NTNU – Trondheim
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# Accessing Cultural Heritage Resources on a Mobile Augmented Reality Platform

A Study on Technology Acceptance

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# Sammendrag

I denne oppgaven brukes en utvidet versjon av akseptansemodellen Technology Acceptance Model (TAM) til å studere teknologiaksept av mobilapplikasjoner som bruker augmented reality til å presentere historiske bilder og annen relevant historisk informasjon. En prototype ble utviklet i samsvar med generelle prinsipper for brukervennlighet. Deretter ble det gjennomført en gateundersøkelse med 42 deltakere som fikk anledning til å prøve applikasjonen før de svarte på et spørreskjema. En modifisert versjon av det samme spørreskjemaet ble senere brukt i en internettbasert undersøkelse med 200 deltakere. Disse så en kort videodemonstrasjon av applikasjonen i bruk og svarte så på spørreskjemaet.

Undersøkelsen viser at det er en interesse for mobilapplikasjoner som bruker augmented reality til å presentere historiske bilder og annen relevant historisk informasjon. Både oppfattet nytte og oppfattet underholdningsverdi har en direkte innvirkning på brukernes intensjon om å bruke applikasjonen. Dette tyder på at institusjoner som utvikler denne typen applikasjoner kan dra nytte av å fokusere på både nytte- og underholdningsverdi når de utvikler sine applikasjoner.

# Abstract

This project follows the design science research methodology and uses an extended version of the technology acceptance model (TAM) to study the acceptance of a mobile augmented reality application with historical photographs and information. A prototype application was developed in accordance with general principles for usability design, and a street survey was conducted, where 42 participants out on the street got the opportunity to try the application before answering a questionnaire. A modified version of the same questionnaire was later on used in a web survey with 200 participants that watched a short video demonstration before answering the questionnaire.

The results show that there is an interest in mobile augmented reality applications with historical pictures and information. Both perceived usefulness and perceived enjoyment have a direct impact on the intention to use this type of application. This finding suggests that institutions developing this type of applications can benefit from focusing on both the fun and the useful aspect of their applications.

# Problem Description

One has access to a large collection of historical pictures and other historical information about Trondheim. The task intends to investigate making these available on a mobile augmented reality platform linked to the location of the user and the picture taken.

Based on investigations in an existing project thesis, a prototype shall be developed and evaluated in a rigorous manner. The project is expected to follow a design science research approach, producing and evaluating an artifact (e.g. as an App) in a scientifically sound manner e.g. using an acceptance model approach. The task should use resources related to Wireless Trondheim Living Lab in an appropriate manner. Code to be produced should be made available under an open source license. It is preferred that the project report is written in English. The results from a good thesis should be possible to use as a basis for developing a scientific publication.

Supervisor: John Krogstie

# Preface

The project has been defined in consultation with my supervisor, professor John Krogstie at the Department of Computer and Information Science (IDI) at the Norwegian University of Science and Technology (NTNU). I would like to thank him for his support and guidance during this project and the computer specialization project in the fall.

I would also like to thank the NTNU University library for the permission to use their images in the application. I am especially grateful for the valuable help from Inger Johanne G. Røkke in selecting suitable photos for the application.

A big thanks goes to Vegard, for always being there and for helping me with the pictures for the video and the collection of data for the street survey. I would also like to thank the other fellow students at Fiol for their valuable input and moral support throughout the year. My thanks also go out to all the people who participated in the surveys and thus made this research possible.

Last, but not the least, I wish to thank my parents for their continuous support and encouragement throughout my education.

Anne-Cecilie Haugstvedt

# Abbreviations

**AR -** Augmented Reality

**AVE -** Average Variance Extracted

**BI -** Behavioral Intention

**GPS -** Global Positioning System

**METG -** Mobile Electronic Tourist Guide

**NTNU -** Norwegian University of Science and Technology

**PDA -** Personal Digital Assistant

**PE -** Perceived Enjoyment

**PEOU -** Perceived Ease of Use

**PLS -** Partial Least Square

**POI -** Point of Interest

**PU -** Perceived Usefulness

**SEM -** Structured Equation Modelling

**TAM -** Technology Acceptance Model

**TRA -** Theory of Reasoned Action

**UMPC -** Ultra-Mobile PC

**UTAUT -** Unified Theory of Acceptance and Use of Technology

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# Chapter 1

# Introduction

## 1.1 Motivation

Several cultural heritage institutions have recently made mobile augmented reality applications with cultural heritage resources such as historical pictures and information. Examples include the Museum of London[1], the Philadelphia Department of Records [9], the Powerhouse Museum in Sydney[2], and the Netherlands Architecture Institute[3].

However, despite the popularity of this type of applications and the fact that user acceptance of technology has been in the interests of both researchers and practitioners for decades, little has been done to study users' acceptance or willingness to use this type of applications with cultural heritage resources.

A number of studies have examined the acceptance of mobile applications and services [24, 30, 38, 41, 42, 62, 67]. Recent studies have also examined the acceptance of mobile tourist guides [52, 59]. There are at least one study that have examined the acceptance of mobile augmented reality applications in general [63]. Nevertheless, acceptance studies of augmented reality applications with cultural heritage resources are rare.

The aim of this study is to examine the factors influencing the acceptance of such systems, and investigate to what extent there seems to be an interest in this type of applications.

## 1.2 Problem Definition

The goal of this project is to design and evaluate a mobile augmented reality application with cultural heritage information such as historical information and pictures. A technology acceptance model for hedonic systems is used to examine the factors influencing the intention to use such applications.

## 1.3 Project Description

This project is a continuation of a project carried out by the author in the fall of 2011. As part of that project, an extensive preliminary study was conducted to explore the need for an augmented

[1] Streetmuseum: `http://www.museumoflondon.org.uk/streetmuseum`
[2] Layar Powerhouse Museum: `http://www.powerhousemuseum.com/layar/`
[3] UAR: `http://en.nai.nl/museum/architecture_app`

reality application with historical photographs. A number of similar solutions were reviewed and stakeholders from local cultural heritage institutions were interviewed to gather requirements. Finally, a prototype was developed and evaluated. The work described in this project builds upon this foundation.

This study follows the guidelines for design science research. The outcome of the project includes two different artifacts: a prototype of a mobile augmented reality system with cultural heritage resources and a technology acceptance model for this type of applications. The outcome also includes suggestions for further improvements of the prototype.

The project started with an iteration back to the design and development phase to improve the effectiveness of the prototype based on feedback gathered during the fall's evaluation. Different models for technology acceptance were reviewed and a questionnaire was designed. Two different surveys were conducted: a street survey with 42 participants who all got the opportunity to try the application before they answered the questionnaire, and a web survey with 200 participants who answered the questionnaire after having watched a video presentation. The data from the surveys were used to examine the interest in mobile augmented reality applications with cultural heritage resources and to investigate the factors influencing the intention to use this type of systems. The results are presented in this report.

## 1.4 Report Outline

Below is a short overview of the different chapters in this report.

**Chapter 2 Background** presents the main findings of the preliminary study that formed the basis for this project, and describes the initial prototype of the Historical Tour Guide.

**Chapter 3 Theories and Models of Technology Acceptance** gives an overview of existing research approaches to IT acceptance by presenting and comparing some of the dominant technology acceptance models. The findings from this chapter forms the basis for the research model and is therefore presented before the chapter on research design and methodology.

**Chapter 4 Research Design and Methodology** describes the research questions and the research model with its constructs. The hypotheses are presented before the chapter continues with a presentation of the methodological choices and the research design. The validity and reliability of the measures are discussed and, finally, the analysis methods are introduced.

**Chapter 5 Presentation of the Historical Tour Guide** contains a description of the new features implemented in the revised version of the Historical Tour Guide. The chapter also explains the technical details of the implementation.

**Chapter 6 Descriptive Analysis of the Results** presents the descriptive results from the street survey and the web survey.

**Chapter 7 Statistical Analysis of the Results** presents the statistical analysis of the two surveys. It starts with an assessment of validity and reliability, and moves on to test the hypotheses.

**Chapter 8 Discussion** discusses the findings of this study.

**Chapter 9 Conclusion and Further Work** concludes the thesis, sums up the results and provides some suggestions for future research.

# Chapter 2

# Background

This thesis builds on the results of the author's specialization project in computer science, conducted in the fall of 2011. As part of that study, the author researched mobile augmented reality and developed and evaluated the Historical Tour Guide, a mobile augmented reality application with historical pictures.

The purpose of this chapter is to provide the necessary background for this research. The chapter starts with a presentation of the findings from the study of mobile augmented reality and mobile augmented reality in the cultural heritage sector. The application is presented in section 2.4 and the results of the evaluation are presented section 2.5.

## 2.1 Mobile Augmented Reality

Augmented reality (AR) aims to enhance our view of the world by superimposing virtual objects on the real world in a way that persuades the viewer that the virtual object is part of the real environment [12]. It is a crossover between the real and virtual world, as illustrated in Paul Milgram's reality-virtuality continuum diagram shown in figure 2.1. Mobile augmented reality systems provide the same services as augmented reality systems without constraining the individual's whereabouts to a specially equipped area [39].

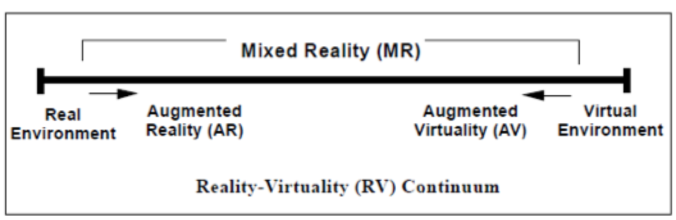



Figure 2.1: Reality-virtuality continuum diagram [43]

### 2.1.1 Historical Background

The term augmented reality (AR) was coined by Tom Caudell and David Mizell in 1992 [13]. The two were at the time working for the Research and Technology organization of Boeing Computer Services and used the term to refer to a system that guided workers through assembling electrical wires in aircrafts by overlaying computer-presented material on top of the real world. The system used a head-mounted display. However, even though the term AR wasn't coined until the early nineties, augmented reality has been around for a while. Ivan Sutherland created the world's first augmented reality system 1968 [57]. The system, shown in figure 2.2, used an optical see-through head-mounted display to display simple wireframe drawings in real time.

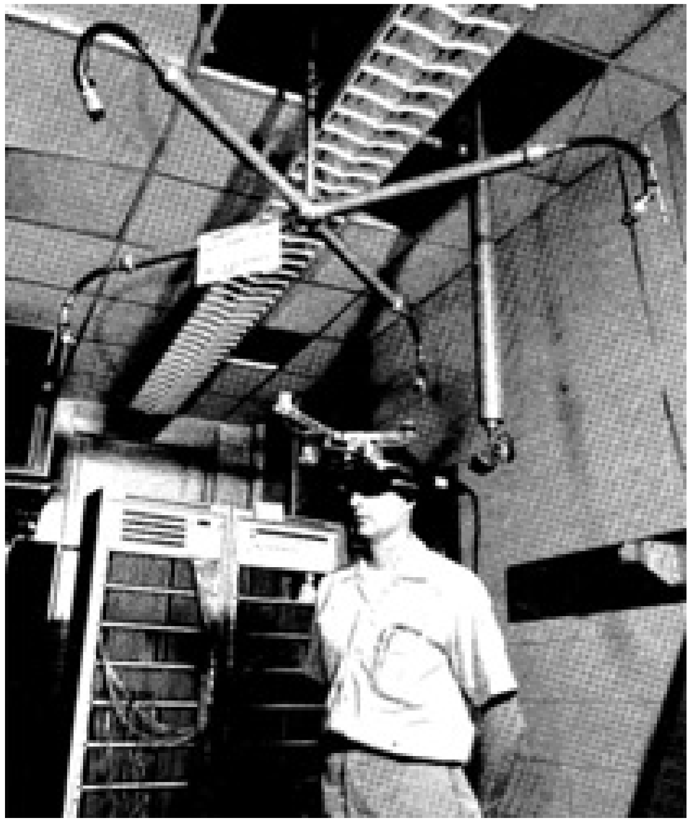


Figure 2.2: Early head-mounted display device developed by Ivan Sutherland [10]

In 1997, Ronald T. Azuma did a survey on the field of augmented reality [4]. He found that, at the time, AR systems were primarily found in academic and industrial research laboratories. While they were being put to use by a number of major companies for visualization, training, and other purposes, the head-mounted displays were too expensive for commercial purposes and the systems were not portable. 1997 was also the year when researchers at Columbia University presented the Touring Machine, the world's first mobile augmented reality system [21]. That system, shown in figure 2.3, required the use of a see-through head-worn display; a backpack holding a computer, differential GPS, and digital radio for wireless web access; a hand-held computer; and a battery belt to power it all.

Increased development of mobile augmented reality systems started with the introduction of the contemporary smartphone [9]. Suddenly, application developers got access to devices packed with sensors such as Wi-Fi sensors, cell tower radio receivers, cameras, compasses and accelerometers. With the release of a new version of the Android operating system for smartphones in summer 2009 they also got the ability to control the camera view and add graphics and other media to the display. A similar capability was added to the iPhone operating system shortly after.

