augmenting the information about the surrounding buildings as users navigate the campus.

3.1 Requirements

3.1.1 Materials

The project required the photos of specific buildings be available and that the latitude and longitude of each building location be assigned. We identified 35 potentially suitable buildings. 22 were selected for inclusion in the iMAP-CampUS.

3.1.2 Stakeholders

The goal of the project is to design and implement a mobile AR system for touring Macquarie University campus. Interviews with students and visitors were conducted at the beginning and end of the development process. The initial interviews showed that there was significant interest in having a tool that would help students and visitors to orient themselves quickly and easily. More importantly, they emphasised that such an application should be easy to learn and easy to use.

The final interviews were conducted after the students and visitors had seen the developed prototype. It was then suggested that the application should be extended to include 3D objects, cover the whole campus, enable indoor navigation and provide an option for vocal guidance for users with disabilities.

3.2 Development

3.2.1 Technologies and Tools

In the last decade, a great many libraries and software kits have been developed to support the development of AR applications. In order to select the most appropriate tools for this project, a preliminary investigation of potential software solutions for developing a GPS tracking system was conducted.

The existing software development kits differ in relation to their quality and ease-of-use. A number of lower-level development tools are available for GPS tracking, but they require programming experience in order to create the actual applications. For outdoor use, a number of small libraries support the creation of sensor-based AR applications, such as DroidAR, 3DAR and BeyondAR, but these are hard to use and are not always updated regularly. One of the largest AR SDK providers, Layar, emerged as the most suitable option for developing iMAP-CampUS app.

The mobile client app was developed using the Layar platform based on Layar SDK. Layar SDK is a freeware tool that assists the development of mobile AR applications. Layar is easy and polished as a professional package since 2007. The Layar SDK offers in a static library that creates the vision and geo location functionalities in a mobile device and shows the AR content to the user. Layar is used on various mobile OS platforms, such as iOS and Android; there are numerous development examples on the official website (https://www.layar.com/). The AR display system follows the Layar's architecture, providing virtual objects based on GPS coordinates and multiple interactions with the virtual real environment.

The GoDaddy development framework was used as the remote data server The MySQL database server was selected because it was free and easy-to-use. We also used HTTP protocol and JSON transmission format are widely used for data communication between client and server.

3.2.2 System Overview and Functionality

iMAP-CampUS developed using the Layar platform [69] is available for both Android and iOS devices. iMAP-CampUS augments information about various buildings as users navigate the campus. The GPS coordinates of 22 locations on campus were stored in a database. The iMAP- CampUS application on the user's smartphone shows the POIs within a particular range, along with the specific information about these points. Supplementary information about each POI was provided by Macquarie University security manager. Geo- location information for each POI was acquired using Google maps.

The iMAP-CampUS app shows important buildings around the campus, such as Macquarie Library, Macquarie Theater and Macquarie Hospital. It visualises POIs in distinct styles, through colour and size, representing various buildings. The size of the icon for each POI is dynamically modified according to the user's distance from it. The bigger the icon, the closer the user is to the POI (Figure 3.1). All POIs are represented by circular icons and displayed as black disks when activated.

Figure 3.1 iMAP-CampUS app main window

The main window of the iMAP-CampUS supports three different types of functionality (Figure 3.1). After the system is launched, GPS information is accessed instantly, and POI information is then loaded according to the user's location. Next, the user can press on one of these POIs to obtain more detailed information about it. Finally, users can ask for navigation directions to a specific location/POI by clicking the ''Take me there'' button. Directions are displayed on Google maps. The iMAP-CampUS also allows other functions, such as calling a phone number, surfing a website, sending an email and playing a video or audio.

3.2.3 System Architecture

The system architecture of the iMAP-CampUS has five components (see Figure 3.2):

iMAP-CampUS reality browser. The client on the mobile device of the user is the browser that retrieves the GPS coordinates (latitude, longitude) of the current location. From these coordinates, iMAP-CampUS searches for POIs in an adjustable range.

Layar server. The core component of the iMAP-CampUS service is the server that provides the interfaces to the iMAP- CampUS reality browser, the Layar publishing site and the external iMAP-CampUS service providers.

Layar publishing website. On the Layar website, developers can register new layers and manage their layers and accounts.

iMAP-CampUS service providers are created by third party developers. The iMAP-CampUS service provider returns only the POI information as inserted in the POI table. The iMAP-CampUS service provider stores the HTTP server (the developer's IIS server), PHP engine, MySQL database server, .php file and MySQL tables, for a particular layer.

iMAP-CampUS content sources provide the content to be viewed in the iMAP-CampUS reality browser. These sources include servers that host content required for viewing the details.

Two interfaces are exposed to third parties: the Layar client API and the Layar server API. The Layar client API is the interface between the Layar server and the iMAP- CampUS app, whereas the Layar server API is the interface between the Layar server and the iMAP-CampUS service providers.

As shown in Figure 3.2, when the students open the app, the iMAP-CampUS client sends a getPOIs request to the Layar platform which, in turn, forwards the HTTP request to the iMAP-CampUS service provider (requestPOIs in Figure 3.2). Then, the iMAP-CampUS service provider sends the AR content back (as a JSON response) to the Layar platform (getPOIs in Figure 3.2). This JSON response contains the array of POIs in the database table. Finally, the Layar platform validates the getPOIs response and passes it to the iMAP-CampUS client (getPOIs in Figure 3.2), which visualises the content to the mobile device.

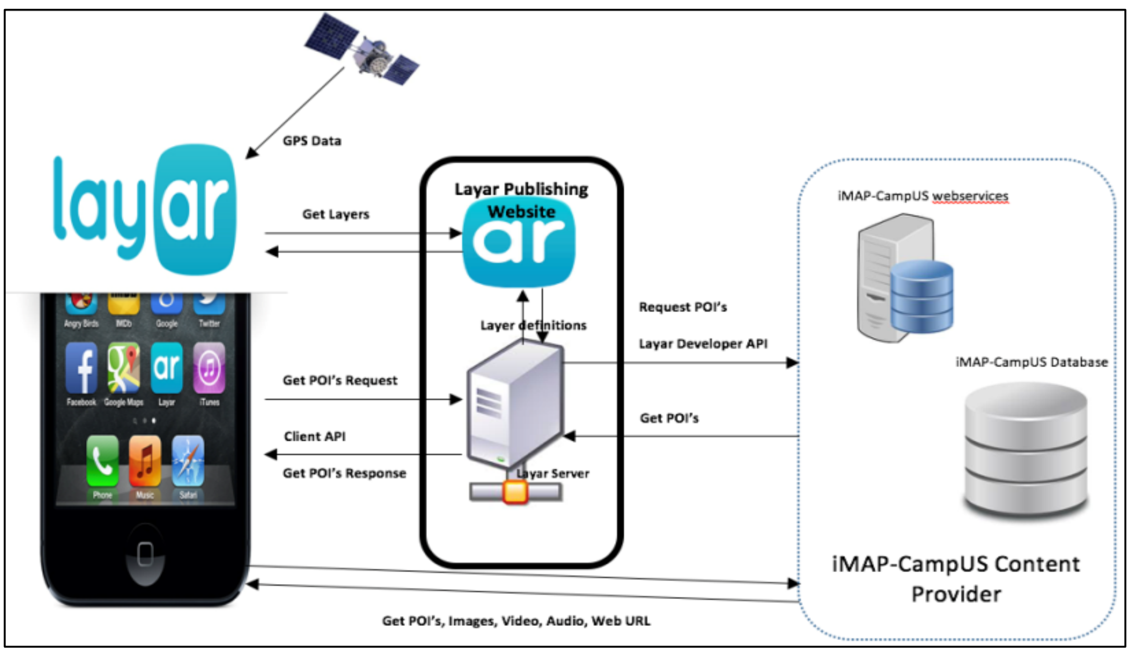

Figure 3.2 iMAP-CampUs System Architecture

A significant part of iMAP-CampUS's architecture is the database, which contains four tables. Each database table consists of Layar-related ID information and all the POIs' GPS coordinates (longitude, latitude and altitude). The information about each POI is also stored in the iMAP-CampUS database to ensure the availability of the information even if the primary source or webpage is down (Figure 3.3).

id	footnote	title	lat	lon
geo_1	Faculty of art	Faculty of art	-33.8322370000	151.0846470000
geo_10	Australian Hearing Hub	Australian Hearing Hub	-33.8394350000	151.0833820000
geo_11	Macquarie lake	Macquarie lake	-33.8356400000	151.0825880000
geo_2	Macquarie Library	Macquarie Library	-33.8300260000	151.0839660000
geo_3	Faculty of Computing	Faculty of Computing	-33.8284020000	151.0858580000
geo_4	Macquarie Theature	Macquarie Theature	-33.8360910000	151.0849760000

Figure 3.3 POI table

3.2.4 User Interfaces

This section explains all the available characteristics of iMAP-CampUS. The iMAP-CampUS reality browser runs on an iPhone or Android. As a 2D application, it consists of various features such as the reality view, map view and POI pop-up window in addition to "about" and "take me there" buttons that give more information about the POI as well as directions on how to get to the POI using the smartphone's map. Other features include a horizontal grid to display distance on the app's screen as well as a filter that adjusts the search range. A share option is also provided to allow users to share iMAP-CampUS with friends through channels such as Facebook, WhatsApp and Twitter. Users can also take photos of what they see on the browser (Figure 3.4).

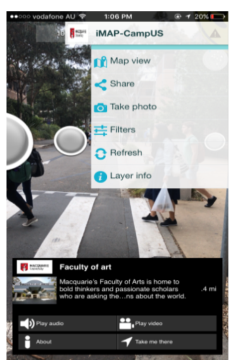

Figure 3.4 iMap-CampUS options

The *reality view* is the default view, which will be the most commonly used view. Students and visitors hold their smartphone vertically to the ground and view reality through the camera lens. Superimposed over reality in a 2D layer are the POI icons. Each POI icon identifies one point of interest. In the Macquarie Campus map, the POI icons mark various buildings around the campus (Figure 3.5.)

The *map view,* as shown in Figure3.6, can be quite helpful.

Choosing a POI launches its *brief information widget* (BIW). The Macquarie Campus Map BIWs contain several buttons such as a title for the POI, a description of what the POI is marking, an image of the POI, a "take me there" option (Figure 3.8), an "About" button that brings up a web site with brief information about the building, and "play video" and "play audio" buttons, among others (Figure 3.7).

Figure 3.5 Reality view

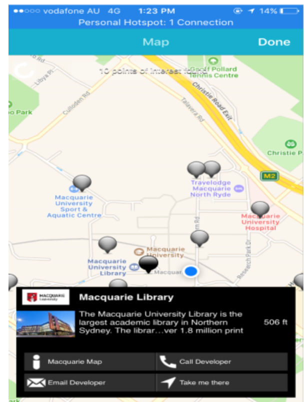

Figure 3.6 Map view

Figure 3.7 BIW pop-up

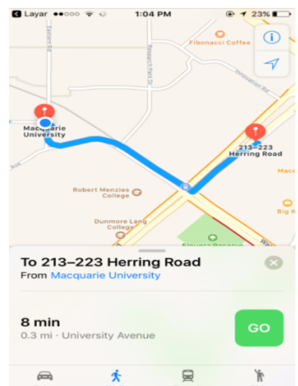

Figure 3.8 Take me there

3.3 Summary

This chapter has described a mobile AR based mobile application, iMAP-CampUS which was developed using the AR platform, Layar. The prototype was developed for both iOS and Android. It requests data about surrounding buildings using a database provided by Macquarie University Property Office as well as Google maps. The application aims to facilitate free-flow navigation of buildings to help students and visitors identify nearby POIs. The app can potentially be extended in various ways, for instance, to cover the whole campus, provide the option of saving the sites visited, provide filters, use 3D objects, add list views, have a transparent video, provide indoor navigation and offer vocal guidance for users with disabilities. The following chapter describes the proposed technology acceptance model and explains the methodology.

Chapter 4: Methodology

This chapter explains the theoretical framework, constructs and relationships of the components in the proposed framework. Our hypotheses are presented, and the operationalisation of constructs is described. This is followed by an account of the experiment design, survey instrument and data collection procedure.

4.1 Research Framework

A framework indicates the perspective used for addressing research questions. It is prescriptive, therefore, can be tested. A model is developed within the framework as a descriptive tool to impose an order on how variables are potentially interrelated so that we can begin to formulate questions aligned with the chosen framework.