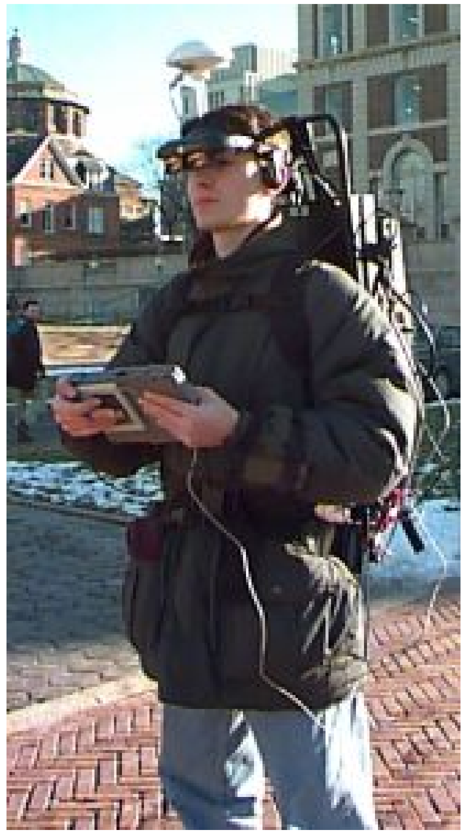


Figure 2.3: Fully equipped user of the Touring machine [21]

### 2.1.2 Tracking Techniques

Tracking is one of the fundamental enabling technologies for AR, and is still an unsolved problem with many fertile areas for research [70]. There are three dominant techniques: vision-based tracking, sensor-based tracking, and hybrid tracking. The vision-based and sensor-based tracking techniques are explained in detail below. The hybrid techniques combine elements from the other two techniques to provide a more robust result.

#### Vision-Based Tracking Techniques

Vision-based tracking techniques use image processing methods to calculate the camera pose relative to real world objects [70]. Applications that use the techniques analyze the images coming in from a digital camera to determine what is visible in the world around the user and where those objects are in relationship to the user.

The available vision-based tracking techniques can be divided into two classes: marker-based and marker-less approaches. Marker-based approaches require that the systems identify an artificial fiduciary marker placed at locations or on objects in the real world in order to bring up the correct information. Marker-less approaches use natural feature detection to identify unaltered real world objects such as book covers, posters or landmarks that have no artificial makers to assist object recognition [12]. Marker-based approaches often use QR codes - essentially 2D bar codes which take the form of a pixilated square that can be read by mobile phones equipped with an appropriate software application [56]. A QR code that links to the url http://www.ntnu.no/ is shown in figure 2.4.

Figure 2.4: Example of a QR-code for http://www.ntnu.no/

Vision-based tracking techniques are rather slow, and often turn out to be too fragile, especially in natural (e.g. outdoor) environments [49]. Furthermore, the marker-based approaches require that markers are placed in the real world. This can be a time-consuming process and requires a certain control of the environment. The developers must have permission to put up the markers and some way of replacing missing and vandalized markers. The marker-less approaches do not require the same control of the environment. However, they are susceptible to slight variations in lightning and surrounding objects. Fast object motions will lead to rapid change of visual content, resulting in time-consuming recovery of new landmarks with a temporary loss of real-time tracking abilities.

A marker-based tracking technique is an easy solution for companies and institutions that are looking for a way to implement augmented reality indoors [9]. For outdoor applications that covers a wide geographical area, it is probably more suitable with a hybrid or sensor-based approach.

### Sensor-Based Tracking Techniques

Sensor-based tracking techniques are based on sensors such as magnetic, acoustic, inertial, optical and/or mechanical sensors [70]. Applications that use the techniques combine data from sensors to estimate where the user is standing and what he or she is looking at.

The location-sensing technologies used for sensor-based tracking can be characterized according to whether they are fine-grained or coarse-grained [33]:

- GPS and cell tower or Wi-Fi triangulation are examples of coarse-grained systems. They exhibit modest accuracy, generally measured in meters. GPS is unsuitable for indoor positioning while triangulation can be used both outside and inside.

- Ultrasound is an example of a fine-grained system, achieving accuracies on the order of centimeters. Since audio is mostly bounded by walls, it can be used to resolve locations to the confines of a physical room. However, the technique requires the installation of sensors and that the users wear tags that can be tracked. There is no support for the approach in today's smartphones.

A common approach in mobile augmented reality systems is to get a basic geographic location from the GPS sensor of the device and augment this by Wi-Fi and cell tower locations. Whatever other sensors are present will then be used to determine exactly what the user is looking at. A compass provides information on the direction the device is pointing, a gyroscope will tell how far up or down the device is pointing and whether is it twisted vertically, and an accelerometer will indicate how the device is moving through space. Finally, the information of choice can be overlaid on the camera view.

The approach mentioned above is bounded by the accuracy and availability of the device's sensors. GPS is a global navigation satellite system and small timing errors can cause the GPS receiver to make different assessment of where it is located, causing a user's supposed location to bounce around while the user is standing still. These errors can be particularly bad in the city, where signals can bounce off buildings. It is also a problem that the signals does not penetrate indoors, making GPS unsuitable for indoor positioning [9]. Not all devices have a gyroscope and the other sensors have their limitations as well. Regardless of this, the approach is often the most suitable for mobile augmented reality applications, since is does not require the installation of any extra equipment.

### 2.1.3 Presentation of Image Overlays

Some definitions of augmented reality (AR), such as the one found in Ronald Azuma's survey of augmented reality [4], insist that the virtual object is a 3D model of some kind. However, most people accept a looser definition where the virtual domain consists of 2D objects such as text, icons and images [12]. This is the approach taken in this project.

Given that it is accepted to use 2D representations in augmented reality, there are two possibilities for displaying image overlays:

1. display the photos as 3D objects in the scene (using absolute rotation)
2. display the photos as flat 2D overlays over the scene (using relative rotation)

When the user is standing directly in front of the photograph and have the same perspective as the photographer, the two methods produce identical results. If the user moves, the last option will result in the image still directly facing the user while the first option will result in an angled view of the photograph. At first glance, the second option might seem inferior. However, the promotional screenshots from successful applications that have used the first approach do not convey the difficulty in real world use [14]. Aligning historic images with 'reality' in 3D view can be an exercise in patience and, as a result, the 3D views ends up being a gimmick instead of a useful feature.

Due to the problems with use and the technical difficulties in developing an application with 3D objects, it was decided to display photographs as flat 2D overlays in the Historical Tour Guide.

## 2.2 Mobile Augmented Reality in the Cultural Heritage Sector

One could argue that cultural heritage institutions already are in the augmented reality business [37]. They readily understand the need to augment the reality of objects and historical sites to help visitors better understand and connect with their collections and the past. Both artifacts and areas are often accompanied by extra material such as descriptions, pictures, maps, or movies. For archeological sites, there are also guides with pictures of how a site looks now printed on normal paper and images of how it looked in the past printed on transparent material. Audio guides are also much used. Mobile augmented reality applications take the technology a step further and let the institutions provide information to the user, where the user is located. They also create publicity and help institutions reach out to new audiences [9].

This section should by no means be regarded as a complete list of all mobile augmented reality projects in the cultural heritage sector. However, it describes the shift from projects using augmented reality systems with head-mounted displays to projects using contemporary AR systems with smartphone applications.

### Archeoguide

The Archeoguide system [69] is a mobile augmented reality system for cultural heritage sites launched in 2001. The system was built around the historical site of Olympia, Greece, and provided personalized contextual information based on the user's position and orientation.

Three different mobile clients were supported within the system: a laptop, a tablet and a Personal Digital Assistant (PDA). The full augmented reality functionality was only available on the laptop client. This client, shown in figure 2.5, required the use of a see-through head-mounted display with an external web camera and a digital compass, a backpack with a GPS receiver, a laptop, wireless communication equipment, and a battery.

The tablets were more conveniently sized and had the GPS receiver, digital compass and wireless communication equipment integrated in a small box at the bottom of the screen. They did not have a camera, but provided customized information and reconstructed augmented views of the surroundings aligned with the user's position and orientation. The PDA did not support user-tracking at all but acted as an electronic version of a written tour guide.

The laptop system used a hybrid approach where a GPS and compass system were used to get a rough estimate of the user's position before vision-based tracking techniques were used to find the exact position and orientation. The vision-based tracking was based on natural landmarks instead of artificial markers.

### iTacitus

The iTacitus project[1] was a European research project that commenced in September 2006 and finished in July 2009. During this time, the researchers explored ways of using augmented reality to provide stimulating experiences at cultural heritage sites and encourage cultural tourism.

One of the systems developed under the iTacitus program was the augmented reality presentation system for remote cultural heritage sites by Zöllner et al. [71]. The system did not use a head-mounted display, but rendered augmented information on top of the camera feed of a commercial device. For positioning, the system relied solely on image-based tracking techniques.

The system was used in several installations, among them the 20 years of the Fall of the Berlin Wall installation at CeBIT 2009 shown in figure 2.6. In that installation, visitors could use Ultra Mobile PCs (UMPCs) to see images of Berlin superimposed on a satellite image of the city laid out on the floor. By touching the screen, they could switch through visualizations from different decades, thus recognizing the situation in Berlin before and after World War II and the construction of the Berlin Wall. The installation also consisted of an outdoor part where users could use their

[1] Intelligent Tourism and Cultural Information through Ubiquitous Services: `http://www.itacitus.org`

Figure 2.5: The laptop client in the Archeoguide system (photo from Gleue and Dähn [28])

smartphone to take a photo of a building and receive overlays from the server that were overlaid on the current view.

### Smartphone Applications by Cultural Institutions

A number of cultural institutions have launched their own augmented reality applications after the introduction of the contemporary smartphone. Examples include the Philadelphia Department of Records, the Museum of London, the Netherlands Architecture Institute and the Powerhouse Museum in Sydney. The focus here will be on the Augmented Reality by PhillyHistory.org application [9], as that project is thoroughly documented through a white paper.

The application was developed as a joint project between a software company and the City of Philadelphia Department of Records. It is built on top of Layar[2], a ready-made augmented reality application for smartphones that supports both Android and iPhone devices. Layar displays points

[2]Layar: `http://www.layar.com`


Figure 2.6: The Fall of the Berlin Wall installation (photo from Zöllner et al. [71])

of interest (POI) as markers on top of the live camera-feed from the smartphone. It handles the positioning and rendering of information on the device and lets the application developers focus on building a web service with the information they want to include.

The application from Philadelphia enables users to view historic photographs of Philadelphia as overlays on the camera view of their smart phones. The local application developers have made an application that contains almost 90.000 geo-positioned images. 500 of these can be viewed as transparent images positioned in 3D, and a selection of 20 contains additional explanatory text developed by local scholars.

## 2.3 Development of the Historical Tour Guide

The Historical Tour Guide is the name of the prototype that was developed last fall. It is a location-aware mobile information system that uses mobile augmented reality to present local historical photographs in Trondheim. The system is built atop CroMAR [44], a system that uses mobile augmented reality to support reflection on crowd management. This section presents CroMAR and the process of gathering requirements and selecting images for the tour guide. The prototype is presented in section 2.4.

### 2.3.1 CroMAR

CroMAR [44] is an augmented reality application developed for Apple's iPad. The application was built to support crowd management but was chosen as a foundation for the Historical Tour Guide as it was a readily available open-source project that used mobile augmented reality.

The main functionality of CroMAR is to present points of interest to the user. Each point of interest is a piece of information, geotagged with a latitude and longitude. The system uses the tablet's WiFi sensor, gyroscope, accelerometer and digital compass to determine the heading and the location of the device. This information is in turn used to locate any points of interest that are within viewing range. Finally, each point of interest within range is displayed as an icon, overlaying the video feed from the camera right where it would be located in the real world.


Figure 2.7: Screenshot from the CroMAR application

Figure 2.7 shows a screen shot from the CroMAR application. The main screen, visible in the background, is the augmented reality view showing the live camera feed. The view on top is one of the application's detailed information views. These are displayed when the users push on one of the icons representing points of interest.

All the functionality mentioned above have been included in Tour Guide. The rest of the functionality in CroMAR have either been changed (such as the timeline and map), or excluded (such as the sharing and rating functions).

### 2.3.2 Requirements of Stakeholders from Cultural Heritage Institutions

Interviews with representatives from cultural heritage institutions were conducted both at the beginning and at the end of the specialization project.

The initial interviews revealed that there is a large interest in local history in Trondheim. There are several historical societies in the area, a number of books on local history have been published and the institutions at the local archive center have done a tremendous job digitalizing their collections.

The University Library and the other institutions at the local archive center have an interest in developing a mobile augmented reality application with historical images from Trondheim. They are willing to help with access to and selection of images, but do not have resources to maintain a system after the end of the development period. For this reason, any system or application developed for these institutions should be as independent as possible and not require the use of a server that would have to be maintained or updated after the end of the development period.

The majority of the people that are members in the local historical societies have limited technical experience. It can be assumed that this will be a characteristic of the application's typical user. The application should therefore be easy to learn and easy to use.