The framework gives the overall structure of the project, while the model explores the specific methodology of research. We developed a conceptual framework for the acceptance of iMAP-CampUS. The proposed framework aims to generate an understanding of the opinions and intentions of students and visitors at MQ regarding the acceptance of the iMAP-CampUS app.

The theoretical basis for the study draws on constructs from UTAUT and extends by adding constructs from the IS success factors and Motivation Theory, as shown in Figure 4.1 The selection of these constructs was based on features identified in the literature review as relevant to the AR area. As mentioned in 2.2, we decided to include only the constructs with a focus on the acceptance of the AR tools. Thus, we did not include all of the constructs in these three models in the proposed framework.

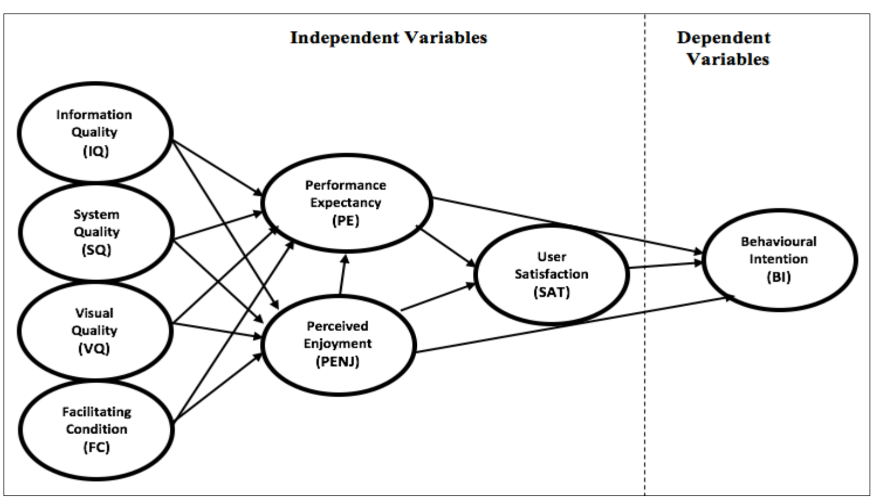

Figure 4.1 The proposed framework

The model suggests system quality (SQ), information quality (IQ), visual quality (VQ) and facilitating conditions (FC) are predictors of performance expectancy (PE) and perceived enjoyment (PENJ). It further suggests that performance expectancy and perceived enjoyment are antecedents to satisfaction (SAT) in AR. Perceived enjoyment (PENJ) in turn influences performance expectancy (PE). Finally, user satisfaction is a predictor of behavioural intention (BI) to use the AR system. System quality, information quality, visual quality, facilitating condition, performance expectancy, perceived enjoyment and satisfaction are independent variables; behavioural intention to use AR is the dependent variable.

4.2 Operationalisation of Constructs and Hypotheses

The theoretical constructs were operationalised based on literature relevant to the field of AR. According to the framework we proposed in Figure 4.1, factors affecting the acceptance of iMAP-CampUS app were: information quality, system quality, visual quality, facilitating conditions, performance expectancy, perceived enjoyment and user satisfaction.

4.2.1 Relationship between External Variables and Mediating Constructs

4.2.1.1 Success measures and AR

According to DeLone and McLean, information quality (IQ) is the quality of the output of the IS. It considers whether the IS provides all relevant information. Information quality (IQ) is also gauged by the style and presentation of information (i.e. Visual Quality [VQ]) [62, 63]. Another success measure in the D&M model, system quality, gauges the functionality and performance of the IS. [70] has shown that information quality and system quality (SQ), together or independently, influence performance expectancy. Saeed and Abdinnour-Helm in [70] proposed that information quality and system quality influence perceived usefulness in IS and eventually affect post-adoption usage. From this standpoint, virtual objects demand accurate tracking in an AR mobile application and, with a high level of information quality, students and visitors will realise that the app is helpful. For AR mobile applications, providing adequate information is important because the applications process various types of information (e.g. location, time, view and direction). Consequently, users expect AR mobile app to provide precise, timely and trustworthy information [71]. If users are provided with comprehensive, high-quality information they may feel that the experience is enjoyable. Thus, information quality and system quality have a significant positive effect on perceived enjoyment.

Several hypotheses about the relationship of SQ and IQ with performance expectancy (PE) and PENJ were formulated from the literature:

Hypothesis 1: Information quality (IQ) would positively affect performance expectancy (PE) about AR systems.

Hypothesis 2: System quality (SQ) would positively affect performance expectancy (PE) about AR systems.

Hypothesis 3. Information quality (IQ) would positively affect perceived enjoyment (PENJ).

Hypothesis 4. System quality (SQ) would positively affect perceived enjoyment (PENJ).

4.2.1.2 Visual quality and AR

Perceived visual quality (VQ) is an external factor defined as the degree to which a user considers that the app is aesthetically appealing. This refers to the style and presentation of information in D & M model [62, 63]. Since the AR is a visualisation technique that combines multimedia information with the real perception, visual quality is likely to influence the use of AR. The initial effect of visual quality might encourage users to judge the usefulness or enjoyableness of the app [72]. A well-designed AR app also supports the delivery of information that is clear and precise. Lee and Lehto recognised that a higher level of visual quality increased the representational richness of information; thus, visual quality (VQ) had a positive effect on performance expectancy PE. Previous research showed that AR systems enhance the user's view of the real world and that a user's familiarity with AR applications influences the performance expectancy and effort expectancy of AR applications [24, 73]. There is empirical evidence that the aesthetics of AR have an effect on motivating positive beliefs such as performance expectancy (PE) and perceived enjoyment (PENJ) [74]. Therefore, we postulated that the visual quality of AR affects students' and visitors' beliefs about the AR app, and proposed the following hypotheses:

Hypothesis 5: Visual quality (VQ) would positively affect AR performance expectancy (PE).

Hypothesis 6: Visual quality (VQ) would positively affect AR perceived enjoyment (PENJ).

4.2.1.3 Facilitating conditions and AR

Facilitating conditions (FC) have been identified as crucial factors in the use of new technology in various studies [75]. Facilitating conditions refers to the degree to which a person believes that the use of AR is supported by an organisational and technical infrastructure. Because AR is a cutting-edge technology [5], facilitating conditions for its use include whether students and visitors have the devices to use the AR application, whether they have the know-how about how to use the AR app, and whether technical assistance is available. When these environmental conditions are satisfied, students and visitors more readily use AR. Some prior studies also found that facilitating conditions are positively related to performance expectancy (PE) [76, 77]. Toe proposed that facilitating conditions are related to beliefs about the technology because they enhance a person's desire to carry out a task [77]. Consequently, those who give high value to facilitating conditions are likely to perceive enjoyment. Hence, this study proposed the following hypotheses:

Hypothesis 7: Facilitating conditions (FC) would positively affect AR performance expectancy (PE).

Hypothesis 8: Facilitating conditions (FC) would positively affect AR perceived enjoyment (PENJ).

4.2.2 Relationship between Main Mediators and Behavioural Intention

<u>4.2.2.1 Performance expectancy</u>

Because system quality can be interpreted as effort expectancy, effort expectancy was removed from the proposed model [78]. Effort expectancy, defined as "the degree to which a person believes that using a particular system would be free of physical and mental effort" [57], is similar to system quality. Performance expectancy (PE) is defined as "the extent to which a person believes that using the system will improve his or her job performance" [57] or bring some future advantage.

In the proposed framework, performance expectancy (PE) is a direct determinant of a user's behavioural intention to use an IS, thus it can be validated. Therefore, performance expectancy (PE) is a mediating variable in the proposed model. Davis suggested that PE influences behavioural intention (BI) towards using an AR system [8]. These relationships were supported by a considerable number of TAM researchers [45, 79] and in research on AR tourism. A large body of research [68, 72] indicates that there is a direct relationship between performance expectancy and behavioural intention to use AR, hence the following hypotheses were constructed:

Hypothesis 9: Performance expectancy (PE) would positively affect behavioural intention (BI) about AR systems.

Hypothesis 10: Performance expectancy (PE) would positively affect students' and visitors' satisfaction (SAT) with AR systems.

<u>4.2.2.2 Perceived enjoyment</u>

As mentioned earlier, a few studies have focused on AR acceptance, and these incorporated perceived enjoyment (PENJ) as a major variable in their AR acceptance model [80]. Some findings, however, indicate that perceived enjoyment (PENJ) influences Performance expectancy (PE). In [81], the authors suggested that "if an education system users feel that the system is enjoyable, that feeling is connected to the feeling that the system is useful". They concluded that the perceived enjoyment (PENJ) of an education system has a significant influence on the Performance expectancy (PE) of the education system. According to [82], a user's intrinsic motivation has a positive effect on behaviour intention (BI). In this thesis, we focused on student and visitor perspectives to predict their intrinsic motivation to use the smartphone AR app which can influence extrinsic motivation and satisfaction. Our hypotheses are as follows:

Hypothesis 11: Perceived enjoyment (PENJ) would positively affect Performance expectancy (PE).

Hypothesis 12: Perceived enjoyment (PENJ) would positively affect students' and visitors' satisfaction.

Hypothesis 13: Perceived enjoyment (PENJ) would positively affect behavioural intention (BI) to use AR systems.

4.2.2.3 Satisfaction

Students' and visitors' satisfaction is connected to their perception, and students' and visitors' positive sense of achievement is linked to their post-usage intention [83]. In previous research, McDougall and Levesque suggested that perceived value is the most significant factor affecting user satisfaction in the service industry [84]. Patterson and Spreng also noted that user satisfaction is affected by Performance expectancy (PE) and Perceived enjoyment (PENJ) in a business-to-business (B2B) service [85]. This thesis applies these results to the context of a mobile AR app. A mobile AR app's level of user satisfaction is affected by utilitarian and hedonic value [83]. If a mobile AR app is helpful and enjoyable, users experience satisfaction. Therefore, it follows that:

Hypothesis 14: Users' satisfaction (SAT) would positively affect behavioural intention (BI) to use AR systems.

4.2.3 Dependent Variable: Behavioural Intention to Use AR

The behavioural intention (BI) construct refers to the possibility of using of the iMAP-CampUS app in our case. Behavioural intention at the user level has been addressed in various AR studies [e.g. 5, 45, 86]. For the purpose of this project, behavioural intention to use iMAP-CampUS is used as a dependent variable. There is empirical evidence that Performance expectancy (PE) and satisfaction (SAT) are powerful predictors of a user's behavioural intention (BI) as supported by [43, 83, 87]. There are many hedonic aspects of smartphone AR apps. Consequently, perceived enjoyment (PENJ) can be an important antecedent of behavioural intention (BI). Using motivation theory, Thong et al. found that performance expectancy (PE), perceived enjoyment (PENJ) and satisfaction (SAT) are the key determinants of a user's behavioural intention (BI) to use AR [87]. Therefore, the framework used in this study incorporates both aspects of motivation theory.

4.3 Research Methodology

A research protocol is necessary to guide decisions about the study and the type of investigation, among other considerations. A good protocol ensures that the results are valid and reliable.

The design of the present study can be categorised as descriptive, causal, explanatory and exploratory [88]. The topic was explored through a literature review to identify the research question, develop the theoretical framework and propose hypotheses. The characteristics of participants and the results of various statistical operations (percentages, averages, etc.) were described, but a descriptive research protocol cannot demonstrate the relationships among variables. Hence explanatory research was used to determine the relationship between factors in the proposed framework.

4.3.1 Research Philosophy, Approach and Strategy

Prior to data collection, researchers must decide which research philosophy is most appropriate to answer the research question [88]. The literature identifies two main research philosophies - positivism and interpretivism [88]. The positivist approach is quantitative in nature and involves the development and testing of hypotheses, whereas the interpretivist approach collects qualitative data. Since the purpose of the study is to identify the external variables that influence the acceptance of iMAP-CampUS and to explore the relationships among these constructs, the positivist (quantitative) approach was more appropriate to validate the hypotheses.

Both qualitative and quantitative methods are utilised in information systems research. Variables and relationships are the main focus in quantitative studies, whereas the interpretation of non-numerical data is central to qualitative methods. Since the main objective of this research was to examine the relationships between variables and identify the influence of external and mediating variables on acceptance of iMAP-CampUS, quantitative methods were most appropriate. A structural model was developed, hypotheses were formulated and the data was analysed statistically.

Researchers must also choose between deductive and inductive approaches [88-90]. In the former approach, a hypothesis is deduced from the theory and then tested. This was the approach adopted in the present study.