All the historical photos from the archive center are copyrighted. A condition for using the images is that it is easy to identify the University Library as the owners of the photos and that the source and photographer for each image is included in the application.

The final interviews were conducted after the representatives had seen the working prototype. It was then suggested that the application should be expanded to include not only photos, but also historical data from the street directory of Trondheim. It was also mentioned that the application needed a user guide.

### 2.3.3 Selection and Preparation of Historical Material

In order to develop a mobile augmented reality application with historical photographs one is dependent upon having photographs associated with a particular location. The assets must at the least be assigned latitude and longitude. If the images are not geocoded, this has to be done manually when adding images to the application.

Cultural heritage institutions typically manage large collections of photographs. Not all of these are connected to a location. Some are portraits or images of artifacts while others do not contain enough information to determine the location or are not suitable to use as overlays because they were not taken at street level. Finding a suitable subset of the images to show in a mobile augmented reality application is an extensive job and requires some knowledge of the collections.

The image selection process for the Historical Tour Guide started with the head librarian at the University Library choosing a subset of 200 images that might be suitable for use in the application. These images were in turn evaluated according to certain criteria to be able to determine which would be most suitable to include in the application. Finally, the images were located on a map and geocoded.

## 2.4 Description of the Historical Tour Guide

As mentioned in section 2.3, the Historical Tour Guide is a location-aware mobile information system that uses mobile augmented reality to present historical photographs and information about the photographs. There are three ways to access information in the application:

- Clicking on a point-of-interest
- Clicking on a photo in the list of available photos
- Looking on the map

All three methods can be combined with filtering to look at photos from a specific decade.

### 2.4.1 Augmented Reality View

The augmented reality view is the the main view of the application where points of interest (POIs) are shown as floating icons overlaying the camera feed. The name of the application is shown in the toolbar at the top. The view is shown in figure 2.8 (a).

### 2.4.2 Photo Overlay

Figure 2.8 (b) shows one of the application's transparent photo overlays. These let the user see historical images over the present day scene. The buttons in the toolbar at the top of the screen are used to close the overlay or go to the detailed information view belonging to the picture.

### 2.4.3 Detailed Information View

Each of the photographs in the application has an associated detailed information view. One of these is shown in figure 2.8 (c). It contains a description of the motive and let the user know when the picture was taken, the source of the photograph and the name of the photographer.

### 2.4.4 Timeline

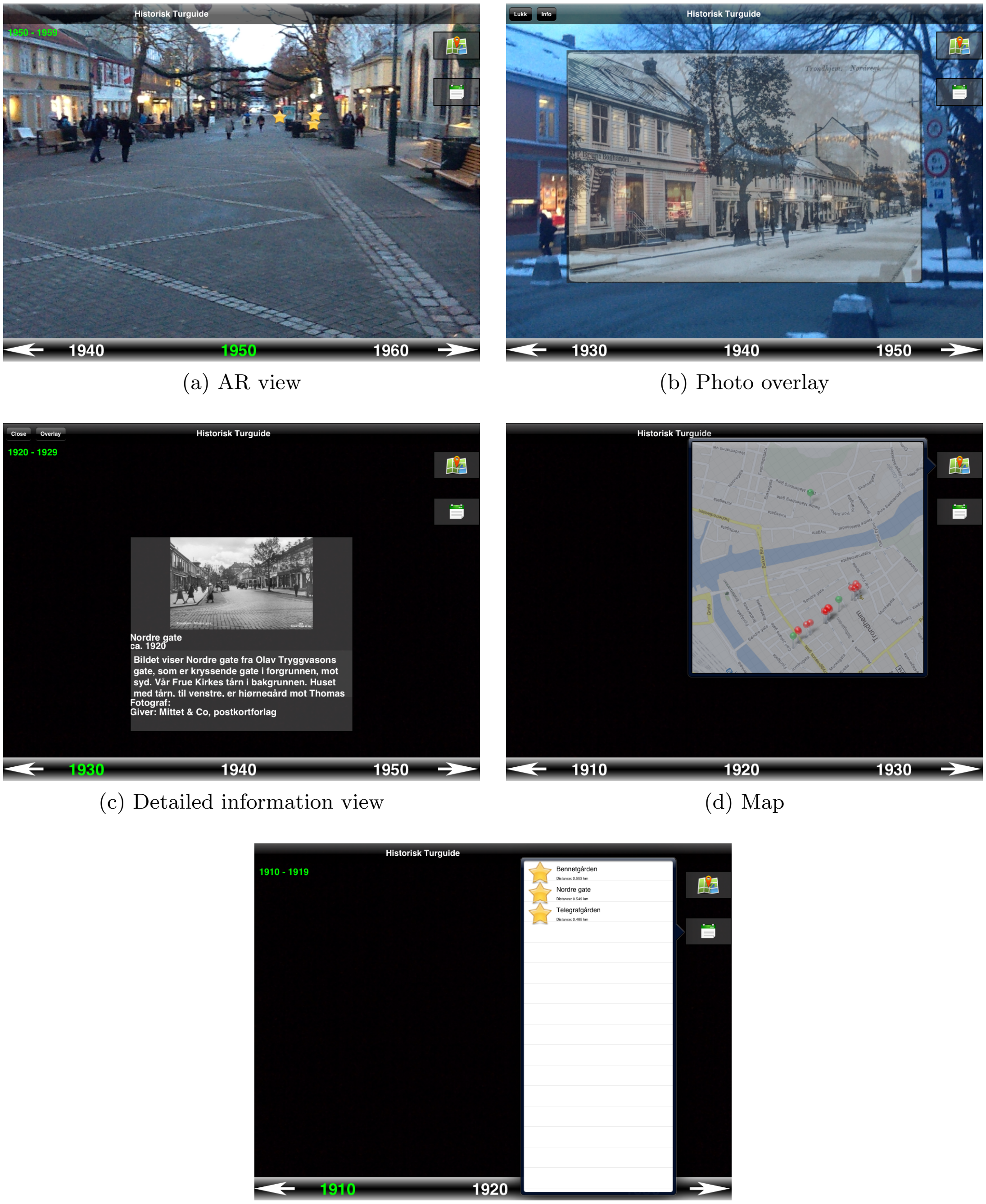
The timeline is always visible at the bottom of the screen. It lets the user filter the amount of incoming information so they only see photographs from a specific decade. The selected decade is marked in green and written in the upper-left corner.

### 2.4.5 Map

Figure 2.8 (d) contains a screen shot of the application's map. It shows the user's current position and the position of photos from the decade selected on the timeline. Each pin is tagged with the name of the photo and the distance from the user. It is not possible to open photographs from the map in this version of the application.

### 2.4.6 List View

Figure 2.8 (e) shows the application's list view. This view shows the user a list of all photographs from the selected decade and provides a convenient method to open detailed views without having to locate the associated markers.




(a) AR view

(b) Photo overlay

(c) Detailed information view

(d) Map

(e) List view

Figure 2.8: Screenshots from the Historical Tour Guide

## 2.5 Evaluation of the Historical Tour Guide

The Historical Tour Guide was evaluated in order to validate the realism and value of the suggested solution. As part of the evaluation, a group of computer science students conducted a heuristic evaluation. Afterwards, the application was tested with prospective users. The users rated the usability of the system on the System Usability Scale (SUS), a simple ten-item scale giving a global view of subjective assessments of usability [11].

### 2.5.1 Heuristic Evaluation

Nielsen [47] recommends that the heuristic evaluation is done with between three to five evaluators and that any additional resources are spent on alternative methods of evaluation. In accordance with this, three master students in computer science received a list of Nielsen's ten heuristics (included in this thesis in section 4.2.2) and were asked to give comments on the user interface of the Historical Tour Guide. The heuristic evaluation uncovered a set of smaller usability issues that were solved before the tests with prospective users. The evaluators also came up with some more complex issues that were added to the list of suggested changes presented at the end of this section.

### 2.5.2 Tests with Prospective Users

A total of five users participated in the usability tests. The evaluations were conducted as part of an iterative design process, where the prototype was updated based on the feedback from each evaluation. Most of the updates happened between the first and second test. Two of the participants in the tests had computer science background and were familiar with tablets. The three others were working at NTNU University Library and the Regional State Archives in Trondheim. They had never used a tablet before.

All the tests were conducted in the same way. The users were given a short presentation of the system, before being asked to conduct a set of three tasks. The tests uncovered some smaller problems that could be fixed at once and some larger issues that were added to the list of suggested changes. Regardless of this, the application still received an overall system usability score of 76.5 out of a 100. This is fairly good, but indicates that there is room for improvement.

### 2.5.3 Summary of Suggested Changes

The following is a list of suggested changes that could make the Historical Tour Guide more valuable to the user and easier to use:

- Include more historical data from the area, not only photos.
- Include a short and easy-to-read user guide for the application.
- Change the navigation by moving the buttons from the toolbar at the top of the screen to their associated views.
- Apply filtering to reduce the number of markers in the augmented reality view.
- Make it possible to open a photo by pressing the associated pin on the map.
- Change the timeline so all options are visible at all times.

The list is based on feedback gathered during the heuristic evaluation, tests with prospective users and final interviews with the stakeholders. It formed the basis for the improvements to the prototype that are presented in chapter 5 of this report.

# Chapter 3

# Theories and Models of Technology Acceptance

Predicting and explaining user acceptance of information systems has been and still is a major research field. A variety of models have been used. The model used in this research is van der Heijden's extension [61] of the technology acceptance model (TAM) [19, 18].

This chapter starts with a presentation of the theory of reasoned action (TRA) [22], the predecessor to TAM. Next, it moves on to present TAM and some of the most used extensions to TAM. Finally, it presents van der Heijden's extension of TAM, the model used in this research.

## 3.1 Theory of Reasoned Action (TRA)

Fishbein and Ajzen's theory of reasoned action (TRA) [22] is a well-researched intention model from social psychology that has been used to explain behavior in a variety of domains. The theory states that the most important determinant of an individual's behavior is behavioral intentions. The intention to perform the behavior is in turn determined by a combination of:

1. The individual's attitude towards performing the behavior.
2. Subjective norms regarding the behavior in question.

Figure 3.1 shows the model. The relative weights of attitude and subjective norm varies, and are typically estimated by regression.

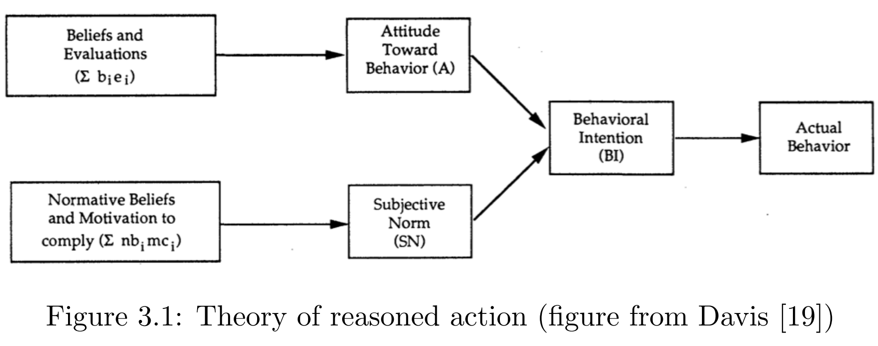



Figure 3.1: Theory of reasoned action (figure from Davis [19])

### 3.1.1 Variables in TRA

The variable **attitude towards the behavior** refers to the individual's feelings toward performing the behavior in question. It is determined by a set of beliefs about the consequences of the action. The variable can be expressed as:

$$A = \sum_{i=1}^{n} b_i e_i \tag{3.1}$$

where

$A$ is the attitude towards the behavior,

$b_i$ is the perceived probability of outcome $i$,

$e_i$ is the evaluation of outcome $i$ (positive or negative), and

$n$ is the number of beliefs about the consequences of the behavior.

The variable **subjective norm** refers to the person's perception of whether others think he should perform the action. It is determined by a combination of what the individual believes "important others" think combined with his or hers willingness to comply with their expectations. The variable can be expressed as:

$$SN = \sum_{i=1}^{n} n_i m_i \tag{3.2}$$

where

$SN$ is the subjective norm,

$n_i$ is the normative belief/the perceived likelihood that referent $i$ approve or disapproves of performing the given behavior,

$m_i$ is the motivation to comply with referent $i$, and

$n$ is the number of referents.

The variable **behavioral intention** refers to the individual's intent to perform a behavior. It is used to predict whether or not the person performs the behavior.

### 3.1.2 Limitations of TRA

The theory of reasoned action is a general model and does not specify the beliefs that are relevant for a particular behavior. As a result, relevant beliefs will have to be elicited from a representative sample of the target population before the model can be applied to a specific setting.

## 3.2 Technology Acceptance Model (TAM)

Davis' technology acceptance model (TAM) [19, 18], shown in figure 3.2, is built upon Fishbein and Ajzen's theory of reasoned action. The model was introduced in 1986 and has since then been used to describe and predict user acceptance of information technology.