The selection of an appropriate research strategy is based not only on the research question and research goals but also on the time and resources available for the study. Various research strategies are available to guide data collection, including survey, experiment, case study, grounded theory and action research. Each one has its strengths and weaknesses. The most common strategies for collecting quantitative data are surveys and experiments [91]. Based on the research question and objectives, the most appropriate strategy for this study was the surveys. Given the time constraints, a cross-sectional rather than longitudinal study design was employed.

4.3.2 Data Collection Method

The choice of data collection technique depends on the research question and study objectives. There are two types of data - primary and secondary [88]. Primary data are collected using questionnaires, interviews, focus group interviews, case studies and observations [92]. Secondary data are collected from pre-existing sources such as periodicals, media accounts and government reports [90].Primary data for this study were collected using a questionnaire developed to measure user acceptance of iMAP-CampUS. A pilot study was conducted to identify any problems in the instrument.

4.3.3 Sampling and Recruitment

In this study, the population of interest comprised all students at MQ and all visitors to the campus. Clearly, it was not possible to determine the total number of such individuals. Hence, a web-based survey was used to reach as many participants as possible. The advantages of web-based surveys include their low cost, fast collection times, wide invitational scope, ease of follow up and ease of analysis [93, 94].

Students and visitors at MQ were randomly approached during orientation week and in the following week in the first term of 2017 and especially first year students were invited to participate in the survey, due to direct benifit. Those who agreed (N-196) provided their email contact details. An invitation letter (Appendix A) was sent via email describing the purpose of the research and explaining the use of the iMAP-CampUS app. The email also asked recipients to forward the invitation letter to friends who were studying, or planning to study, at MQ (a technique known as snowball sampling). The invitation letter contained a link and QR code for completing the survey. It also contained a YouTube video link to familiarise participants with the app before completing the survey. The online questionnaire was accessible from 22 March to 5 April 2017. One reminder email was sent on 28 March 2017.

4 3.4 Instrument

Our questionnaire contained 40 questions designed to evaluate the eight constructs of the proposed model (information quality, system quality, visual quality, facilitating condition, performance expectancy, perceived enjoyment, satisfaction and behavioural intention). These items were derived from previously published measures and were adapted to our research setting.

The online questionnaire was built and managed in Qualtrics (www.qualtrics.com). The data were collected through the online platform of Qualtrics. Copies of the questionnaire and consent form are provided in Appendix 1 and 2, respectively.

The items in the online questionnaire were kept simple and easy to follow to encourage completion. The responses were constructed on a 7-point Likert scale from “strongly disagree” (1) to “strongly agree” (7). This is the most commonly used scale in previous studies of AR. All of the questionnaire items were close-ended to facilitate analysis.

The questionnaire had two sections. The introductory section collected demographic data about age, gender, nationality, education, occupation and experience with using any AR app (6 questions). The second section collected data on the eight constructs of our technology acceptance model (34 measurements in total).

In order to ensure that the instrument was free of errors and ambiguities, the questionnaire was pre-tested by two experts in AR, who were asked to evaluate the wording of the items. To expose any weaknesses in the design of the questionnaire, a pilot study was conducted using members of VISOR (Virtual and Interactive Simulations of Reality) research group at MQ. Minor changes were made to the instrument as a result of the pre-test and pilot.

4.3.4.1 Operationalisation of variables

The proposed model constructs were operationalised using validated items from previous related research. Some changes in wording were made to reflect the purpose of the study.

Information quality (IQ)

IQ1: Using iMAP-CampUS application is beneficial.

IQ2: The iMAP-CampUS application provides precise information that the user needs.

IQ3: Information that is provided by the iMAP-CampUS application is clear and understandable.

System quality (SQ)

SQ1: The iMAP-CampUS application is easy to use.

SQ2: The interaction with the iMAP-CampUS application does not require much effort.

SQ3: I find it easy to access the desired information through the iMAP-CampUS application.

SQ4: The iMAP-CampUS application for AR is fast.

SQ5: The iMAP-CampUS application for AR is easy to navigate.

Visual Quality (VQ)

VQ1: The iMAP-CampUS application is in harmony with the environment at Macquarie University.

VQ2: The iMAP-CampUS application is quite attractive.

VQ3: The iMAP-CampUS application is visually quite appealing.

VQ4: The iMAP-CampUS application provided a way for users to easily experience it.

Facilitating Conditions (FC)

FC1: I have the necessary resources to use iMAP-CampUS application.

FC2: I have the necessary knowledge to use iMAP-CampUS application.

FC3: I can use the iMAP-CampUS application with my current smartphone.

FC4: An assistant is available for help with using the iMAP-CampUS application.

Performance Expectancy (PE)

PE1: The iMAP-CampUS application makes the tour at the Macquarie University useful.

PE2: Using iMAP-CampUS application helps me to know the surrounding places.

PE3: Using iMAP-CampUS application guides me in case of getting lost.

PE4: Using the iMAP-CampUS application enables me to get desired building quickly.

PE5: Using the iMAP-CampUS application makes it easier for me to choose which building I will visit.

Perceived Enjoyment (PENJ)

PENJ1: Using iMAP-CampUS application is interesting.

PENJ2: Using iMAP-CampUS application makes me feel enjoyable.

PENJ3: Using iMAP-CampUS application is a good way to spend my leisure time.

PENJ4: Using iMAP-CampUS application involves me in the enjoyable process.

Satisfaction (SAT)

SAT1: I am satisfied with using the iMAP-CampUS app.

SAT2: I am satisfied with using the iMAP-CampUS app functions.

SAT3: I am satisfied with the contents of the iMAP-CampUS app.

SAT4: The iMAP-CampUS application fulfills my demand.

Behavioural intention to use iMAP-CampUS app (BI)

BI1: I use (intend to use) the iMAP-CampUS application frequently.

BI2: I use (intend to use) the iMAP-CampUS application whenever appropriate.

BI3: I would recommend the iMAP-CampUS application to others .

BI4: I would say positive things about the iMAP-CampUS app.

BI5: I will visit the Macquarie University again after experiencing the iMAP-CampUS app.

4.4 Summary

The need for a self-guided tour to help students and visitors at MQ motivated us to develop the iMAP-CampUS app. To examine factors that affect user acceptance of the iMAP-CampUS app, we proposed a theoretical framework that integrated factors from the unified theory of acceptance and use of technology (UTAUT), IS success factors and motivation theory. This produced three success measures (information quality, system quality and user satisfaction) and two acceptance constructs (effort expectancy and facilitating conditions). Using motivation theory, we also added visual quality, since perceived enjoyment is affected by visual quality. In the first part, we developed 14 hypotheses. The second part of this chapter described the research methodology. A cross-sectional quantitative survey design was employed. The data collection instrument (questionnaire) was described in detail.

Chapter 5: Data Analysis, Results and Discussion

This chapter describes the procedures used to analyse the data, presents the results of this analysis and discusses the findings in relation to the research question and hypotheses.

5.1 Data Analysis

Two software tools were employed in data analysis. First, the survey data were recorded by Qualtrics and imported to SPSS. SPSS software is readily available and can be used to generate descriptive statistics and support the process of data analysis. Various analyses were performed using SPSS. Descriptive statistics were used to analyse each variable separately and to summarise the demographic characteristics of participants. Second, partial least squares (PLS) regression was used for structural equation modeling (SEM).

Before any analyses were conducted, data normality for each measured item was tested for skewness. The skewness values for the eight constructs were between -3 and +3. This indicated that that the eight items were almost normally distributed, so further calculations were performed, as elaborated below.

5.2 Characteristics of Participants

We received far fewer responses than we had expected. Although the questionnaire link was sent to 196 respondents to the invitation letter, and they were asked to pass it on to their friends, only 125 questionnaires were received. After filtering, 39 of these were found to be incomplete. The actual completion (response) rate could not be calculated since we did not know how many people received the invitation letter. A variety of psychological and technical factors influence the response rate in online surveys. People may forget to complete it or be too busy to do so, or the survey might be too long. Other factors include lack of sufficient access to the internet, technical problems and issues with security.

Gender. There was a fairly equal distibution of males (57%) and females (43%).

Age. The largest group of respondents (34%) was aged 26-30, followed by those aged 22--25 (24%), 31- 35 (17%), 18- 21 (12%) and 36- 40 (8%). Only 5% of participants belonged to the 41+ category as shown in Figure 7.3 (See Appendix E).

Nationality. Only two options for nationality were available - Australian and non-Australian. The majority (70%) reported that they were non-Australian.

Education. Most respondents were highly educated; 62% were undergraduate university students; 17% were postgraduate students; 16% were enrolled in a 2-year college degree; and 5% were high school students.

Occupation. Four options were available: Student, Employed, Unemployed and Retired. The largest category of respondents was students (86%); 12% of participants were employed, and only 1% was unemployed or retired as shown in Figure 7.3 (See Appendix E).

Experience with AR app. More than two-thirds (81%) of respondents had previously used an AR app; 19% were first time users.

5.3 Statistical Procedures

This section explains the statistical procedures of Structural Equation Modeling (SEM) and Partial Least Squares (PLS) regression analysis.

5.3.1 Structural Equation Modeling

Structural Equation Modeling (SEM) is a statistical analysis technique that uses 2nd generation regression tools to answer a group of interrelated research questions in a unified, systematic and comprehensive way [95]. In SEM, the casual relationships among multiple independent and dependent constructs are tested simultaneously. Two statistical techniques are used: covariance-based analysis, such as LISREL and AMOS; and the partial-least-squares (PLS) approach, which describes the relationships between two or more latent variables [95].

The two techniques have different aims. Covariance-based SEM is able to assess unidimensionality, that is, the degree to which all the measurement items reflecting a single construct measure the same latent variable. Covariance-based SEM also provides better coefficient estimates and more accurate model analyses than PLS-based SEM. Nevertheless, there are cases where PLS-based techniques are more appropriate [95].

Latent variables (LV) are the dependent and independent constructs proposed by the researcher for the purpose of understanding the research problem. There are two basic types of LV: exogenous variables (independent variables) and endogenous variables (dependent variables). Exogenous variables are predicted by factors external to the model, whereas endogenous variables are predicted by other variables in the proposed model.

PLS-based SEM is especially appropriate for data analysis of small samples. This was the case in the present study, where the sample was too small for a covariance-based SEM analysis.

SEM is comprised of a structural model and a measurement model. The structural model (inner model) describes the relationship between a set of dependent and independent constructs (LV). The measurement model (outer model) specifies the loadings of the measurement items on their expected latent variables (constructs) and describes the validity and reliability of the constructs. The path relationships are indicated by arrows connecting the LVs.

5.3.2 Partial least squares

To test the proposed research model we used a partial least squares (PLS) regression analysis using SmartPLS 3.0. PLS regression analysis has several advantages; for instance, it is appropriate for small sample sizes [96]. PLS is used to model the relationship between a dependent and an independent variable. PLS was used in this study since it does not require normal-distribution input data [97].

5.4 Model Validation

This section describes the assessment and testing of the proposed model using SEM. Because PLS does not provide goodness-of-fit criteria, the procedure for testing PLS was performed in two stages: assessing the reliability and validity of the measurement model; and testing the hypotheses in the structural model.

5.4.1 Measurement Model

5.4.1.1 Reliability analysis

Reliability refers to the stability, consistency and reproducibility of measurement results [98]. Reliability is significant when there are multiple measurement items for each construct. In our study, all measurements had multiple items. The measurement model is evaluated by estimating the internal consistency reliability. The internal consistency reliability is assessed using the values for Cronbach's alpha, composite reliability and average variance extracted (AVE) [99].

Cronbach's alpha is a measure of internal consistency that measures the correlation between items in a scale. The Cronbach's alpha for each construct had to be greater than 0.7 [100] .

Composite reliability is similar to Cronbach's alpha. It measures the actual factor loadings rather than assuming that each item is equally weighted. The standardised path loading of each item should be statistically significant. In addition, the loadings should, ideally, be at least greater than 0.7.

AVE indicates the amount of variance in a measure that is due to the hypothesised underlying latent variable. The average variance extracted (AVE) for each construct has to exceed 0.5. Values greater than 0.50 are considered satisfactory. They indicate that at least 50% of the variance in the answers to the items is due to the hypothesised underlying latent variable.

All eight scales reached a composite reliability value of at least 0.71 (ranging from 0.711 to 0.897). Thus, they exceeded the 0.70 threshold for composite reliability. In addition, the scales exhibited high internal consistency; the lowest Cronbach's alpha was 0.81, which is well above the 0.70 threshold for confirmatory research. The AVE for each construct was greater than 0.5 (ranging from 0.628 to 0.758) as shown in Tables 3 (see Appendix E). Therefore, the internal consistency reliability for the constructs was confirmed [101].