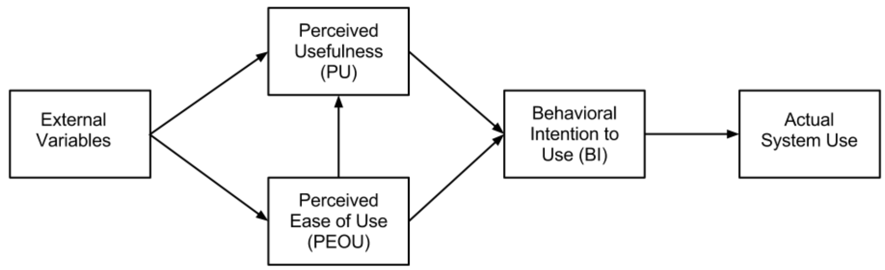



Figure 3.2: Technology acceptance model

### 3.2.1 Variables in TAM

TAM posits that the behavioral intention to use a system can be explained by two beliefs: perceived usefulness and perceived ease of use. The beliefs are defined as follows:

**Perceived Usefulness (PU):** the degree to which a person believes that using a particular system would enhance his or her job performance.

**Perceived Ease of Use (PEOU):** the degree to which a person believes that using a particular system would be free of effort.

The original model also included the attitude construct from the theory of reasoned action. This construct was excluded from the model in 1989 because it did not fully mediate the effect of perceived ease of use on intention and because the perceived usefulness to behavioral intention link seemed more significant [18].

The external variables in the model refer to a set of variables ranging from system characteristics to the nature of the implementation process. Later research have looked into these variables and tried to identify the determinants of perceived usefulness and perceived ease of use.

- Venkatesh [64] proposed a model which posits that personal characteristics of the user (computer self-efficacy, computer playfulness and computer anxiety), characteristics of the institution (facilitating conditions) and characteristics of the system determines the perceived ease of use of the system. This model explained 60% of the variance in perceived ease of use and it was found that an "individual's general beliefs regarding computers were the strongest determinants of system-specific perceived ease of use, even after significant direct experience with the target system."

- Venkatesh and Davis [65] proposed TAM2, a model which posits that social influence processes (subjective norm, voluntariness, and image) and cognitive instrumental processes (job relevance, output quality, result demonstrability), along with perceived ease of use, determines the perceived usefulness of the system. This model explained up to 60% of the variance in perceived usefulness.

### 3.2.2 Extensions to TAM

TAM has been extended with different constructs and combined with a variety of other models since its introduction. The perhaps most known of these extensions are TAM2 and UTAUT.

### TAM2

Venkatesh and Davis [65] developed TAM2. The model, shown in figure 3.3, is a theoretical extension of TAM that includes the subjective norm variable from TRA. As explained earlier, the model also identifies determinants of perceived usefulness.

TAM2 was evaluated in a longitudinal field study involving four different systems at four organizations: two that were mandatory to use and two that were voluntary to use. User perceptions and self-reported use were collected at three points in time: prior to implementation, one month after implementation, and three months after implementation.

In their research, Venkatesh and Davis found that TAM2 performed well in both mandatory and voluntary settings. Subjective norm did have a direct effect on perceived usefulness and behavioral intention, but only for mandatory systems. Furthermore, this effect decreased with experience and was non-significant three months after implementation. Perceived usefulness and perceived ease of use continued to have a consistent effect on intention to use across all four systems in all three time-periods.

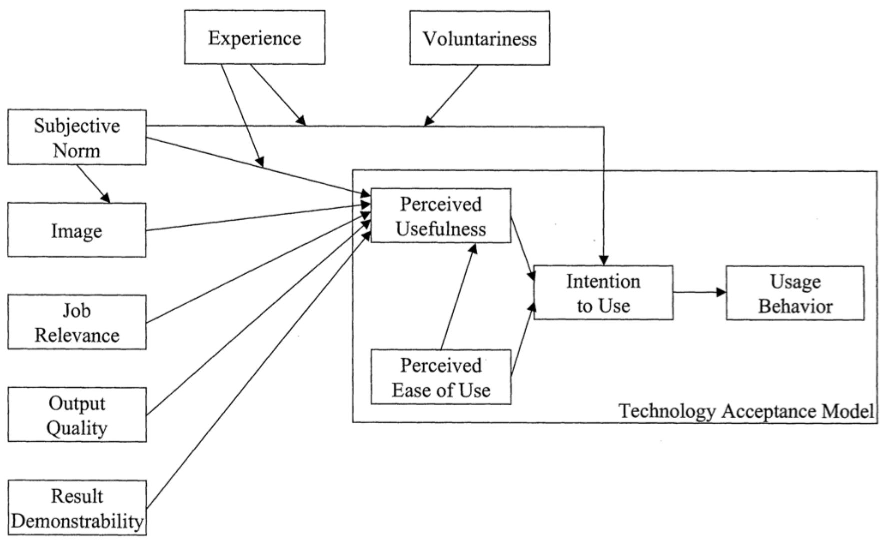



Figure 3.3: TAM2 (figure from Venkatesh and Davis [65])

### UTAUT

Venkatesh et al. [66] developed UTAUT, the unified theory of acceptance and use of technology. The model, shown in figure 3.4, is a research model that combines TAM with seven other models, including the theory of reasoned action (TRA - the predecessor of TAM) and the theory of planned behavior (TPB - the ancestor of TRA).

The construction of UTAUT began with a longitudinal field study involving four organizations and four systems: two were the perceptions of voluntariness were high and two were the perceptions of voluntariness were low. User perceptions and actual usage behavior were collected over a six-month period with three points of measurement.

The data from the field study was first used to test the original eight models. These models explained between 17% and 53% of the variance in usage intentions. Next, UTAUT was formulated and tested using the same data. The model explained 69% of the variance in usage intention. To further validate this result, data was collected from two additional organizations. The model explained 70% of the variance in usage intention.

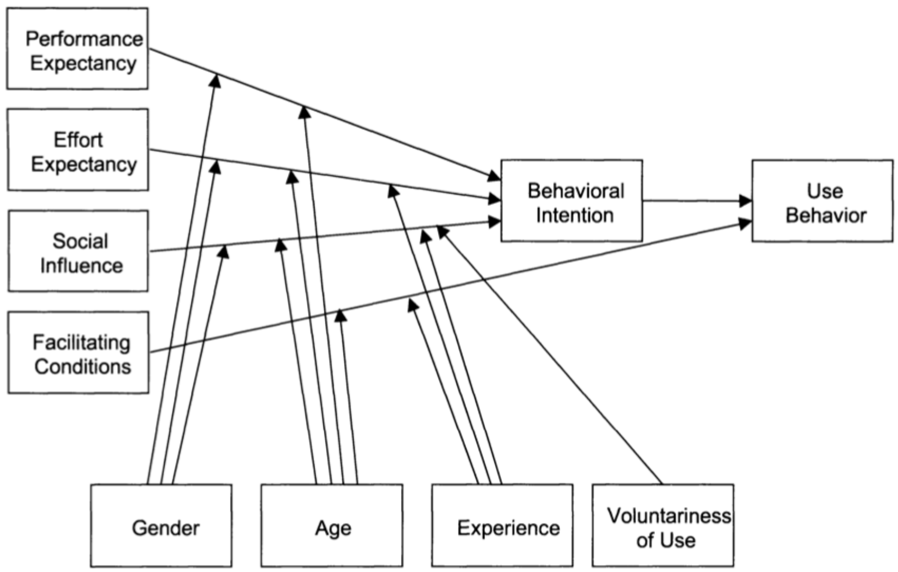



Figure 3.4: Unified theory of acceptance and use of technology (figure from Venkatesh et al. [66])

### 3.2.3 Limitations of TAM and its Extensions

TAM has been used to study user acceptance for over two decades. Several studies have confirmed the robustness of the model and its suitability for predicting system usage. However, there are also researchers that have criticized the model.

Benbasat and Barki [7] states that "the inability of TAM as a theory to provide a systematic means of expanding and adapting its core model has limited its usefulness in the constantly evolving IT adoption context". They suggest that researchers should go back to the origin of TAM and look for other potentially salient beliefs that may affect user acceptance. In order to do so, they suggest using the theory of planned behavior (TPB), a more comprehensive version of the theory of reasoned action. This theory requires an initial extraction of salient beliefs that are relevant for the system in question. Using the theory would remedy the potential problems caused by TAM's neglect of group, social, and cultural aspects of decision making aspects of decision making as such influences will be included in the model if they are relevant.

Another approach is to use the UTAUT model. This model is more comprehensive than TAM and includes social influences and facilitating conditions. However, UTAUT is no more open to expansions and adaptions than TAM, and it is a complicated model. As Bagozzi [5] points out: "we are left with a model with 41 independent variables for predicting intentions and at least eight independent variables for predicting behavior". For reasons such as these, the original parsimonious version of TAM continues to be used to evaluate user acceptance of systems.

Some researchers choose to use TAM, but includes beliefs that are relevant for the specific context. Van der Heijden's inclusion of perceived enjoyment to measure user acceptance of a hedonic system [61] is an example of this type of adjustment. The problem with this approach is that the researchers often will have to develop their own scales or depend on less validated scales.

## 3.3 Technology Acceptance Model for Hedonic Systems

Figure 3.5 presents the technology acceptance model with perceived enjoyment. This model was developed by Davis et al. in 1992 [20]. It is built upon the 1989 TAM model without the attitude construct.

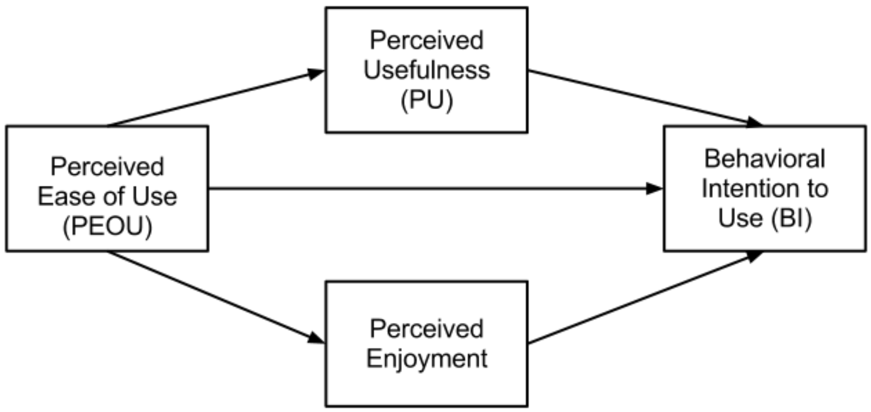



Figure 3.5: Technology acceptance model for hedonic systems (adapted from van der Heijden [61])

### 3.3.1 Variables in the Technology Acceptance Model for Hedonic Systems

Perceived enjoyment is defined as follows:

> **Perceived enjoyment:** the extent to which the activity of using the computer system is perceived to be enjoyable in its own right, apart from any performance consequences that may be anticipated.

Perceived enjoyment is not included in most of the research that uses TAM. A reason for this is the amount of research that has shown that perceived usefulness is the strongest predictor of user acceptance and that the effect of perceived enjoyment is consistently weaker than the effects of perceived usefulness and perceived ease of use [20, 35, 36]).

However, van der Heijden [61] noted that there were some exceptions to the rule that perceived usefulness is the strongest predictor of user acceptance. Specifically, there seemed to be a difference between productivity-oriented (or utilitarian) and pleasure-oriented (or hedonic) information systems. To investigate this, van der Heijden used Davis' model from 1992 [20] to do an online survey on the usage intentions of one hedonic information system - a Dutch movie website with information, news and gossip about upcoming movies, listings of cinemas in major Dutch cities and the opportunity for users to comment on movies. The results of the study showed that perceived enjoyment and perceived ease of use were stronger determinants of intentions to use the system than perceived usefulness.

### 3.3.2 Limitations of the Technology Acceptance Model for Hedonic Systems

Perceived enjoyment will not have a significant effect on the intention to use all systems. Chesney [16] used the same model as van der Heijden to investigate the factors associated with acceptance of a system used both for productive and pleasurable interaction. The study showed that perceived usefulness was more important than perceived enjoyment when determining intention to use the Lego Mindstorm system. This finding is consistent with the results of Davis [20] and other researchers that have shown that perceived usefulness is the strongest predictor of user acceptance. However, Chesney does not suggest that perceived enjoyment should be left out of future studies. To the contrary, he agrees with van der Heijden in that purpose of use is important in determining the factors that predict acceptance and suggest that "progress in user acceptance models can be made by focusing on the nature of use."

In his study of a hedonic system, van der Heijden was only able to explain 35% of the total variance. This low explanatory power is typical for acceptance studies and is partly why Venkatesh et al. [66] constructed UTAUT. However, Chesney [16] used the same model as van der Heijden and managed to explain 62% of the total variance on the intention to use the Lego Mindstorm system. Both researchers conducted an online study, but van der Heijden had 1.144 participants while Chesney had 68. It is possible that parts of the difference in explanatory power can be explained by the different nature of the systems. As the acceptance model does not include a construct that measure social influence, it may be more suitable for the Lego Mindstorm system than it is for a movie website that is social in nature and where the opportunity to comment on movies is one of the popular features.

# Chapter 4

# Research Design and Methodology

This chapter describes the research questions and the research model with its constructs. The hypotheses are presented before the chapter continues with a presentation of the methodological choices and the research design. The validity and reliability of the measures are discussed and, finally, the analysis methods are introduced.

## 4.1 Conceptual Framework

### 4.1.1 Research Questions

The following questions guided the research:

- Is there an interest for using augmented reality applications with historical pictures and information?

- Do the previously established relationships between the constructs in the technology acceptance model (TAM) extended with perceived enjoyment hold for augmented reality applications with historical pictures and information?

The first research question deals with the interest in using this type of application. The aim is to discover if there is an interest and whether this interest is dependent on the application being available on a specific type of device. It is also desirable to know if people want to use this application in their hometown or when visiting a new city.

The second question deals with the relationship between the constructs in the acceptance model. Van der Heijden [61] showed that perceived enjoyment and perceived ease of use were stronger predictors of intention to use a hedonic system than perceived usefulness. This project aims to find out if the same is true for augmented reality applications with historical pictures and information. This information can be used to find ways to make this type of applications more acceptable to users.

### 4.1.2 Research Model

Figure 4.1 shows the research model used in this study. This is the technology acceptance model with perceived enjoyment used by Davis et al. [20] and van der Heijden [61].

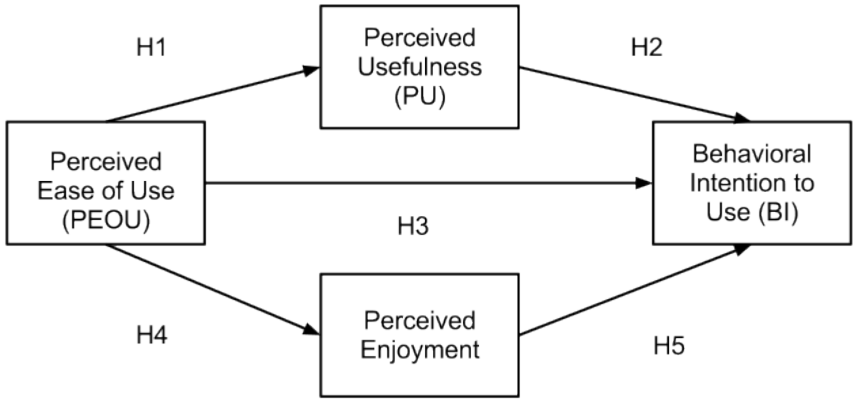



Figure 4.1: Research model (adapted from van der Heijden [61])

Four constructs are included in the model: perceived enjoyment, perceived usefulness, perceived ease of use and behavioral intention. The paths between the variables are as van der Heijden [61] describes them. It was predicted that while the strength of the paths might change, the structure of the relationships would remain the same. This lead to the following five hypotheses:

- **H1** There is a positive relationship perceived ease of use and perceived usefulness.
- **H2** There is a positive relationship between perceived usefulness and intention to use.
- **H3** There is a positive relationship between perceived ease of use and intention to use.
- **H4** There is a positive relationship between perceived ease of use and perceived enjoyment.
- **H5** There is a positive relationship between perceived enjoyment and intention to use.

## 4.2 General Research Approach

### 4.2.1 The Design Science Research Process

Design science is a problem-solving paradigm that seeks to extend the boundaries of human and organizational capabilities by creating new and innovative artifacts. It involves a rigorous process to design artifacts to solve observed problems, to make research contributions, to evaluate the designs, and to communicate the results to appropriate audiences [34].

Figure 4.2 illustrates the design science research process. The figure is the result of work done by Peffers et al. [50, 51]. The process is structured in a sequential order; however, it is possible to start at almost any step in the process. After evaluating the artifact in step 5, the researchers can decide whether to iterate back to design and development to improve the effectiveness of the artifact or to continue on to communication and leave further improvements to subsequent projects.

The model used in this research was developed using a problem-centered approach, starting with problem identification and motivation. The prototype, on the other hand, was developed and evaluated last fall. As such, it was more suitable to use a design and development-centered approach, starting with an iteration back to the design and development phase to improve the effectiveness of the prototype.

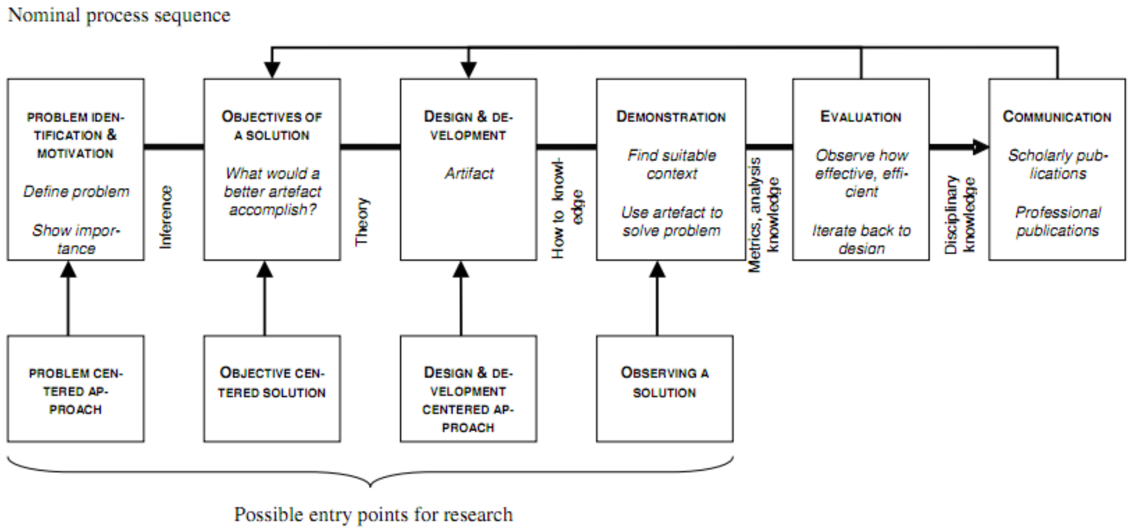



Figure 4.2: Design science research process (figure from Peffers et al. [50])

To ensure that the research was conducted in a sound manner, this project followed the seven guidelines for conducting design-science research developed by Hevner et al. [34]. These guidelines are summarized in table 4.1.

The first guideline states that design science research "must produce a viable artifact in the form of a construct, a model, a method, or an instantiation". There are two artifacts in this project:

1. The Historical Tour Guide application.

2. An acceptance model for augmented reality applications with historical pictures and information.

The second guideline states that the objective of design-science research is to "develop technology-based solutions to important and relevant business problems". The motivation section of the introduction in this report explains why the development and acceptance of mobile augmented reality applications with historical pictures are relevant problems.

The third guideline states that the "utility, quality, and efficacy of a design artifact must be rigorously demonstrated via well-executed evaluation methods". The prototype was evaluated for usability last fall. Chapter 5 covers how the new features implemented in the revised version satisfy the general principles for usability design. Chapter 7 focus on evaluation of the acceptance model. It covers both the validity and reliability assessment and the testing of the proposed research model.

The fourth guideline states that "effective design-science research must provide clear and verifiable contributions". The results of the acceptance testing and the final prototype are the research contributions from this project.

The fifth guideline states that design science research relies upon "the application of rigorous methods in both the construction and evaluation of the design artifact". The rest of this chapter presents the methods used to develop and evaluate the prototype, research model and survey. The prototype was developed and evaluated in accordance with principles for usability design while the research model and survey were developed and evaluated in accordance with standard methods for acceptance and survey research.

| Guideline | Description |
|---|---|
| Guideline 1: Design as an Artifact | Design-science research must produce a viable artifact in the form of a construct, a model, a method, or an instantiation. |
| Guideline 2: Problem Relevance | The objective of design-science research is to develop technology-based solutions to important and relevant business problems. |
| Guideline 3: Design Evaluation | The utility, quality, and efficacy of a design artifact must be rigorously demonstrated via well-executed evaluation methods. |
| Guideline 4: Research Contribution | Effective design-science research must provide clear and verifiable contributions in the areas of the design artifact, design foundations, and/or design methodologies. |
| Guideline 5: Research Rigor | Design-science research relies upon the application of rigorous methods in both the construction and evaluation of the design artifact. |
| Guideline 6: Design as a Search | The search for an effective artifact requires utilizing available means to reach desired ends while satisfying laws in the problem environment. |
| Guideline 7: Communication of Research | Design-science research must be presented effectively both to technology-oriented as well as management-oriented audiences. |

Table 4.1: Design science guidelines

The sixth guideline states that "search for an effective artifact requires utilizing available means to reach desired ends while satisfying laws in the problem environment". This research has been carried as a continuous search, starting with a description of the problem and arriving at the solution by making informed design decisions.

The seventh guideline states that design-science research "must be presented effectively both to technology-oriented as well as management-oriented audiences". The results of this project are communicated through this report and an article [32].

### 4.2.2 Designing for Usability

Guideline 5 for design-science states that design-science research relies upon the application of rigorous methods in both the construction and evaluation of the design artifact. When building a system for users, designing for usability is a part of this. It affects both the construction and the evaluation of the artifact.

The first version of the Historical Tour Guide application was designed and evaluated for usability as part of the author's fall project. The results of the evaluation are summarized in section 2.5. However, in accordance with the design-science research process, this research project started by iterating back to design and development to improve the effectiveness of the artifact. Designing for usability became an issue once more and is therefore covered in this section.

### Definitions of Usability

There exists several definitions of usability. In computer science, it is sometimes described as the ease-of-use or user-friendliness of the system. ISO 9241 [1] is more specific and defines usability as "The extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use." Nielsen [45] takes a slightly different approach and defines usability in terms of five quality attributes:

**Easy to learn** - so users can go quickly from not knowing the system to doing some work.

**Efficient** - letting the expert user attain a high level of productivity.

**Easy to remember** - so infrequent users can return after a period of inactivity without having to learn everything all over.

**Relatively error-free or error-forgiving** - so users do not make many errors, and so those errors are not catastrophic (and are easily recovered from).

**Pleasant to use** - satisfying users subjectively, so they like to use the system.

Both the definitions can be of help when designing, developing and evaluating new software where usability is an issue. Nielsen's definition helps to identify attributes that the final product should possess while the ISO definition is stresses who and what to consider when designing, developing and evaluating the system.

### Principles of Usability Design

Not even the best usability experts can design perfect user interfaces in a single attempt [45]. For this reason, developers should be using methods that support the concept of iteration.

Gould and Lewis [29] propose early focus on users and tasks, empirical measurement, and iterative design as three principles for system design that can help designers attain a useful and easy to use computer system. They recommend interviews and discussions with potential users prior to system design, early empirical tests where intended users use simulations and prototypes to carry out real work, and an iterative cycle of design, test, empirical measurements and redesign, repeated as often as necessary.

Nielsen [45] recommend an iterative development of user interfaces, involving steady design refinement based on user testing and other evaluation methods. It is possible to perform rigorous evaluations with a large number of test subjects measured carefully in several different ways while performing a fixed set of tasks. However, this was not the goal of this project. Instead, the usability evaluation was used to get a list of usability problems and suggestions for interface improvements. This is possible with only a few test subjects and no collection of quantitative measurement data.

### Guidelines for User Interface Design

Nielsen [46] has developed ten heuristics for good user interface design. These should not be regarded as strict rules, but rather as general principles that can used as a rule of thumb when developing and evaluating user interfaces. The heuristics are as follows:

**Visibility of system status** The system should keep users informed about what is going on through appropriate feedback within reasonable time.

**Match between system and the real world** The system should speak the users' language and use words, phrases and concepts familiar to the user, rather than system-oriented terms. It should also follow real-world conventions, making information appear in a natural and logical order.

**User control and freedom** Users often choose system functions by mistake. The system should provide a clearly marked "emergency exit" to leave the unwanted state without having to go through an extended dialogue.

**Consistency and standards** The system should follow platform conventions and use a consistent language so that users do not have to wonder whether different words, situations, or actions mean the same thing.

**Error prevention** Even better than good error messages is a careful design which prevents a problem from occurring in the first place. Either eliminate error-prone conditions or check for them and present users with a confirmation option before they commit to the action.

**Recognition rather than recall** Minimize the user's memory load by making objects, actions, and options visible. The user should not have to remember information from one part of the dialogue to another. Instructions for use of the system should be visible or easily retrievable whenever appropriate.

**Flexibility and efficiency of use** Allow users to tailor frequent actions. Accelerators are unseen by the novice user but speed up the interaction for the expert user such that the system can cater to both inexperienced and experienced users.

**Aesthetic and minimalist design** Dialogues should not contain information which is irrelevant or rarely needed. Every extra unit of information in a dialogue competes with the relevant units of information and diminishes their relative visibility.

**Help users recognize, diagnose, and recover from errors** Error messages should be expressed in plain language (no codes), precisely indicate the problem, and constructively suggest a solution.