5.4.1.2 Validity analysis

Validity refers to the accuracy of measurements [98]. In this study, the measurement model was calculated by evaluating the construct validity. Construct validity consists of convergent validity and discriminate validity.

Convergent validity is achieved when each measurement item correlates strongly with its proposed theoretical construct. It is checked by testing the factor loadings of the outer model. The outer model loadings for all items are all above 0.50 as shown in Table 2 and Figure 7.1 attached in Appendix E. Therefore, convergent validity was established [102].

Discriminant validity is achieved when each measurement item correlates weakly with all other proposed constructs than the one to which it is theoretically associated. The discriminant validity of the measurement model is tested using two criteria suggested by Gefen and Straub [95]: (1) item loading to construct correlations is larger than its loading on any other constructs ; and (2) the square root of the AVE for each latent construct should be greater than the correlations between that construct and other constructs in the model . The lowest acceptable value is 0.50. As shown in Tables 4, 5 and 6 (see Appendix E), all items showed substantially higher loading than other factors, and the square root of the AVE for each construct exceeded the correlations between that construct and the other constructs. Therefore, discriminant validity was established [102].

5.4.2 Structural Model

After the reliability and validity of our measurement model were confirmed, it was possible to estimate the inner structural model. This section presents the results of hypotheses examination. This study presents 14 hypotheses that were used to examine the relationships between the latent variables. Two types of latent variables were used in the proposed framework: endogenous variables and exogenous variables. Exogenous constructs were information quality, system quality, visual quality and facilitating conditions. Endogenous constructs were performance expectancy, perceived enjoyment, students' and visitors' satisfaction and behavioural intention to use the iMAP-CampUS app. This study assessed the path coefficient and significance level of indicators using bootstrapping procedure with a sub-sample of 200.

The structural model was assessed by evaluating the following criteria:

Path coefficients. Path coefficients are explained with the t-statistics computed using bootstrapping 200 samples as shown in Figure 7.2 (see Appendix E). The tests point to positive or negative relationships between exogenous constructs and endogenous variables and the strength of these relationships. Path coefficients should be directionally consistent with the hypothesis.

Coefficient of determination as R^2 values (in circles). R^2 provides the amount of variance of dependent variables explained by the independent variables. In our analysis, the R^2 coefficient of determination indicates the predictive power of the model for each dependent construct. According to [103], an R^2 value of 0.67 in the PLS path model is considered substantial. Therefore, our model has the ability to explain the endogenous constructs.

According to the path coefficients and t-test values presented in Figure 5.1, we found adequate evidence for each hypothesis. The path coefficient (t statistics) values for n = 200 (sub-samples from bootstrapping), $p<0.05$, $p<0.01$, and $p<0.1$.

The SEM results revealed that most of the proposed external variables (exogenous variables), except visual quality (SQ, SQ and FC), have significant effect on endogenous variables (PE and PENJ, SAT and BI) regarding the user intention to use iMAP-CampUS. Out of the proposed 14 hypotheses, 10 were supported. Thus, four paths were not statistically significant as shown in Tables 6 (see Appendix E).

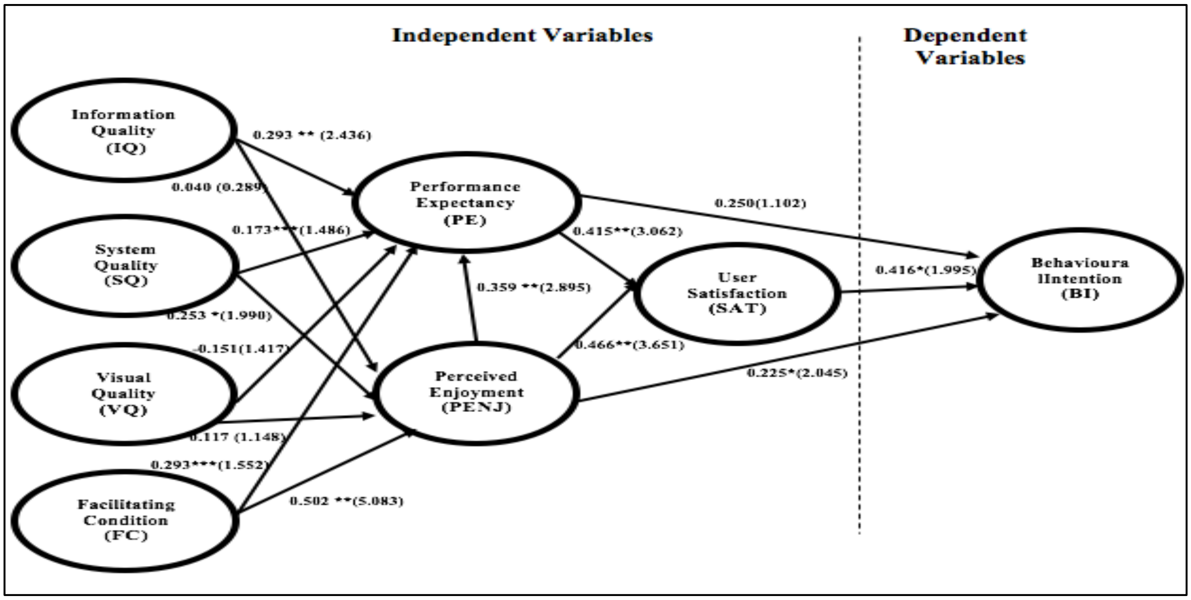

Figure 5.1 PLS results for the proposed model

- Consistent with hypothesis 1 (H1), information quality (IQ) was found to have a positive influence on performance expectancy (PE), with path coefficient = 0.17 and t = 2.44 ($p<0.01$, 1-tail).
- Information quality (IQ) was found to have no significant influence on perceived enjoyment (PENJ), which is not consistent with hypothesis 2 (H2), with values for path coefficient = 0.04 and value for t = 0.029($p<0.1$, 1-tail).
- Hypothesis 3 (H3) was supported; system quality (SQ) had a positive influence on performance expectancy (PE), with t = 1.5 and path coefficient = 0.17 ($p<0.1$, 1-tail).
- Consistent with hypothesis 4 (H4), system quality (SQ) had a positive influence on perceived enjoyment (PENJ), with path coefficient = 0.26 and t = 2 ($p<0.05$, 1-tail).
- Visual quality (VQ) had a negative influence on performance expectancy (PE) of iMAP-CampUS and was not consistent with hypothesis 5 (H5), with path coefficient = -0.15 and t = 1.4 ($p<0.1$, 1-tail). The negative value of the path coefficient between VQ and PE suggests that VQ was negatively associated with (or related to) PE.
- Hypothesis 6 (H6) was also rejected; visual quality (VQ) had no significant influence on perceived enjoyment (PENJ), with path coefficient = 0.1 and t = 1.14 (1-tail).
- Hypothesis 7 (H7) was supported; facilitating conditions (FC) will have a positive influence on performance expectancy (PE), with path coefficient = 0.27 and t = 1.6 ($p<0.1$, 1-tail).
- Consistent with hypothesis 8 (H8), facilitating conditions (FC) had a positive influence on perceived enjoyment (PENJ), with path coefficient = 0.5 and t = 5.1 ($p<0.01$, 1-tail).

- Performance expectancy (PE) was found to have no significant influence on behavioural intention (BI) to use iMAP-CampUS app, which is not consistent with hypothesis 9 (H9), with values for path coefficient = 0.25 and t = 1.1(1-tail).
- Consistent with hypothesis 10 (H10), performance expectancy (PE) was found to have a positive influence on students' and visitors' satisfaction (SAT) with AR systems, with path coefficient = 0.4 and t = 3.1 ($p<0.01$, 1-tail).
- Hypothesis 11 (H11) was supported; perceived enjoyment (PENJ) had a positive influence on performance expectancy (PE), with t = 2.9 and path coefficient = 0.36 ($p<0.01$, 1-tail).
- Consistent with hypothesis 12 (H12), perceived enjoyment (PENJ) had a positive influence on students' and visitors' satisfaction (SAT) with AR systems, with path coefficient = 0.5 and t = 3.7 ($p<0.01$, 1-tail).
- Hypothesis 13 (H13) was also supported; perceived enjoyment (PENJ) had a positive influence on behavioural intention (BI) to use iMAP-CampUS app, with path coefficient = 0.26 and t = 2.04 ($p<0.05$, 1-tail).
- Similarly, students' and visitors' satisfaction (SAT) with AR systems had a positive influence on behavioural intention (BI) to use iMAP-CampUS app, which was consistent with hypothesis 14 (H14) with path coefficient = 0.41 and t = 2 ($p<0.05$, 1-tail).

Overall, the endogenous variable PE was found to be significantly determined by three variables (IQ, SQ, FC) and PENJ, resulting in an R^2 of .748, which means that the IQ, SQ, FC and PENJ jointly accounted for 74.8% of the variance in PE. However, the VQ constructs were found to have a nonsignificant effect on PE. Therefore, H5 is rejected. Similarly, PENJ was significantly determined by SQ and FC resulting in an R^2 of .693, indicating that 69.3% of the variance of PENJ is explained by SQ and FC. However, the IQ and VQ constructs were found to have a nonsignificant effect on PENJ. Therefore, H2 and H6 are rejected. SAT was significantly determined by PE and PENJ resulting in an R^2 of .695, indicating that 69.5% of the variance in SAT is explained by these two variables (PE and PENJ). Finally, BI was found to be significantly determined by PENJ and SAT, resulting in an R^2 of .687, which means that PENJ and SAT accounted for 68.7% of the variance in BI . However, the PE constructs were found to have a nonsignificant effect on BI. Therefore, H9 is rejected.

In summary, the results indicated that the proposed AR acceptance model had high predictive power in determining students' and visitors' behavioural intention to use iMAP-CampUS app.

5.5 Discussion

The current research combined well-known theories that have been employed in similar studies. The research framework used constructs from UTAUT, IS Success Factors, Modified IS Success Factors, Motivation Theory and other relevant literature. The overall results were consistent with findings from similar studies and showed strong and positive relationships between the various study constructs and students' behavioural intention to use iMAP-CampUS app.

The findings suggest that most of the previously mentioned variables can positively influence students' and visitors' behavioural intention to use iMap-CampUS app. Students' and visitors' behavioural intention to use iMAP-CampUS app is highly impacted by the perception of its performance expectancy, perceived enjoyment and students' and visitors' satisfaction either directly or indirectly. Information quality, system quality and facilitating conditions are also important external factors that enhance students' and visitors' behavioural intention by increasing performance expectancy, perceived enjoyment and satisfaction in relation to iMap-CampUS app. In contrast, the results showed that visual quality is less likely to influence students and visitors toward a positive behavioural intention.

5.5.1 Descriptive Statistics of Construct Items

This section presents a descriptive analysis of responses to each of the constructs followed by the expression of the hypotheses. A 7-point Likert scale, ranging from strongly disagree (1) to strongly agree (7), were used to measure the constructs. The results of the 86 respondents' scores for each item of this construct are shown in Table 7 (see Appendix E).

5.5.1.1 Behavioural intention to use the iMAP-CampUS app

The respondents were asked to indicate their behavioural intention of using iMAP-CampUS app in the future. Five items were used to measure this construct. The mean scores ranged between 5.52 and 5.80. The average mean scores of all items was 5.70, which was greater than the neutral point (4), indicating that *the respondents strongly agree that they will use iMAP-CampUS app in the future.*

5.5.1.2 Information quality

The respondents rated the three items of information quality construct. All answers were in the range from 4.99 to 5.16. In total, all three items achieved high scores and had a mean above 5 which was greater than the neutral point (4), indicating that the respondents strongly agree that *iMAP-CampUS app is beneficial,* provides precise information that the user needs and has clear and understandable information.

5.5.1.3 System quality

Five items were used to measure this construct. The mean scores of the 86 respondents' scores for each item of this construct ranged between 5.23 and 5.40. The average mean scores of all items was 5.32 which was greater than the neutral point (4), indicating that the *iMAP-CampUS app is easy to use, fast, easy to navigate* and does not require much effort.