**Help and documentation** Even though it is better if the system can be used without documentation, it may be necessary to provide help and documentation. Any such information should be easy to find, focused on the user's task, list concrete steps to be carried out, and not be too large.

The heuristics were originally developed as a checklist for use under heuristic evaluations. In this research, they have been used as a guideline when updating the system and the user interface.

**Standard Gestures for Touch-Based Interfaces**

The "consistency and standards" heuristic for good user interface design states that a system should follow platform conventions. For a touch-based application like the Historical Tour Guide, this includes implementing navigation using standard gestures for touch-based user interfaces. Villamor, Willis, and Wroblewski's Touch Gesture Reference Guide [68] provides an overview of the various touch gestures that are available on different platforms. The list below gives an overview of the gestures that are used in the Historical Tour Guide and explains what they are used for.

**Tap:** A gesture used to push in a button or select a link. Done by tapping the screen. Used to open and close views or apply filtering.

**Double-tap:** A gesture used to zoom in on a map or picture. Done by rapidly tapping the screen twice. Used to zoom in on the map.

**Flick:** A gesture used to scroll or pan quickly. Done by placing a finger on the screen and quickly swiping it in the desired direction. Used to quickly pan the map or scroll in the list.

**Drag:** A gesture used to scroll or pan. Done by placing a finger on the screen and moving it in the desired direction without lifting it from the screen. Used to pan the map or scroll in the list with a bit more control than when flicking.

**Pinch open:** A gesture used to zoom in on a map or picture. Done by placing two fingers close together on the screen and moving them apart without lifting them from the screen. Used to zoom in on the map or video feed.

**Pinch close:** A gesture used to zoom out on a map or picture. Done by placing two fingers a distance apart on the screen and moving them toward each other without lifting them from the screen. Used to zoom out on the map or video feed.

## 4.3 Instrument Development

### 4.3.1 Instrument Design

Two surveys were conducted to measure the users' intentions to use the system and the constructs perceived ease of use, perceived enjoyment, and perceived usefulness. Both questionnaires consisted of five major parts:

1. Perceived usefulness
2. Perceived ease of use
3. Perceived enjoyment
4. Behavioral intention
5. Background information

The two surveys are included in appendix A and appendix B. Table 4.2 gives an overview over the constructs and measurement items. The questionnaires also included questions on age, sex, knowledge about local history and tablet ownership.

The measure for perceived usefulness was developed specifically for this project in line with the thinking of van der Heijden [61]. He noted that the original TAM scale was developed for utilitarian information systems and found that the measure for perceived usefulness was problematic because of the focus on improved job performance. Because of this, he developed a new set of items that were more appropriate for the hedonic system used in his research. These items have later on been used as an example of how to develop a set of reflective items that all measure the same idea within the perceived usefulness construct [53]. His items were too specific to be used in this research but were used as a model for the author when constructing a set of new reflective items, appropriate for an augmented reality system with historical information.

The scales used to measure perceived ease of use and behavioral intention in this research are based on two Likert scales developed by Venkatesh and Davis [65]. The scale used to measure perceived enjoyment is a seven-point semantic differential, developed by Chang and Cheung [15]. The use of this type of scale to measure perceived enjoyment or affect are suggested by Triandis [58] and is the same approach as was used in research by van der Heijden [61] and Chesney [16].

The format of the scales used in the street survey and the web survey were different. Only the web survey used *proper* Likert scales that fulfill all of the criteria as listed by Uebersax [60]:

1. The scale contains several items.
2. Response levels are arranged horizontally.
3. Response levels are anchored with consecutive integers.
4. Response levels are also anchored with verbal labels which connote more-or-less evenly-spaced gradations.
5. Verbal labels are bivalent and symmetrical about a neutral middle.
6. In Likert's usage, the scale always measures attitude in terms of level of agreement/disagreement to a target statement.

The scales used to measure perceived usefulness, perceived ease of use and behavioral intention in the street survey are not genuine Likert scales but rather *semantic differentials* or *discrete visual analog scales (DVAS)*. The scales contain a full set of numeric labels but are only anchored with verbal labels at the upper and lower endpoints. They thus fail on criteria number four for Likert scales.

The use of only partially labeled scales can be defended. According to O'Muircheartaigh et al. [48], it is a common convention to use partially labeled scales in market and social research interviews. However, some researchers (such as Krosnick and Berent [40]) have found that fully labeled scales are more reliable measures and may be preferable in terms of variance explanation. Then again, some researchers (such as Andrews [3]) have found otherwise. Furthermore, using fully labeled scales has its own problems as it can be problematic to find verbal labels for the intermediate points in all but the simplest three-point scales. In the end, it was decided to use partially labeled scales on the paper survey where there was limited space and fully labeled scales on the web survey where this was less of an issue.

The fifth part of the study asked about individual variables such as gender, age and historical interest. The street survey also asked about whether the respondent had experience with a tablet. In the web survey, this question was removed and replaced by two questions: the first asking about whether he or she owned a smart phone and the second asking about whether he or she owned a tablet.

### 4.3.2 Instrument Pre-Testing and Translation

The instrument primarily used validated items from prior research. However, the items for perceived usefulness were developed specifically for this research. Furthermore, all items were translated into Norwegian. To ensure that the items were properly translated and adapted appropriately to the current context, two separate focus groups evaluated the survey.

There were five persons in each focus group and both groups reported problems with the questions regarding behavioral intention. They were unsure of how to answer as the questions asked about general use and their answers would be different depending on whether they considered use on tablet or a smart phone, in this specific city or in a city they visited as a tourist. As a result of this feedback, the two items regarding behavioral intentions were exchanged for eight items that were more specific and included different contexts. Minor suggested wording changes were also performed.

| Construct | Source | Items | Scale |
|---|---|---|---|
| Perceived usefulness (PU) | van der Heijden [61] | -By using the app, I can more quickly and easily find historical pictures and information.<br>-By using the app, I learn more about history in Trondheim.<br>-By using the app, I can quickly find historical pictures and information from places nearby.<br>-By using the app, I am more likely to find historical pictures and information that interests me. | Street survey: 7 point semantic differential ranging from highly disagree to highly agree.<br>Web survey: 7 point Likert scale. |
| Perceived ease of use (PEOU) | Venkatesh and Davis [65] | -Interaction with the app is clear and understandable.<br>-Interaction with the app does not require a lot of mental effort.<br>-I find the app easy to use.<br>-I find it easy to get the app to do what I want it to do. | Street survey: 7 point semantic differential ranging from highly disagree to highly agree.<br>Web survey: 7 point Likert scale. |
| Perceived enjoyment (PE) | Chang and Cheung [15] | -Using the app is: <disgusting-enjoyable><br>-Using the app is: <dull-exciting><br>-Using the app is: <unpleasant-pleasant><br>-Using the app is: <boring-interesting> | Street survey: 7 point semantic differential.<br>Web survey: continuous scale. |
| Behavioral intention (BI) | Venkatesh and Davis [65] | -I intend to use the app on a smartphone.<br>-I predict that I will use the app on a smartphone.<br>-I intend to use the app on a tablet.<br>-I predict that I will use the app on a tablet.<br>-I intend to use the app in a city I visit as a tourist.<br>-I predict that I will use the app in a city I visit as a tourist.<br>-I intend to use the app in my hometown.<br>-I predict that I will use the app in my hometown. | Street survey: 7 point semantic differential ranging from highly disagree to highly agree.<br>Web survey: 7 point Likert scale. |

Table 4.2: Constructs and items used in the street survey

## 4.4 Data Collection

A street survey and a web survey were conducted to collect data in this research. Together, they covered two of the basic methods of data collection:

1. Personal interviews
2. Self-enumeration

The personal interview method was used to collect data for the street survey. When using this method, an interviewer assists the respondent if he or she needs help to complete the questionnaire. The overall quality of the data can be improved since the interviewer can assist the respondent with any problems interpreting the questionnaire. On the negative side, interviewer bias can be a problem.

Self-enumeration was used to collect data for the web survey. With using this method, the respondent completes the survey without the assistance of a researcher. This method is less time-consuming than personal interviews, so larger samples can be selected. The anonymity of the respondents are guaranteed. On the negative side, there is no one present who can clarify questions.

| Data collection method | Advantages | Disadvantages |
| --- | --- | --- |
| Personal interviews | Questions can be clarified | Time-consuming<br>Interviewer bias |
| Self-enumeration | Anonymity<br>Less time-consuming, can have larger samples | Cannot clarify questions<br>Computer literacy a must, biased selection of respondents |

Table 4.3: Comparison of survey methods

The general advantages and disadvantages of personal interviews and self-enumeration are summarized in table 4.3. In addition to these, there were some advantages and disadvantages that were relevant for this specific project.

The respondents to the street survey got to try the application before they answered the questionnaire while the web survey participants watched a short video presentation of the application instead. This may have given the street survey participants a better understanding of the actual user experience. However, it also introduced an additional error source since the amount of time the street survey participants spent with the application varied. Furthermore, the local weather conditions put severe restrictions on when the data could be collected out on the street. The web survey respondents all had the same exposure to the application and data could be collected regardless of the weather conditions.

Both surveys were cross-sectional. They were used to gather information at a single point in time and can therefore not be used to describe changes in the population.

## 4.5 Presenting Survey Data

According to Allen and Seaman [2], data collected from a survey are generally characterized as one of four types of data:

**Nominal data:** Categories without numerical representation.

**Ordinal data:** Data where an ordering or ranking of responses is possible but no measure of distance is possible.

**Interval data:** Integer data where ordering and distance measurement are possible.

**Ratio data:** Data in which meaningful ordering, distance, decimals and fractions between variables are possible.

Data collected from the individual items in a Likert scale or any other scale with verbal anchors are strictly speaking categorized as ordinal data. The response levels have relative positions, but it cannot be assumed that participants perceive the difference between adjacent levels to be equal. It is possible that the participants perceive the difference between "neutral" and "somewhat agree" as smaller or larger than the difference between "agree" and "strongly agree".

Furthermore, adding a response of "strongly agree" (coded as 7) to three responses of "strongly disagree" (coded as 1) would give a mean of 2.5 (somewhere between "disagree" and "somewhat disagree"), without that number telling too much. Because of this, it can be better to use the median or mode to summarize the central tendency of the data.

The mean is useful in that it gives an indication of the general direction of the average answer. The standard deviation is also important as it gives an indication of the average distance from the mean. A low standard deviation means that the answers are clustered around the mean, while a high standard deviation means that there are a lot of variation in the answers. The minimum and maximum are also useful data to include as they show the range of answers given by the survey population.

## 4.6 Data Analysis

### 4.6.1 Statistical Tools

The data collected in this study were analyzed using two different statistical software programs. IBM SPSS Statistics version 19 was used to get the descriptive statistics, while Smart PLS 2.0 [54], was used to do the path modeling.

### 4.6.2 Statistical Methods to Analyze Data from Likert Scales

As mentioned in section 4.5, data collected from the individual items in a Likert scale are strictly speaking ordinal data. However, when multiple Likert items are combined to form a scale, parametric procedures can be used in the statistical analysis of the data if the scales pass the Cronbach's alpha or the Kappa test of intercorrelation and validity [2]. For this reason, the statistical analysis in chapter 7 starts with an assessment of the fit and validity of the measurement model.

### 4.6.3 Structured Equation Modeling (SEM)

Structured Equation Modeling (SEM) techniques are a set of second-generation regression tools that can be used to answer a set of interrelated research questions in a single, systematic and comprehensive manner [26]. First-generation regression tools, such as linear regression, can only analyze one layer of linkages between independent and dependent variables at a time. In SEM,

| Issue | Covariance-Based SEM | Partial-Least-Square-Based SEM |
|---|---|---|
| Objective of overall analysis | Show that the null hypothesis of the entire proposed model is plausible, while rejecting path-specific hypotheses of no effect. | Reject a set of path-specific null hypotheses of no effect. |
| Objective of variance analysis | Overall model fit, such as insignificant $\chi^2$ or high AGFI. | Variance explanation (high $R^2$) |
| Required theory base | Requires sound theory base. Supports confirmatory research. | Does not necessarily require sound theory base. Supports both exploratory and confirmatory research. |
| Required minimal sample size | At least 100-150 cases [31, 8]. | At least 10 times the number of items in the most complex construct [6]. |

Table 4.4: Comparative analysis of SEM techniques

the relationships among multiple independent and dependent constructs are modeled simultaneously [27].

A SEM-analysis is assessing two models at the same time:

**1. The structural model** - describing the assumed causation between a set of dependent and independent constructs.

**2. The measurement model** - describing the loadings of the measurement items on their expected latent variables (constructs).

The combined analyses of the two models makes it possible to combine factor analysis and hypothesis testing in one operation. It also makes it possible to analyze the measurement errors of the observed variables as an integral part of the model, resulting in a more complete picture of how the data supports the research model than first-generation regression tools would give.

There are two distinct statistical techniques used for SEM:

- Covariance-based analysis such as LISREL and AMOS.
- Partial-least-squares-based analysis, also referred to as PLS analysis.

The two techniques differ in the objectives of their analyses. Table 4.4, adapted from a table by Gefen et al. [26], summarize the objectives, required theory base, and minimal sample size for each of the two types of techniques.