5.5.1.4 Visual Quality

The respondents rated the four items of visual quality construct. All answers were in the range from 4.14 to 5.60. All three items achieved high scores and had a mean above 5 which was greater than the neutral point (4), indicating that the respondents strongly agree that *iMAP-CampUS app is quite attractive and visually appealing.*

5.5.1.5 Facilitating conditions

Four items were used to measure this construct. The mean scores of the 86 respondents' scores for each item of this construct ranged between 5.62 and 5.72. The average mean scores of all items were above 5 which was greater than the neutral point (4), indicating that participants have the resources necessary to use the iMAP-CampUS application, that *they have had the knowledge necessary to use the app, and that assistance is available for help with using the app.*

5.5.1.6 Performance expectancy

The respondents rated the four items of visual quality construct. All answers were in the range from 5.55 to 5.71. All three items achieved high scores and had a mean of 5.64 which was greater than the neutral point (4), indicating that the respondents agree that *iMAP-CampUS app is useful for getting around Macquarie University and helps users to get know places in the campus.*

5.5.1.7 Perceived enjoyment

Four items were used to measure this construct. The mean scores of the 86 respondents' scores for each item of this construct ranged between 5.49 and 5.59. The average mean scores of all items were above 5 which was greater than the neutral point (4), indicating that *the iMAP-CampUS app is interesting and that the app is enjoyable to use.*

5.5.1.8 Students' and visitors' satisfaction

The respondents rated the four items of the students' and visitors' satisfaction construct. All answers were in the range from 5.40 to 5.57. All three items achieved high scores and had a mean above 5 which was greater than the neutral point (4), indicating that the respondents strongly agree that *iMAP-CampUS app fulfills their demands and therefore they are generally satisfied with it.*

5.5.2 Expression of Hypotheses

The structural model shows that ten out of the 14 hypotheses were supported. The t-statistics for the paths shown in Figure 5.1 from IQ to PENJ, PE to BI, VQ to PE and VQ to PENJ indicate that these paths are not significant. Thus, hypotheses H2, H5, H6 and H9 cannot be confirmed. The model supports the rest of the hypotheses with a positive relationship between them as shown in Table 6 and Figure 7.2 (see Appendix E). The study results make several interesting contributions to the literature on AR applications.

5.5.2.1 Statistically significant hypotheses

Hypothesis 1: Information quality would positively affect performance expectancy about AR systems.

As shown in Figure 5.1, the path coefficient and t-statistics for IQ to PE are 0.17 and 2.44 respectively, indicating that this path is statistically significant at the $P<0.01$ for a 1-tail test. Thus, the results showed strong support for H1, which was suggested in the framework explained in Chapter 4. This thesis supports the finding that information quality has a relatively strong influence on performance expectancy. This is consistent with the findings of previous research [6, 70, 83]. According to Saeed and Abdinnour-Helm, the level of information quality directly affects the performance expectancy of an IS and is a significant antecedent of performance expectancy. In summary, information quality was found to be a significant determinant of the performance expectancy of iMAP-CampUS app.

Hypothesis 3: System quality would positively affect performance expectancy about AR systems.

As shown in Figure 5.1, the results showed that system quality (SQ) had a significant positive effect on performance expectancy (PE) of iMAP-CampUS app. This indicates that students and visitors place emphasis on quality issues including functions, content, navigation speed and interaction capability of the app. This finding is in line with recent studies that reported various system issues, such as suitability of screen design and ease of use, were important characteristics that directly or indirectly benefit users and influence their behavioural intentions [6]. In brief, system quality was found to be an important determinant of the performance expectancy of iMAP-CampUS app.

Hypothesis 4: System quality would positively affect perceived enjoyment.

As shown in Figure 5.1, system quality positively influenced perceived enjoyment of iMAP-CampUS app. The findings support previous research by confirming the effects of system quality on perceived enjoyment and the behavioural intention to use the app [71]. System quality was found to be the second major determinant of perceived enjoyment in our proposed model.

Hypothesis 7: Facilitating conditions would positively affect AR performance expectancy.

As shown in Figure 5.1, the path coefficient and t-statistics for FC to PE were 0.27 and 1.6 respectively, indicating that this path is statistically significant. Thus, the study revealed a positive effect of facilitating conditions (FC) on performance expectancy toward using iMAP-CampUS. These include adequate guidance on the use of the app and availability of immediate assistance. Previous studies identified facilitating conditions as a critical factor affecting technology acceptance. Our findings confirm the effect of this factor on performance expectancy in the context of AR. This finding is consistent with McGill, Klobas, and Renzi, who showed that facilitating conditions had a significant positive impact on PE [104]. However, our current finding contradicts the results of Panda and Mishra , which indicated that inadequate FC was one of the most important barriers to new technology usage by users [105]. Facilitating conditions were a significant determinant of the performance expectancy of iMAP-CampUS app.

Hypothesis 8: Facilitating conditions would positively affect AR perceived enjoyment.

As shown in Figure 5.1, the path coefficient and t-statistics for FC to PENJ showed that this was a major determinant of the perceived enjoyment of iMAP-CampUS app. Thus, the results showed strong support for H8, which was suggested in the model explained in Chapter 4. In fact, the relationship between facilitating conditions and perceived enjoyment of the app was the strongest relationship among all relationships. Therefore, a focus on facilitating conditions is needed to enhance the perceived enjoyment of iMAP-CampUS. Our findings partially support Teo and Timothy in [106] stating that facilitating conditions had positive effects on hedonic factors.

Hypothesis 10: Performance expectancy would positively affect students' and visitors' satisfaction with AR systems.

As shown in Figure 5.1, performance expectancy was a strong predictor (p = 0.4 and t = 3.1) of students' satisfaction with AR systems. Since mobile AR app have utilitarian and hedonic characteristics, performance expectancy has a direct and indirect effect on satisfaction and behavioural intention. That is, performance expectancy significantly affects students' satisfaction, which implies that iMAP-CampUS developers should be more concerned with improving the performance expectancy factors of their applications as well as the enjoyment factors when seeking to enhance behavioural intention to use iMAP-CampUS app. This result is consistent with the findings of earlier studies which reported that performance expectancy is a strong predictor of user satisfaction [83].

Hypothesis 11: Perceived enjoyment would positively affect PE.

As shown in Figure 5.1, the t-statistics and path coefficient for PENJ to PE were 2.9 and 0.36 respectively, indicating that this path is statistically significant at the $P<0.01$ for a 1-tail test. Thus, the results showed strong support for H11 which was suggested in the framework explained in Chapter 4. The results indicate that perceived enjoyment influences students' and visitors' performance expectancy of the iMAp-CampUS app. In previous research, perceived enjoyment was shown to be a strong predictor of PE, which is consistent with our results [83]. In short, perceived enjoyment was a significant determinant of the performance expectancy of iMAP-CampUS app.

Hypothesis 12: Perceived enjoyment would positively affect students' and visitors' satisfaction.

As shown in Figure 5.1, the t-statistics and path coefficient for PENJ to SAT were 3.7 and 0.5 respectively, indicating that this path is statistically significant at the $P<0.01$ for a 1-tail test. Therefore, the results showed strong support for H12, namely, that perceived enjoyment would positively affect students' satisfaction. In fact, the results indicate that perceived enjoyment influences students' and visitors' satisfaction of the iMAp-CampUS more than performance expectancy does. This result is significant because it extends the findings of previous studies to the new context of mobile AR app.

Hypothesis 13: Perceived enjoyment would positively affect behavioural intention to use AR systems.

As shown in Figure 5.1, perceived enjoyment had a direct and indirect effect on behavioural intention to use AR systems through performance expectancy or students' and visitors' satisfaction. The t-statistics and path coefficient for PENJ to BI were 2.04 and 0.26 2.04 respectively. In fact, the relationship between perceived enjoyment and behavioural intention to use the app is stronger than the relationship between performance expectancy and behavioural intention. More importantly, the relationship between perceived enjoyment and behavioural intention to use the app is stronger than the relationship between students' and visitors' satisfaction and behavioural intention. In other words, a focus on perceived enjoyment is required to improve the behavioural intention to use AR systems. In previous research, perceived enjoyment was shown to be a strong predictor of BI, which is consistent with our results [107]. In short, perceived enjoyment was found to be a major determinant of the behavioural intention to use iMAP-CampUS app.

Hypothesis 14: Students' and visitors' satisfaction would positively affect behavioural intention to use AR systems.

As shown in Figure 5.1, the path coefficient and t-statistics for SAT to BI were 0.41 and 2 respectively, indicating that this path is statistically significant at the $P<0.05$ for a 1-tail test. Thus, the results showed strong support for H14. This study supports the finding that students' and visitors' satisfaction has a relatively strong influence on behavioural intention to use AR systems. This is consistent with the findings of previous research. According to [83], students' and visitors' satisfaction directly affects the behavioural intention of an IS. students' and visitors' satisfaction was found to be a significant determinant of the behavioural intention to use iMAP-CampUS app.

5.5.2.2 Statistically non-significant hypotheses

Hypothesis 2: Information quality would positively affect perceived enjoyment.

As shown in Figure 5.1, information quality had no significant effect on perceived enjoyment of iMAP-CampUS app. In fact, the relationship between information quality and perceived enjoyment has the lowest t-statistics. This finding is not in line with previous studies, which reported that information quality would positively affect perceived enjoyment [83]. Information quality was found to be a weak determinant of the perceived enjoyment of iMAP-CampUS app.

Hypothesis 5: Visual quality would positively affect AR performance expectancy.

As shown in Figure 5.1, visual quality had only a weak effect on performance expectancy than information quality and system quality. Therefore, H5 was rejected. Unexpectedly, visual quality had a negative influence on performance expectancy. This shows that, within the AR environment, users are more concerned with high visual quality content. Users of AR have necessarily accepted visual appeal as a stimulus factor influencing performance expectancy of the AR app. Overall, visual quality plays a role in users' satisfaction. AR application developers, however, should concentrate primarily on the well-represented virtual contents including 2D and 3D models and videos. Our results contradict those from earlier studies related to visual appeal [5]. In short, visual quality had the weakest effect among the three quality dimensions (IQ, SQ and VQ).

Hypothesis 6: Visual quality would positively affect AR perceived enjoyment.

As shown in Figure 5.1, the path coefficient and t-statistics for VQ to PRNJ were 0.1 and 1.14 respectively, indicating that this path was not statistically significant. Thus, the results showed weak support for H15. This result reflects the lack of interactivity with virtual objects in the iMAP-CampUS app. According to [6], interactivity with virtual content has a strong influence on perceived enjoyment in an AR smartphone application context. Also, interaction with virtual objects gives the user an opportunity to participate, which is related to perceived enjoyment. Therefore, AR application developers should focus on generating interactive virtual objects and improving the visual quality of the virtual objects in order to motivate users to experience the iMAP-CampUS app.

Hypothesis 9: Performance expectancy would positively affect behavioural intention about AR systems.

As shown in Figure 5.1, perceived enjoyment had a significant positive impact on students' and visitors' behavioural intention to use the iMAP-CampUS app, while performance expectancy did not have a strong positive influence on students' and visitors' behavioural intention to use the app. The path coefficient and t-statistics for PE to BI were 0.25 and 1.1 respectively, indicating that this path was not statistically significant. Thus, the study revealed a weak effect of performance expectancy on behavioural intention toward using the iMAP-CampUS app. It seemed that students and visitors did not use the iMAP-CampUS app just because it was useful, but rather because they found it enjoyable for their task. Therefore, iMAP-CampUS app developers need to find ways to increase the iMAP-CampUS app's functionality. This also suggests that content providers have to pay more attention to the usefulness of the content available on the app for students and visitors. This finding is not consistent with those from previous research. According to [83, 108], performance expectancy positively affects behavioural intention towards AR systems.

5.6 Summary

This chapter has presented our empirical findings. The characteristics of participants were described. SmartPLS 3.0 was used to explain the relationships between the measurement items by applying two approaches in SEM: a measurement model and a structural model. The results of the study were then presented and discussed in relation to the research question and hypotheses.

Chapter 6: Conclusion

This chapter starts with presenting the revised AR acceptance model after removing non-significant paths followed by answering the research questions briefly. Also, this chapter elaborates the implications of the thesis' findings and summarises its main contributions. Some limitations of the study are discussed, and directions for future research are suggested.

6.1 The Mobile AR User Acceptance Model

As we discussed in the previous chapter, 4 out of 14 hypotheses i.e.H2: IQ->PENJ, H5: VQ->PE, H6: VQ->PENJ and H9: PE->BI were statistically not significant and thereby they were rejected. Consequently, the structural model was revised by deleting four non-significant paths.