An important difference between the two types of techniques is that covariance-based SEM enables an assessment of unidimensionality. Unidimensionality is the degree to which all the measurement items reflecting a single construct measure the same latent variable. There should be no **parallel** significant correlational patterns among the measures. Covariance-based SEM techniques are also thought to provide better coefficient estimates and more accurate model analyses than PLS-based SEM [26]. As such, it might seem superior to PLS-based SEM. However, there are situations where PLS-based techniques are more suitable.

PLS-based SEM is especially suited for the analysis of small data samples. The required minimum sample size is 10 times the number of items in the most complex construct [6]. In the context of this research, this translates into a sample size of 40. This is definitely less than the 100-150 cases required for covariance-based techniques [31, 8]. Another advantage of PLS is that it does not require a sound theory base and thus supports both confirmatory and exploratory research. Since the sample size of the street survey was too small for a covariance-based SEM analysis, it was decided to use PLS-based SEM in this research project.

### 4.6.4 Assessing Reliability and Validity

The first stage of structural equation modeling is to assess the reliability and validity of the measurement model. In PLS, this is done by performing a confirmatory factor analysis (CFA). First, the pattern of loadings in the measurement model is explicitly specified by the user. Then, the statistical program examines the fit of this model and produces a set of values that are used to determine the reliability, convergent validity, and discriminant validity of the measurement model.

#### Reliability

Reliability is determined by looking at the values for Cronbach's alpha, composite reliability and average variance extracted (AVE):

**Cronbach's alpha** is a measure of internal consistency that measures the pairwise correlation between items in a scale. It should be above 0.60 for exploratory research and above 0.70 for confirmatory research [26].

**Composite reliability** is similar to Cronbach's alpha but takes into account the actual factor loadings rather than assuming that each item is equally weighted. It is recommended that the values for composite reliability are greater than 0.70 [23].

**AVE** indicates the amount of variance in a measure that is due to the hypothesized underlying latent variable. 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 hypothesized underlying latent variable [23].

#### Convergent Validity

Convergent validity is shown when each measurement item correlates strongly with its assumed theoretical construct. It is determined by examining the factor loadings of the outer model. However, since the exact threshold for significant factor loadings depends on sample size, t-values are used as a measurement instead. For two-tailed tests, $t > 1.96$ is significant at $p < 0.05$, $t > 2.576$ is significant at $p < 0.01$, and $t > 3.29$ is significant at $p < 0.001$.

### Discriminant Validity

Discriminant validity is shown when each measurement item correlates weakly with all other constructs than the one to which it is theoretically associated. If this is the case, two things should happen [25]:

1. The measurement items should load highly on their theoretically assigned factors and not highly on the other factors.
2. The square root of the AVE (Average Variance Extracted) for each latent construct should be much larger than any of the inter-construct correlations, and at least 0.50 [17, 23].

# Chapter 5

# Presentation of the Historical Tour Guide

This chapter presents the Historical Tour Guide. This is the prototype that was developed as part of this master thesis. It is a location-aware mobile information system that uses mobile augmented reality to present local historical photographs and information in Trondheim.

The tour guide is based on a prototype developed as part of the author's specialization project in computer science. It has gone through substantial changes based on feedback gathered during the heuristic evaluation last fall, and the testing with prospective users conducted last fall and during this thesis.

This chapter begins with a presentation of the changes and the new features implemented in this version of the guide. It moves on to present the technical details of the application.

## 5.1 New Functionality

This section presents the new features implemented in the revised version of the Historical Tour Guide. The presentation of the user interfaces is linked to Nielsen's [46] ten heuristics for good user interface design, presented in section 4.2.2. Refer to section 2.4 for screenshots from the original version of the prototype made last fall.

### 5.1.1 Augmented Reality View with Timeline

Figure 5.1 shows the application's main view in the original and the new version of the tour guide. Points of interest (POIs) are shown as floating icons overlaying the camera feed. The original prototype used star icons to represent points of interest associated with historical photographs. The new version of the application uses two types of icons to represent the two types of information available in the application: a camera for the photo-POIs, and a contact card for the POIs with historical information about specific addresses. This is in accordance with the heuristic "match between system and the real world".

The timeline at the bottom of the screen lets the user filter the amount of incoming information so they only see POIs from a specific decade. The selected decade is marked in white and written in the upper-left corner. The original version of the prototype used a timeline with three labels and two arrows. The users could select any of the visible labels but would have to use the arrows

(a) Original AR view

(b) New AR view

Figure 5.1: Screenshots of the AR view in the original and new version of the Historical Tour Guide

(a) Information view


(b) Photo overlay

Figure 5.2: Screenshots of an information view and a photo overlay in the Historical Tour Guide

if they wanted to look at another an earlier or later decade. There are two drawbacks to this approach. First, it takes longer as the user must find the decade before it can be selected. Second, it creates confusion as the users can select a decade and move to another part of the timeline without noticing that the decade is still selected. Both these issues are solved in the new version of the timeline where all the choices are visible at all times. This is in accordance with the heuristics "error prevention", "recognition rather than recall", and "visibility of system status".

### 5.1.2 Photo Overlays and Information Views

Figure 5.2 shows the information view and photo overlay associated with one of the application's photographs. The figure also gives a good view of the updated navigation and the consistent black-and-white color scheme used throughout this version of the application.

The information view is the first view users see when they click on a point of interest. It is also the view that opens when users click on an item in the list view or on a pin on the map. The view contains a description of the motive and lets the user know when the picture was taken, the source of the photograph and the name of the photographer. Both the photograph and the button in the right corner can be pressed to open the photo overlay associated with the photograph.

The transparent overlays over the camera feed let the user see historical images over the present day scene. The button in the right corner is used to go back to the detailed information view while the x in the upper-left corner is used to close the view. The slider in the lower-left corner is used to turn transparency on and off. This functionality was added after it was discovered that users also wanted to use the application at home. In this setting, the transparency added nothing to the user experience, but made it harder to see details in the picture.

All buttons were located in the toolbar at the top of the screen in the original version of the application. Tests with prospective users uncovered that this was an inconvenient placement that did not feel natural. It is the reason why the navigation was changed in the new version of the application.

The ability to open a photo overlay by tapping the small picture is an additional short-cut that was added because of the more experienced users who automatically tried this approach when they wanted to see a larger version of the image. Including shortcuts like this, unseen by the novice user, is in accordance with the "flexibility and efficiency of use" heuristic.

### 5.1.3 Map and List View

Figure 5.3 shows the application's map and list view. The navigation of both views are implemented using the standard gestures for touch-based user interfaces described in section 4.2.2. This is in accordance with the "consistency and standards" heuristic.

The map shows the user's current position and the position of nearby POIs. Each pin on the map is annotated with the title of the point of interest and its distance from the user. In the new version of the application, the annotation also contains a blue button for opening the associated view. This was a much missed short-cut in the original version of the application and is an example of a feature that was added in accordance with the "flexibility and efficiency of use" heuristic. Other changes that were done to the map includes making the map larger to ease navigation and making it opaque to make it easier to read.

The list shows the title of each POI and the distance to get there. The icon to the left of each item indicates whether the POI contains a picture or general information. The list in the new version of the application is wider than the list in the original version to ease navigation and make it possible to see the entire title of each item.

(a) Map (b) List view

Figure 5.3: Screenshots of the map and list view in the Historical Tour Guide

## 5.2 Technical Details

As mentioned in chapter 2, the Historical Tour Guide application is built on top of CroMAR [44]. As such, most of the technical details of these two applications are similar. However, there are some changes. These are outlined in the next sections.

### 5.2.1 Programming Language

The code for CroMAR is written in Objective-C, the programming language for native iOS applications. The Historical Tour Guide is written in the same language, but was updated at the beginning of this thesis to use Automatic Reference Counting (ARC), a compiler feature of XCode that provides automatic memory management of Objective-C objects.

ARC relieves the developer of the responsibility of releasing and retaining memory as it automatically inserts the appropriate memory management calls at compile time. The result is less code and a reduced number of crashes due to memory problems.

### 5.2.2 Application Overview

Figure 5.4 shows the key objects in the Historical Tour Guide. As can be seen from the diagram, the application is organized around the model-view controller (MVC) pattern. This pattern separates the data objects in the model from the views used to present the data. It facilitates the independent development of different components and makes it possible to swap out views or data without having to change large amounts of code.

The system objects in the diagram are standard objects that are part of all iOS applications. These have no subclasses and cannot be modified by application developers. This is unlike the custom objects that are instances of custom classes written for this specific application.

The `UIApplication` object is the system object that manages the application event loop. It receives events from the system and dispatches these to the application's custom classes. It works together with the application delegate, a custom object created at launch time that is responsible for the initialization of the application. In the Historical Tour Guide, this object is called `AppDelegate`. It initializes the `RootViewController`, which in turn initializes the rest of the view controllers.

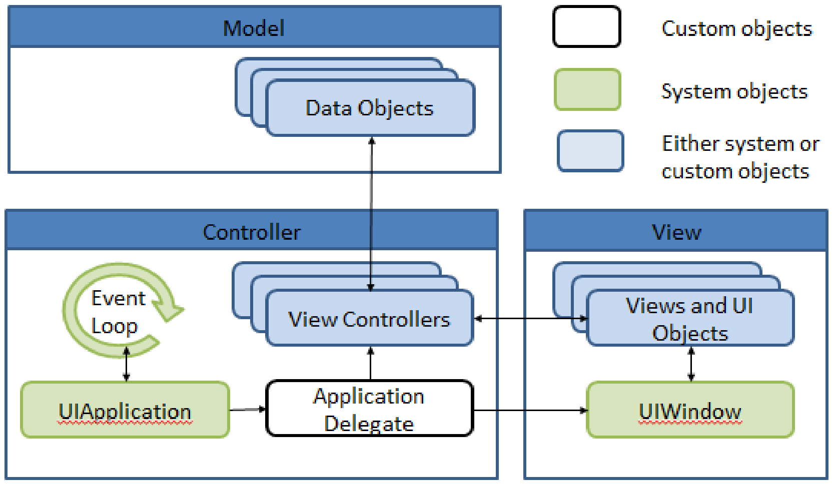



Figure 5.4: Key objects in the Historical Tour Guide

The view controller objects manage the presentation of the application's content on the screen. Each of them manages a single view and its collection of subviews. An example is the `TimelineViewController`, responsible for managing the timeline and its labels.

The `TimelineViewController` subclasses `UIViewController`. The other custom view controllers in the application also subclasses either this, or one of the other standard iOS view controllers. The list below describes the different types of standard view controllers that are used in the Historical Tour Guide:

**UIViewController** - presents a standard view. Used to present the timeline, the custom views that are shown in the middle of the screen and the buttons at the side of the screen.

**UIImagePickerController** - used to present the camera feed.

**UIPopoverController** - used to present the map and list views as popovers that can be dismissed by tapping outside the views.

**UITableViewController** - used to manage the content of the list. Provides automatic support for scrolling.

The applications views and controls provide the visual representation of the application's content. Each view covers a specific area and responds to events within that area. Controls are a specialized type of view for implementing buttons, check boxes, text fields or similar interface objects.

The views and view controllers are connected. When a view controller is presented, it makes its views visible by installing them in the application's window. This is represented by a system object of the type `UIWindow`.

The last group of objects are the data model objects. These objects store the application's content, such as the points of interest, photographs or historical information.

### 5.2.3 Application Launch

The Historical Tour Guide is launched when the user taps the custom application icon. At this point in time, the application moves from the not running state to the active state, passing briefly through the inactive state. As part of this launch cycle, the system creates a process and a thread for the application and calls the application's main function. This function, located in the file `main.m`, promptly hands over the control to application's application delegate and the method `didFinishLaunchingWithOptions`.

```
- (BOOL)application:(UIApplication *)application didFinishLaunchingWithOptions:(NSDictionary *)launchOptions
{
    self.window = [[UIWindow alloc] initWithFrame:[[UIScreen mainScreen] bounds]];
    RootViewController *rvc = [[RootViewController alloc] init];
    [self.window setRootViewController:rvc];
    [self.window makeKeyAndVisible];
    return YES;
}
```

Figure 5.5: The method didFinishLaunchingWithOptions()

As shown in figure 5.5, the application delegate initializes the UIWindow and the `RootViewController`. The `RootViewController` initializes the `ARController` and the view controllers for the map, list, timeline and info view. It also loads the data objects representing points of interest. The `ARController` sets up the `UIImagePickerController` that controls the camera feed that is shown in the background when the application is running.

### 5.2.4 Event-Driven Programming

The Historical Tour Guide is an event-driven application. The flow of the program is determined by two types of events:

1. Touch events, generated when users touch the views of the application.
2. Motion events, generated when users move the device.