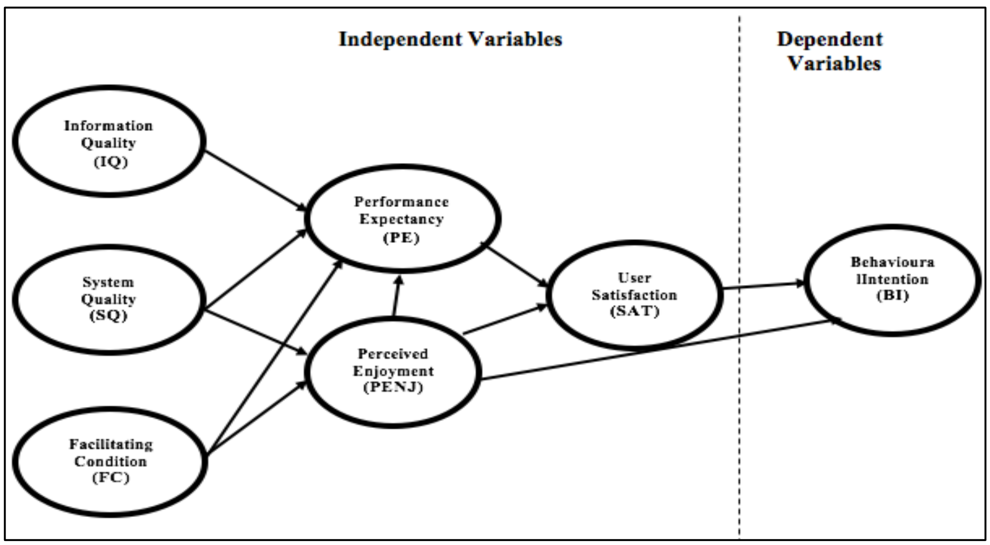

Figure 6.1 The mobile AR user acceptance model

We have had one primary research questions and two secondary questions to answer in this thesis.

RQ 1: Can a theoretical model be developed and used to predict the acceptance of a typical mobile AR app (iMAP-CampUS) by determining the correlations between the proposed constructs in the existing models for user acceptance?

This thesis has demonstrated that it is possible to develop a model as seen in Figure 6.1 to predict the acceptance of a mobile AR app.

> **RQ 1.1:** What are the factors that influence students' and visitors' behavioural intention to use iMAP-CampUS?

The revised structural model shown in Figure 6.1 shows that all factors except visual quality (VQ) have a strong impact on students' and visitors' behavioural intention (BI) to use iMAP-CampUS. Both sections 5.4.2 and 5.5.2 explained this issue in detail.

RQ 1.2: What are the correlations between these factors?

As shown in Table 6 (See Appendix E), ten out of the 14 relationships were highly correlated.

6.2 Theoretical Implications

First, to the best of our knowledge, this is one of the first studies to examine students' and visitors' acceptance of self-guided tours using AR in Australia. The thesis developed a new model from three existing models (UTAUT, IS success factors and motivation) and applied it to the context of AR app acceptance. The results clearly showed that the inclusion of external factors (information quality, system quality and facilitating conditions) in the proposed framework in figure 5.1 was effective and that the proposed model has significant explanatory power. In summary, the integration of information quality, system quality and facilitating conditions with performance expectancy, perceived enjoyment and user satisfaction was shown to be empirically significant and theoretically consistent.

Second, the comprehensive research model proposed in Figure 6.1 can be used to investigate acceptance of other AR apps since this study has identified the most important factors from the literature on mobile AR app. Thus, the proposed model makes a significant contribution to the literature on AR app acceptance.

Third, previous studies related to smartphone application acceptance focused on the effect of the core constructs in TAM, such as perceived usefulness and perceived ease of use, on the behavioural intention toward technology acceptance. As noted in Chapter 1, however, a few studies measured users' acceptance by integrating different factors from different models and theories. Hence, this study has made a major contribution to knowledge of the success factors for AR mobile app.

Fourth, the present study investigated technology acceptance from the perspective of users in a mobile AR app context. Earlier research, at most, concentrated on the technical aspects of an AR system to enhance its functional performance. Our approach generated new insights, demonstrating that six factors information quality (IQ), system quality (SQ), facilitating condition (FC), performance expectancy (PE), perceived enjoyment (PENJ) and user satisfaction (SAT) were the most important determinants of users' behavioural intentions (BI) to use AR smartphone applications.

Fifth, our findings highlighted the importance of aesthetics, which was the strongest predictor of perceived enjoyment (PENJ) in users' behavioural intentions (BI) to use mobile AR app. This finding shows that aesthetic features of an AR app can stimulate hedonic perception. This is a significant result since most of the previous studies regarding the constructs that affect users' behavioural intentions (BI) to use an app have only examined utilitarian factors such as performance expectancy (PE) and effort expectancy [5, 6]. Finally, the use of different research methods is recommended to provide in-depth understanding of the acceptance of the iMAP-CampUS app.

6.3 Practical Implications

The key findings from this study also have important practical implications for AR designers and developers. Effective development of an iMAP-CampUS app requires a comprehensive understanding of the factors affecting users' acceptance.

First, this study highlighted the importance of information quality (IQ) and system quality (SQ). These have indirect impacts on the behavioural intention (BI) to use the AR app, but only when performance expectancy (PE) and perceived enjoyment (PENJ) are improved. Thus, both should be strengthened and frequently updated in order to enhance performance expectancy (PE), perceived enjoyment (PENJ) and users' satisfaction (SAT).

Second, improving visual quality (VQ) could also enhance users' behavioural intention (BI) to use AR. Although our findings did not confirm that visual appeal had a significant effect on both performance expectancy (PE) and perceived enjoyment (PENJ), visualisation is clearly important in AR and should be a focus of future development of AR apps in higher education institutions.

Third, facilitating conditions (FC) were found to be the most significant external factor affecting the mediating factors performance expectancy (PE) and perceived enjoyment (PENJ). Developers should therefore pay attention to such factors as network access, technological support, and online and face-to-face support to ensure the smooth operation of the iMap-CampUs app and encourage students' and visitors' to use it.

Fourth, the results showed that, although performance expectancy (PE) is important, perceived enjoyment (PENJ) of the app is even more important. Hence, users may be more interested in attractive

AR content than in the system itself. Perceived enjoyment (PENJ) was found to be the main determinant of users' behavioural intention (BI) to use the iMAP-CampUS app, whereas users' satisfaction (SAT) and performance expectancy (PE) were ranked second and third, respectively.

6.4 Limitations of the Study

Several limitations of this research should be noted. First, the study employed a cross-sectional research design. Longitudinal data will enhance our understanding of what constructs affect individuals' behavioural intention to use the iMAP-CampUS app. Only quantitative data were collected. Qualitative data generated from interviews or focus groups could yield insight into other factors that affect users' satisfaction and behavioural intentions.

Second, interpretation of the results was limited by the small sample size (86) and low completion rate. A larger sample would have improved the ability to generalise the findings to a wider population. It should be noted, however, that the use of SmartPLS as a data analysis tool overcomes this limitation since it can generalise results with a very small sample size (see Chapter 5). Third, the study was conducted in one university (MQ) so the results may not be applicable to all Australian universities, even if the education system and culture are the same.

Fourth, this study examined a marker-less AR application in a controlled outdoor environment (MQ) based on GPS-enabled technology. Similar research should be conducted in an indoor environment to confirm the result. Fifth, the study participants were students and visitors aged 18 years and over. Future research should include children. Finally, not all factors related to the higher education institution were taken into consideration. AR usage in such institutions will be better understood if other factors, such as cultural motivation and visitor knowledge, are taken into account.

6.5 Recommendations for Future Research

Future research should examine the validity of the proposed model in different cultural settings. Second, as mentioned above, the desirability of collecting both longitudinal and qualitative data is indicated. Third, actual usage of the iMAP-CampUS app could be added as another dependent variable to measure user acceptance. It would also be useful to explore the role of other constructs, such as users' characteristics, experience, complexity of and familiarity with the app, and to add to the original constructs found in the models that informed this research. Finally, other statistical tests such as multiple regressions could be conducted to affirm the constructs' validity.

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Appendix A: Invitation Letter

Dear new Colleagues,
My name is Hamed Alqahtani and I am a Mres student at the Department of Computing.

I would like to invite you to participate in using a Mobile tour guide system based on Augmented Reality called "iMAP-CampUS".

The purpose of our app is for locating and providing information about surrounding buildings at Macquarie University. The application can be very beneficial particularly for the students who visits places never explored before. The app aims to simplify searching for buildings surrounding the students by only moving the camera in the direction of the desired site. The information is presented on the screen without blocking the view. The iMAP-CampUS is programmed to work on both iOS and Android platforms and is deployed to run on devices with different screen sizes. The iMAP-CampUS utilises Global Positioning System (GPS) sensor, phone network and Internet connection to pinpoint current location. The app uses google maps to get information about the places of interest.

There is no compensation for participating in this study. However, your participation will be a valuable addition to our research and findings could lead to greater public understanding of Augmented Reality and the people in the field.

To start using the iMAP-CampUS app, you do NOT need to prepare anything in advance, just have experience with smartphones. What you need is the following points:

- Download the free **"Layar" app** for your device using the link below.
  https://www.layar.com/mobile-download/

- After downloading, scan the following **QR code** below by using Layar app in order to launching the iMAP-CampUS app. Afterward, the iMAP- CampUS application on the your smartphone shows the points of interest (POI's) within a particular range, along with information regarding these points. Enjoy

- To know more about how to use iMAP-CampUS app, just visit this YouTube video:
  https://www.youtube.com/watch?v=9rWq2m9fmYE

The study is anonymous and the data will be confidential.

- If you need to know further information about the iMAP-CampUS app just send me an email on **hamed-saleh-d.alqahtani@students.mq.edu.au**.

By the time you are finishing using iMAP-CampUS app, there are two ways to complete a **short Questionnaire** about the app either by scan the QR code below or visit the following link https://mqedu.qualtrics.com/jfe/form/SV_56mbH9uhptqsmq1

Appendix B: Information and Consent Form

Department of Computing
Faculty of Science and Engineering
MACQUARIE UNIVERSITY NSW 2109
Phone: +61 (2) 9850 9514
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Email: sci.compquery@mq.edu.au

MACQUARIE University SYDNEY·AUSTRALIA

Participant Information and Consent Form

iMAP-CampUS (an Intelligent Mobile Augmented Reality Program on Campus as a Ubiquitous System): A theoretical framework to measure user's behavioural intention

Research team contacts

Hamed Alqahtani	A/Prof Manolya Kavakli
Phone:	Phone:
Email:	Email:

Description
This project is being undertaken as part of a Master of Research (MRes) research project by Hamed Alqahtani. The project is not funded by any authorities. Access to data obtained during the project will be accessed by Mr Hamed Alqahtani as well as the supervisor, A/Prof Manolya Kavakli, who teaches at Macquarie University, after the participants being de-identified.

This project aims to develop a mobile augmented reality application that would have the capability to show university campus related information and examining the factors influencing the acceptance of such application using Technology Acceptance Model.

Participation
Your participation in this project is voluntary. You are expected to be between the ages of 18 to 65 to participate in this study. If you are not between 18 and 65, you should not continue your participation. If you agree to participate, you can withdraw from participation at any time during the project without any questions or penalty. If you will be a student and visitor at Macquarie University, your decision to participate will in no way impact upon your current or future relationship with the university.

Your participation will involve participating in using the AR mobile application (**iMAP-CampUS**) during the experiment which will last for a few minutes.

Your participation will involve participating in the Online Survey (Questionnaire).
The collected data might be used in future for Human Research Ethics Committee-approved projects.

Expected benefits

This study will help the students and visitors travel the campus without any guiding and provide students and visitors with the opportunity to get to know unknown surroundings in an enjoyable and interactive manner.

Risk

This study is not associated with any potential risks or burdens.

Privacy

The identity of the participants will not be disclosed under any circumstances. Participants will be assigned a code and no link between the code and the identity of the participant or the consent form will be made. Disseminated data will be completely anonymous. All hard copy files will be locked in a filing cabinet and all soft copy files will be stored in a secure cloud storage.

Consent to participate

The return of the completed attached Consent Form is accepted as an indication of your consent to participate in this project.

Further Information

If you have any question or need any further information, please do not hesitate to contact the research team members of the project.

Hamed alqahtani

Phone:

Email:

<u>Consent form</u>

iMAP-CampUS (an Intelligent Mobile Augmented Reality Program on Campus as a Ubiquitous System): A theoretical framework to measure user's behavioural intention

<u>Statement of consent</u>

- By signing below, you are indicating that you:
  - are an adult between the ages of 18 to 65.
  - have read and understood the information document regarding this project
  - have had any questions answered to your satisfaction
  - understand that if you have any additional questions you can contact the research team
  - understand that you are free to withdraw at any time, without comment or penalty
  - agree to participate in the project

Name: --------------------------- Signature: ----------------------- Date: -----------------------------

Appendix C: The Research Design

Phase 1: Investigation

- *An extensive review of the literature*
- *Understanding different systems developed by using Augmented reality technology.*
- *Development of a technology acceptance framework for iMAP-CampUs*

Phase 2: Data gathering

- *Preparation of online survey(Questionnaire) to collect data*
- *Sending an invitation to numerous number of participant to fill in the survey via email.*
- *Collection the data*
- *Documentation of the result from questionnaire*

Phase 3: analysis

- *Using PLS*
- *Proposed model Validation*
- *Documentation of the result from validation step*
- *Expression the hypothesis.*

Appendix D: The Questionnaire

Q1 Gender

- Male
- Female

Q2 Age

*20 *21 –25 *26 – 30 *31 – 35 *36 – 40 *41+

Q3 Nationality

- Australian
- Other

Q4 Education

- Middle and High school
- 2 Year College
- University
- Graduate School

Q5 Occupation

- Student
- Employed
- Unemployed
- Retired

Q6 Experience with using any Augmented Reality app

- Yes
- No

From Q7 to Q14: All items were measured on a 7-point Likert scale with end points of “strongly disagree” (1) and “strongly agree” (7).

Q7 Information quality (IQ)

- Using iMAP-CampUS application is beneficial.
- The iMAP-CampUS application provides precise information that the user needs.
- Information that is provided by the iMAP-CampUS application is clear and understandable.

Q8 System quality (SQ)

- The iMAP-CampUS application is easy to use.

- The interaction with the iMAP-CampUS application does not require much effort.
- I find it easy to access the desired information through the iMAP-CampUS application.
- The iMAP-CampUS application for AR is fast.
- The iMAP-CampUS application for AR is easy to navigate.

Q9 Visual Quality (VQ)

- The iMAP-CampUS application is in harmony with the environment at Macquarie University.
- The iMAP-CampUS application is quite attractive.
- The iMAP-CampUS application is quite visually appealing.
- The iMAP-CampUS application provided a way for users to easily experience it.

Q10 Facilitating Condition (FC)

- I have the resources necessary to use iMAP-CampUS application.
- I have the knowledge necessary to use iMAP-CampUS application.
- I can use the iMAP-CampUS application with my current smartphone
- An assistant is available for help with using the iMAP-CampUS application.

Q11 Performance Expectancy (PE) of the app

- The iMAP-CampUS application makes the tour at the Macquarie University useful
- Using iMAP-CampUS application helps me to get known the surrounding places.
- Using iMAP-CampUS application guides me in case of getting lost.
- Using the iMAP-CampUS application enables me to get desired building quickly.
- Using the iMAP-CampUS application makes it easier for me to choose which building I will visit.

Q12 Perceived Enjoyment (PENJ)

- Using iMAP-CampUS application is interesting.
- Using iMAP-CampUS application makes me feel enjoyable.
- Using iMAP-CampUS application is a good way to spend my leisure time.
- Using iMAP-CampUS application involves me in the enjoyable process.

Q13 Satisfaction (SAT)

- I am satisfied with using the iMAP-CampUS application.
- I am satisfied with using the iMAP-CampUS application functions.
- I am satisfied with the contents of the iMAP-CampUS application.
- The iMAP-CampUS application fulfills my demand.

Q14 Behavioural intention to use iMAP-CampUS app (BI)

- I use (intend to use) the iMAP-CampUS application frequently.
- I use (intend to use) the iMAP-CampUS application whenever appropriate.
- I would recommend the iMAP-CampUS application to others.
- I would say positive things about the iMAP-CampUS application.
- I will visit the Macquarie University again after experiencing the iMAP-CampUS application.

Appendix E: The Data Analysis Table

Table 1 and 2 show the Path Coefficients and factor loading respectively. All values of the internal consistency reliability are in the acceptance range (>0.7).

	BI	FC	IQ	PE	PENJ	SAT	SQ	VQ
BI								
FC				0.269	0.502			
IQ				0.293	0.040			
PE	0.250					0.415		
PENJ	0.225			0.359		0.466		
SAT	0.416							
SQ				0.173	0.253			
VQ				-0.151	0.117			

Table 2 shows the Factor Analysis. All items loading are highly loading >0.70.

	BI	FC	IQ	PE	PENJ	SAT	SQ	VQ
BI_1	**0.863**							
BI_2	**0.745**							
BI_3	**0.816**							
BI_4	**0.829**							
BI_5	**0.859**							
FC_1		**0.740**						
FC_2		**0.776**						
FC_3		**0.858**						
FC_4		**0.835**						
IQ_1			**0.864**					
IQ_2			**0.855**					
IQ_3			**0.892**					
PENJ_1					**0.825**			
PENJ_2					**0.763**			
PENJ_3					**0.860**			
PENJ_4					**0.779**			
PE_1				**0.896**				
PE_2				**0.726**				
PE_3				**0.713**				
PE_4				**0.773**				
PE_5				**0.840**				
SAT_1						**0.840**		
SAT_2						**0.897**		
SAT_3						**0.801**		

SAT_4						**0.831**		
SQ_1							**0.711**	
SQ_2							**0.808**	
SQ_3							**0.838**	
SQ_4							**0.816**	
SQ_5							**0.835**	
VQ_1								**0.839**
VQ_2								**0.862**
VQ_3								**0.830**
VQ_4								**0.842**

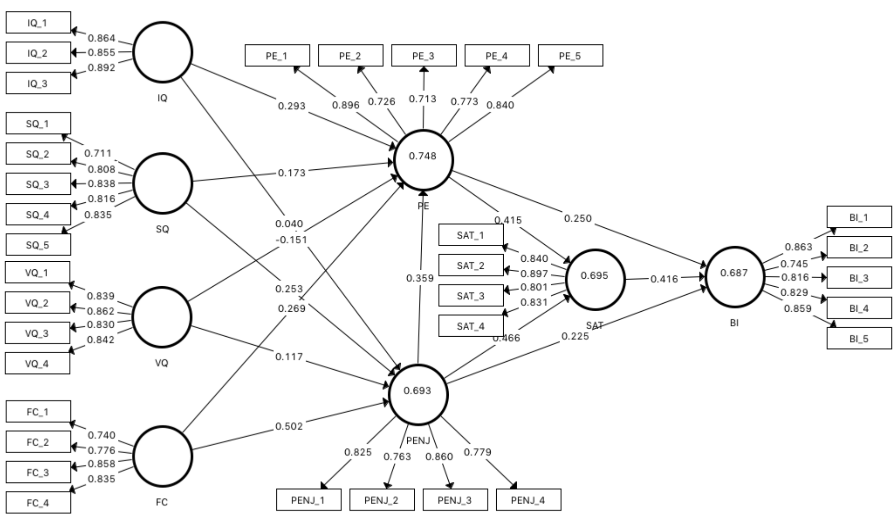


Figure 7.1 PLS Model

Table 3 shows the Construct Reliability and Validity. The Construct Reliability for all eight constructs were found to be greater than 0.70. Also, Table 3 shows the strong convergent validity since AVE for all items is more than the threshold 0.5.

	Cronbach's Alpha	Composite Reliability	Average Variance Extracted (AVE)
BI	**0.881**	**0.913**	**0.678**
FC	**0.817**	**0.879**	**0.646**
IQ	**0.840**	**0.904**	**0.758**
PE	**0.850**	**0.894**	**0.628**
PENJ	**0.821**	**0.882**	**0.652**
SAT	**0.863**	**0.907**	**0.710**
SQ	**0.861**	**0.900**	**0.645**
VQ	**0.865**	**0.908**	**0.711**

Table 4 shows the Discriminant Validity that all the scales used in the survey satisfy the requirements mentioned in chapter 5. The square roots of the AVE-s are shown in bold. Off diagonal elements are correlation between constructs. The AVE form the constructs should be greater than the AVE shared between the item and other items in the proposed model.

	BI	FC	IQ	PE	PENJ	SAT	SQ	VQ
BI	**0.823**							
FC	0.720	**0.803**						
IQ	0.695	0.686	**0.870**					
PE	0.754	0.776	0.745	**0.793**				
PENJ	0.754	0.797	0.664	0.792	**0.808**			
SAT	0.791	0.720	0.691	0.784	0.795	**0.843**		
SQ	0.741	0.730	0.781	0.751	0.738	0.704	**0.803**	
VQ	0.733	0.700	0.698	0.614	0.684	0.668	0.739	**0.843**

Table 5 shows the Cross Loadings.

	BI	FC	IQ	PE	PENJ	SAT	SQ	VQ
BI_1	0.863	0.643	0.604	0.693	0.746	0.730	0.638	0.665
BI_2	0.745	0.526	0.462	0.464	0.437	0.494	0.532	0.584
BI_3	0.816	0.585	0.571	0.578	0.616	0.660	0.580	0.576
BI_4	0.829	0.660	0.629	0.707	0.645	0.689	0.673	0.615
BI_5	0.859	0.534	0.572	0.622	0.608	0.645	0.614	0.577
FC_1	0.406	0.740	0.455	0.483	0.556	0.383	0.453	0.464
FC_2	0.650	0.776	0.523	0.571	0.533	0.579	0.586	0.588
FC_3	0.630	0.858	0.607	0.727	0.725	0.618	0.644	0.605
FC_4	0.610	0.835	0.600	0.677	0.713	0.697	0.642	0.584
IQ_1	0.572	0.604	0.864	0.633	0.571	0.614	0.630	0.540
IQ_2	0.623	0.589	0.855	0.640	0.576	0.603	0.715	0.655
IQ_3	0.618	0.599	0.892	0.671	0.587	0.587	0.693	0.626
PENJ_1	0.588	0.603	0.602	0.664	0.825	0.621	0.597	0.541
PENJ_2	0.543	0.691	0.556	0.632	0.763	0.589	0.607	0.543
PENJ_3	0.658	0.663	0.484	0.668	0.860	0.737	0.600	0.555
PENJ_4	0.642	0.617	0.510	0.592	0.779	0.612	0.580	0.570
PE_1	0.694	0.754	0.664	0.896	0.718	0.714	0.656	0.556
PE_2	0.506	0.538	0.478	0.726	0.527	0.551	0.464	0.313
PE_3	0.536	0.481	0.536	0.713	0.520	0.528	0.625	0.433
PE_4	0.581	0.536	0.599	0.773	0.594	0.609	0.586	0.475
PE_5	0.650	0.723	0.655	0.840	0.745	0.682	0.636	0.619
SAT_1	0.674	0.574	0.570	0.668	0.648	0.840	0.566	0.573
SAT_2	0.679	0.612	0.568	0.636	0.704	0.897	0.627	0.547
SAT_3	0.621	0.568	0.493	0.639	0.641	0.801	0.547	0.557
SAT_4	0.689	0.667	0.689	0.696	0.682	0.831	0.629	0.573
SQ_1	0.523	0.516	0.659	0.576	0.486	0.463	0.711	0.550

SQ_2	0.557	0.577	0.699	0.654	0.582	0.623	0.808	0.558
SQ_3	0.598	0.647	0.599	0.623	0.593	0.571	0.838	0.520
SQ_4	0.634	0.574	0.578	0.567	0.661	0.585	0.816	0.646
SQ_5	0.658	0.613	0.606	0.593	0.629	0.574	0.835	0.690
VQ_1	0.607	0.588	0.619	0.525	0.592	0.507	0.727	0.839
VQ_2	0.597	0.519	0.554	0.473	0.539	0.511	0.624	0.862
VQ_3	0.583	0.571	0.532	0.494	0.524	0.532	0.558	0.830
VQ_4	0.675	0.668	0.637	0.570	0.637	0.684	0.581	0.842

Table 6 shows the hypotheses testing including T-statistics and P values. The last Column shows the statistically significant hypothesis.

Hypothesis	Relationship	T Statistics	P Values	Support
H1	**IQ -> PE**	2.436	0.015	Yes
H2	**IQ -> PENJ**	0.289	0.773	No
H3	**SQ -> PE**	1.486	0.138	Yes
H4	**SQ -> PENJ**	1.990	0.047	Yes
H5	**VQ -> PE**	1.417	0.157	No
H6	**VQ -> PENJ**	1.148	0.251	No
H7	**FC -> PE**	1.552	0.121	Yes
H8	**FC -> PENJ**	5.083	0.000	Yes
H9	**PE -> BI**	1.102	0.271	No
H10	**PE -> SAT**	3.062	0.002	Yes
H11	**PENJ -> PE**	2.895	0.004	Yes
H12	**PENJ -> SAT**	3.651	0.000	Yes
H13	**PENJ -> BI**	2.045	0.041	Yes
H14	**SAT -> BI**	1.995	0.047	Yes

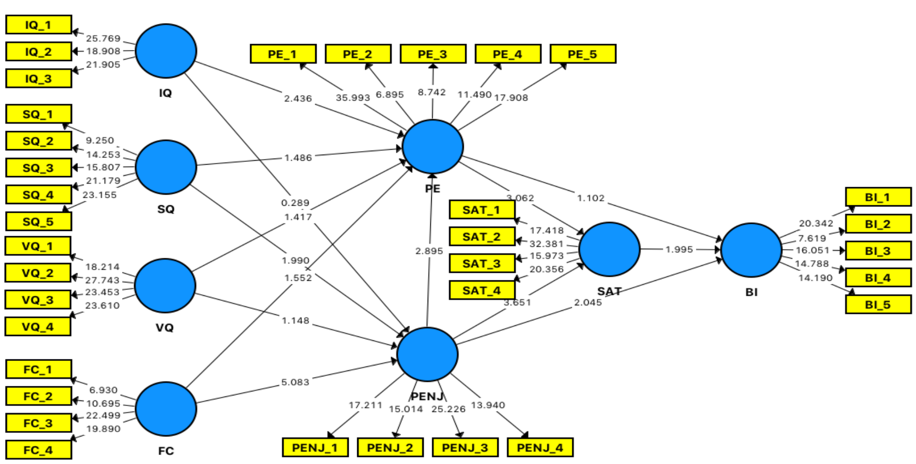


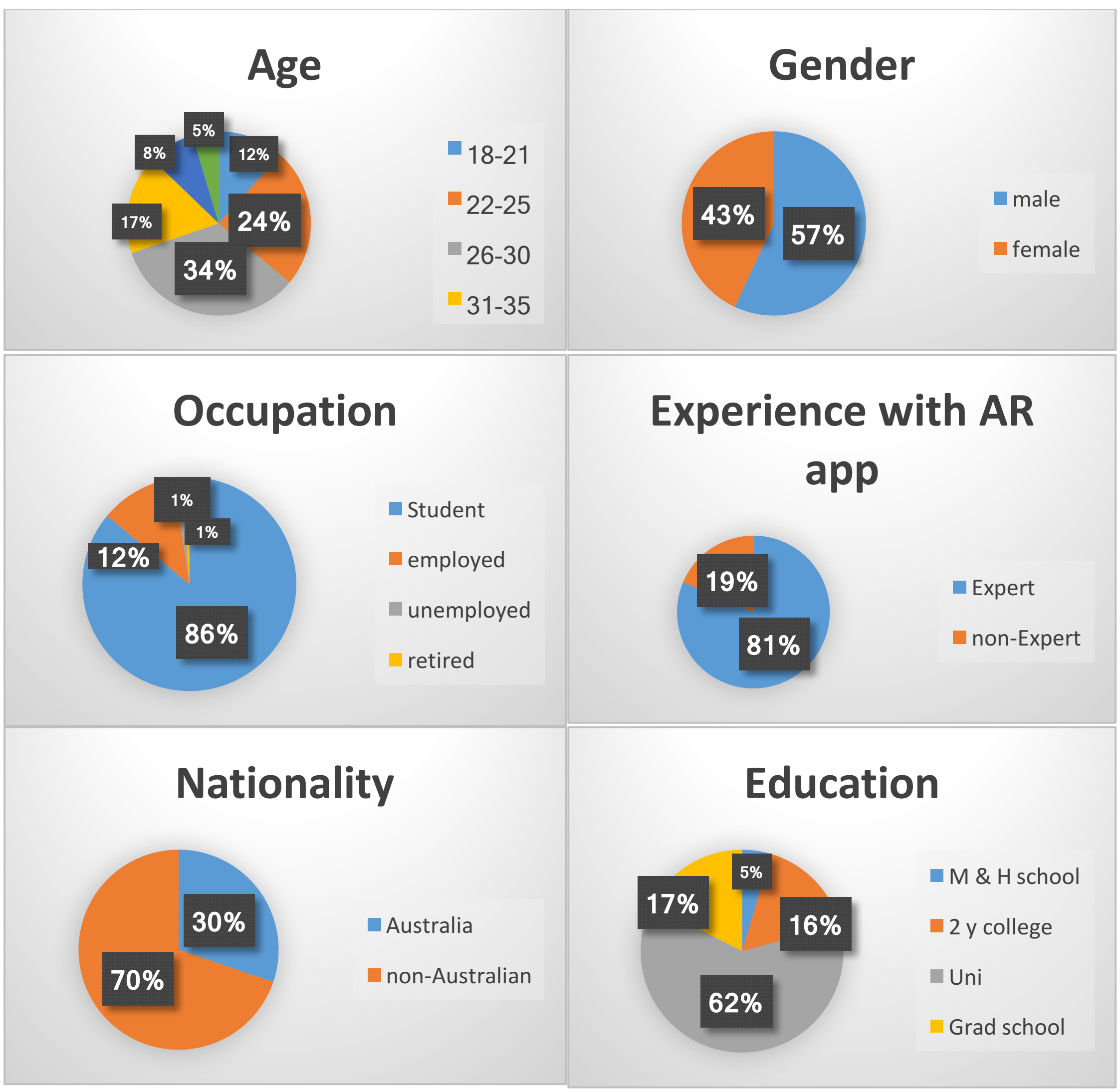
Figure 7.2 Bootstrapping Model

As shown in Table 7, the mean scores of all the items ranged from 5 to 5.80 (somewhat agree to agree) and the standard deviations of the scores ranged from 0.96 to 1.34, indicating that on students and visitors are agreed on the statements. The data is normally distributed since the skewness statistics for the eight constructs were between -3 and +3.

Item	Mean	Standard Deviation	Variance	Skewness statistics
BI 1	**5.52**	**1.15**	**1.31**	**-1.48**
BI 2	**5.80**	**1.10**	**1.22**	**-1.60**
BI 3	**5.75**	**0.96**	**0.92**	**-.0.85**
BI 4	**5.72**	**1.10**	**1.21**	**-1.58**
BI 5	**5.73**	**1.29**	**1.66**	**-1.96**
IQ 1	**5.14**	**1.03**	**1.06**	**-1.41**
IQ 2	**5**	**1.09**	**1.19**	**-1.60**
IQ 3	**5.16**	**1.14**	**1.30**	**-1.81**
SQ 1	**5.38**	**1.08**	**1.02**	**-0.978**
SQ 2	**5.28**	**1.17**	**1.38**	**-1.37**
SQ 3	**5.40**	**1.24**	**1.54**	**-1.60**
SQ 4	**5.23**	**1.18**	**1.40**	**-1.25**
SQ 5	**5.29**	**1.34**	**1.79**	**-1.04**
VQ 1	**5.14**	**1.16**	**1.35**	**-0.70**
VQ 2	**5.42**	**1.13**	**1.28**	**-0.94**
VQ 3	**5.36**	**1.17**	**1.29**	**-0.61**
VQ 4	**5.60**	**1.12**	**1.25**	**-1.17**
FC 1	**5.63**	**1.12**	**1.25**	**-0.98**
FC 2	**5.65**	**1.15**	**1.31**	**-1.30**
FC 3	**5.72**	**1.13**	**1.29**	**-1.66**
FC 4	**5.62**	**1.34**	**1.79**	**-1.67**
PE 1	**5.55**	**1.21**	**1.47**	**-1.28**
PE 2	**5.71**	**1.06**	**1.13**	**-1.02**
PE 3	**5.58**	**1.17**	**1.38**	**-0.83**
PE 4	**5.71**	**0.99**	**0.99**	**-0.86**

PE 5	**5.65**	**1.26**	**1.59**	**-1.57**
PENJ 1	**5.49**	**1**	**0.98**	**-0.75**
PENJ 2	**5.55**	**1.24**	**1.54**	**-1.30**
PENJ 3	**5.5**	**1.19**	**1.41**	**-0.89**
PENJ 4	**5.59**	**1.07**	**1.14**	**-0.67**
SAT 1	**5.40**	**1.18**	**1.39**	**-1.17**
SAT 2	**5.41**	**1.18**	**1.40**	**-0.89**
SAT 3	**5.57**	**1.29**	**1.66**	**-1.17**
SAT 4	**5.57**	**1.23**	**1.51**	**-1.09**

Figure 7.3 Below shows the participants' demographic information in terms of gender, age, education, nationality, occupation and AR app usage experience.



Appendix F: Ethics Approval Letter

From: Faculty of Science Research Office [mailto:
Sent: Thursday, 16 March 2017 12:18 PM
To: Manolya Kavakli-Thorne;
Cc: fse.ethics; Katherine Shevelev; Cathi Humphrey-Hood
Subject: Ethics Project 5201600796 - Final Approval

Dear A/Prof Kavakli-Thorne

RE: Ethics project entitled: "iMAP-CampUS:?an Intelligent Mobile Augmented reality Program on Campus as a Ubiquitous System"

Ref number: 5201600796

The Faculty of Science and Engineering Human Research Ethics Sub-Committee has reviewed your application and granted final approval, 16/03/2017. You may now commence your research.

This research meets the requirements of the National Statement on Ethical Conduct in Human Research (2007). The National Statement is available at the following web site:

http://www.nhmrc.gov.au/_files_nhmrc/publications/attachments/e72.pdf.

The following personnel are authorised to conduct this research:

Associate Professor Manolya KavakliThorne
Mr Hamed Saleh D Alqahtani

NB. STUDENTS: IT IS YOUR RESPONSIBILITY TO KEEP A COPY OF THIS APPROVAL EMAIL TO SUBMIT WITH YOUR THESIS.

Please note the following standard requirements of approval:

1. The approval of this project is conditional upon your continuing compliance with the National Statement on Ethical Conduct in Human Research (2007).

2. Approval will be for a period of five (5) years subject to the provision of annual reports.

Progress Report 1 Due: 16/03/2018
Progress Report 2 Due: 16/03/2019
Progress Report 3 Due: 16/03/2020
Progress Report 4 Due: 16/03/2021
Final Report Due: 16/03/2022

NB. If you complete the work earlier than you had planned you must submit a Final Report as soon as the work is completed. If the project has been discontinued or not commenced for any reason, you are also required to submit a Final Report for the project.

Progress reports and Final Reports are available at the following website:

http://www.research.mq.edu.au/for/researchers/how_to_obtain_ethics_approval/human_research_ethics/forms

3. If the project has run for more than five (5) years you cannot renew approval for the project. You will need to complete and submit a Final Report and submit a new application for the project. (The five year limit on renewal of approvals allows the Committee to fully re-review research in an environment where legislation, guidelines and requirements are continually changing, for example, new child protection and privacy laws).

4. All amendments to the project must be reviewed and approved by the Committee before implementation. Please complete and submit a Request for Amendment Form available at the following website:

http://www.research.mq.edu.au/for/researchers/how_to_obtain_ethics_approval/human_research_ethics/forms

5. Please notify the Committee immediately in the event of any adverse effects on participants or of any unforeseen events that affect the continued ethical acceptability of the project.

6. At all times you are responsible for the ethical conduct of your research in accordance with the guidelines established by the University. This information is available at the following websites:
http://www.mq.edu.au/policy/

http://www.research.mq.edu.au/for/researchers/how_to_obtain_ethics_approval/human_research_ethics/policy

If you will be applying for or have applied for internal or external funding for the above project it is your responsibility to provide the Macquarie University's Research Grants Management Assistant with a copy of this email as soon as possible. Internal and External funding agencies will not be informed that you have final approval for your project and funds will not be released until the Research Grants Management Assistant has received a copy of this email.

If you need to provide a hard copy letter of Final Approval to an external organisation as evidence that you have Final Approval, please do not hesitate to contact the Ethics Secretariat at the address below.

Please retain a copy of this email as this is your official notification of final ethics approval.

Yours sincerely,
Human Research Ethics Sub-Committee
Faculty of Science and Engineering
Macquarie University
NSW 2109