Events of the first type are generated when a user presses a button, scrolls in a list, or interacts with any of the other views. An action message is generated and sent to the target object that was specified when the view was created. Figure 5.6 shows the code for specifying a target object. The method `backFromPhotoOverlay()` is specified as the target object that receives an action event when a user presses the back button in one of the photo views. This code is located in the method `showPhotoOverlay()` in `ARMarkerDetailsViewController.m`.

```
// Add action to the back button
[self.photoOverlayView.backButton addTarget:self action:@selector(backFromPhotoOverlay)
    forControlEvents:UIControlEventTouchUpInside];
```

Figure 5.6: Code for specifying the target object of a button

The `ARController` is a `UIAccelerometerDelegate` and a `CLLocationManagerDelegate`. During initialization, it also registers as an observer for orientation changes. As a result, it receives the notifications that are generated when a user changes location or moves the device to look in another direction. It uses this information to redraw the marker icons and update the distance labels shown on the map and in the list.

### 5.2.5 Filtering

Both CroMAR and the original tour guide prototype showed all points of interest in the direction the user was looking. This became a problem when the number of points of interest increased and the marker icons started to overlap. The users would have to use the timeline to filter the points of interest, not because they were interested in photographs from a specific decade, but because they needed to reduce the number of visible icons. The new version of the prototype implements additional filtering and only shows icons for points of interest less than 50 meters away.

### 5.2.6 Frameworks

The map in both CroMAR and the Historical Tour Guide are implemented using Apple's Map Kit framework. This is a framework that uses Google services to provide map data. The framework provides automatic support for the touch events that let users zoom and pan the map.

The application also uses Apple's UIKit, Foundation, CoreGraphics and CoreLocation frameworks.

# Chapter 6

# Descriptive Analysis of the Results

This chapter presents the descriptive analysis of the results from the two surveys that were conducted. The chapter begins with a presentation of the demographics of the two groups of participants and moves on to a descriptive analysis of the responses to each of the constructs. The statistical analysis of the data is presented in chapter 7. The discussion of the results is in chapter 8.

As mentioned in section 4.5, the mean alone can give an incomplete picture of the data. For completeness, both the median and the mean are included in this presentation. The mode can be read straight from the frequency tables. The minimum and maximum values as well as the standard deviation are also included to show the range of answers and give an indication of their distribution.

## 6.1 Demographics

### 6.1.1 Demographic Profile of Street Survey Respondents

Table 6.1 shows the demographic profile of the participants in the street survey. Their ages ranged from 14 to 60, with a mean age of 27.8. 59.5% of the respondents were male.

About a fifth of the respondents replied that they had used a similar application. The intention of this question was to see if the respondent had any experience with an augmented reality application. Instead of trying to name all similar applications at the beginning of the question, it was followed up with a question asking the respondents to name the application. If the respondent wrote down the name of an unrelated application, their response was registered as a no.

57% of the respondents stated that they had experience with using tablets while 45% stated that they have read a book on local history.

### 6.1.2 Demographic Profile of Web Survey Respondents

Table 6.2 shows the demographic profile of the participants in the web survey. Their ages ranged from 20 to 45 years old, with a mean age of 33.3. The gender distribution was about equal, but with slightly more female respondents.

One of the downsides of conducting a web survey, is that there is no interviewer that can assist the respondents in completing the questionnaire. Because of this, the web survey also included a “do not know” option for two of the questions. Furthermore, instead of asking whether a respondent

| Characteristic | Item | n | % |
|---|---|---|---|
| Gender | Male | 25 | 59.5 |
| | Female | 17 | 40.5 |
| Age | 10-19 years | 7 | 16.7 |
| | 20-29 years | 24 | 57.1 |
| | 30-39 years | 4 | 9.5 |
| | 40-49 years | 3 | 7.1 |
| | 50-59 years | 3 | 7.1 |
| | 60-69 years | 1 | 2.4 |
| Tablet experience | Yes | 24 | 57.1 |
| | No | 18 | 42.9 |
| Have read a book on local history | Yes | 19 | 45.2 |
| | No | 23 | 54.8 |
| Have used a similar application | Yes | 8 | 19.0 |
| | No | 34 | 81.0 |

Table 6.1: Demographic characteristics of the participants in the street survey

had any experience with a tablet, it was decided to ask whether he or she owned a tablet. A question on smartphone ownership was also included.

81.5% of the respondents owned a smartphone, while only 30.5% owned a tablet. 13.5% replied positively to the question on whether they had experience with a similar application while 44.5% responded yes to the question on whether they had read a book on local history.

| Characteristic | Item | n | % |
|---|---|---|---|
| Gender | Male | 96 | 48.0 |
| | Female | 104 | 52.0 |
| Age | 20-29 years | 76 | 38.0 |
| | 30-39 years | 67 | 33.5 |
| | 40-49 years | 57 | 28.5 |
| Tablet ownership | Yes | 61 | 30.5 |
| | No | 139 | 69.5 |
| Smartphone ownership | Yes | 163 | 81.5 |
| | No | 37 | 18.5 |
| Have read a book on local history | Yes | 89 | 44.5 |
| | No | 95 | 47.5 |
| | Does not know | 16 | 8.0 |
| Have used a similar application | Yes | 27 | 13.5 |
| | No | 169 | 84.5 |
| | Does not know | 4 | 2.0 |

Table 6.2: Demographic characteristics of the participants in the web survey

## 6.2 Perceived Usefulness

This section describes the responses to the items measuring the perceived usefulness of the application. The respondents in both surveys rated these items on a scale from 1 to 7, where 1 was highly disagree and 7 highly agree. The scale used in the street survey was only labeled at the end-points while the scale used in the web survey was fully labeled with the seven levels. The following labels were used: highly disagree, disagree, slightly disagree, neutral, slightly agree, agree, and highly agree.

### 6.2.1 Perceived Usefulness in the Street Survey

Table 6.3 shows the frequency table of the street survey responses to items measuring perceived usefulness. These responses are further summarized in table 6.4.

The first thing to notice is that the respondents did not use the entire scale. Apart from one response of 3 to the last item, all answers were in the range from 4 to 7.

All four items achieved high scores and have a mean above 6, a median of 6 and a mode of 6 or 7. However, the responses to pu1 ("By using the app, I can more quickly and easily find historical pictures and information") and pu4("By using the app, I am more likely to find historical pictures and information that interests me") are slightly less positive than the responses to pu2 ("By using the app, I learn more about history in Trondheim") and pu3 ("By using the app, I can quickly find historical pictures and information from places nearby").

| | 1 | | 2 | | 3 | | 4 | | 5 | | 6 | | 7 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | n | % | n | % | n | % | n | % | n | % | n | % | n | % |
| pu1 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 3 | 7.1 | 10 | 23.8 | 13 | 31.0 | 16 | 38.1 |
| pu2 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 1 | 2.4 | 1 | 2.4 | 21 | 50.0 | 19 | 45.2 |
| pu3 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 1 | 2.4 | 4 | 9.5 | 21 | 50.0 | 16 | 38.1 |
| pu4 | 0 | 0.0 | 0 | 0.0 | 1 | 2.4 | 1 | 2.4 | 8 | 19.0 | 17 | 40.5 | 15 | 35.7 |

Table 6.3: Frequency table showing street survey responses to items measuring perceived usefulness.

| Item | N | Min | Max | Mean | Median | Std. Deviation |
|---|---|---|---|---|---|---|
| pu1 | 42 | 4 | 7 | 6.00 | 6.0 | 0.963 |
| pu2 | 42 | 4 | 7 | 6.38 | 6.0 | 0.661 |
| pu3 | 42 | 4 | 7 | 6.24 | 6.0 | 0.726 |
| pu4 | 42 | 3 | 7 | 6.05 | 6.0 | 0.963 |

Table 6.4: Statistical summary of street survey responses to items measuring perceived usefulness

### 6.2.2 Perceived Usefulness in the Web Survey

Table 6.5 shows the web survey responses to items measuring perceived usefulness. These responses are further summarized in table 6.6.

Unlike their street survey counterparts, the respondents to this survey used the entire scale to answer the items. The standard deviations are larger and the means lower than in the street survey.

The responses to pu1 (“By using the app, I can more quickly and easily find historical pictures and information”), pu2 (“By using the app, I learn more about history in Trondheim”) and pu3 (“By using the app, I can quickly find historical pictures and information from places nearby”) all have a median of 6.0, a mode of 6 and a mean between 5.3 and 5.4. Item pu4 (“By using the app, I am more likely to find historical pictures and information that interests me”) received a lower score than the other items. It still has a mode of 6, but the median is 5.0 and the mean 5.1.

| | 1 | | 2 | | 3 | | 4 | | 5 | | 6 | | 7 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | n | % | n | % | n | % | n | % | n | % | n | % | n | % |
| pu1 | 3 | 1.5 | 2 | 1.0 | 5 | 2.5 | 35 | 17.5 | 46 | 23.0 | 85 | 42.5 | 24 | 12.0 |
| pu2 | 2 | 1.0 | 3 | 1.5 | 6 | 3.0 | 33 | 16.5 | 51 | 25.5 | 80 | 40.0 | 25 | 12.5 |
| pu3 | 2 | 1.0 | 1 | 0.5 | 7 | 3.5 | 40 | 20.0 | 41 | 20.5 | 76 | 38.0 | 33 | 16.5 |
| pu4 | 6 | 3.0 | 4 | 2.0 | 11 | 5.5 | 42 | 21.0 | 49 | 24.5 | 61 | 30.5 | 27 | 13.5 |

Table 6.5: Frequency table showing web survey responses to items measuring perceived usefulness

| Item | N | Min | Max | Mean | Median | Std. Deviation |
|---|---|---|---|---|---|---|
| pu1 | 200 | 1 | 7 | 5.35 | 6.0 | 1.181 |
| pu2 | 200 | 1 | 7 | 5.34 | 6.0 | 1.171 |
| pu3 | 200 | 1 | 7 | 5.39 | 6.0 | 1.202 |
| pu4 | 200 | 1 | 7 | 5.08 | 5.0 | 1.393 |

Table 6.6: Statistical summary of web survey responses to items measuring perceived usefulness

## 6.3 Perceived Ease of Use

This section describes the responses to the items measuring the perceived ease of use of the application. As with the scale for perceived usefulness, the respondents in both surveys rated these items on a scale from 1 to 7, where 1 was highly disagree and 7 highly agree. The scale used in the street survey was only labeled at the end-points while the scale used in the web survey was fully labeled.

### 6.3.1 Perceived Ease of Use in the Street Survey

Table 6.7 shows the street survey responses to the items relating to perceived ease of use. These responses are further summarized in table 6.8.

The respondents did not use the entire scale. The two first items have one reply of 3 while the rest of the responses range from 4 to 7.

The responses to the four items all have a median of 6.0. Item peuo1 ("Interaction with the app is clear and understandable") has the highest mode, with 7 being the most frequent response. At the same time, it has the lowest average score with a mean of 5.52. Items peou2 ("Interaction with the app does not require a lot of mental effort"), peou3 ("I find the app easy to use"), and peou4 ("I find it easy to get the app to do what I want it to do") all have a mode of 6 and means between 5.5 and 5.9.

| | 1 | | 2 | | 3 | | 4 | | 5 | | 6 | | 7 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | n | % | n | % | n | % | n | % | n | % | n | % | n | % |
| peou1 | 0 | 0.0 | 0 | 0.0 | 1 | 2.4 | 10 | 23.8 | 9 | 21.4 | 10 | 23.8 | 12 | 28.6 |
| peou2 | 0 | 0.0 | 0 | 0.0 | 1 | 2.4 | 4 | 9.5 | 5 | 11.9 | 21 | 50.0 | 11 | 26.2 |
| peou3 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 6 | 14.3 | 8 | 19.0 | 17 | 40.5 | 11 | 26.2 |
| peou4 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 8 | 19.0 | 10 | 23.8 | 16 | 38.1 | 8 | 19.0 |

Table 6.7: Frequency table showing street survey responses to items measuring perceived ease of use

### 6.3.2 Perceived Ease of Use in the Web Survey

Table 6.9 shows the web survey responses to the items relating to perceived ease of use. These responses are further summarized in table 6.10.

While most of the respondents in the street survey restricted their answers to the right side of the scale, the respondents to this survey used the entire scale to answer the items. The standard

| Item | N | Min | Max | Mean | Median | Std. Deviation |
|---|---|---|---|---|---|---|
| peou1 | 42 | 3 | 7 | 5.52 | 6.0 | 1.215 |
| peou2 | 42 | 3 | 7 | 5.88 | 6.0 | 0.993 |
| peou3 | 42 | 4 | 7 | 5.79 | 6.0 | 1.001 |
| peou4 | 42 | 4 | 7 | 5.57 | 6.0 | 1.016 |

Table 6.8: Statistical summary of street survey responses to items measuring perceived ease of use

deviations are larger and the means lower than in the street survey.

All the items have a mode of 6 and a mean between 4.9 and 5.3. The median of the first item, peuo1 ("Interaction with the app is clear and understandable"), is 6.0. The three other items, peou2 ("Interaction with the app does not require a lot of mental effort"), peou3 ("I find the app easy to use"), and peou4 ("I find it easy to get the app to do what I want it to do"), have a median of 5.0.

| | 1 | | 2 | | 3 | | 4 | | 5 | | 6 | | 7 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | n | % | n | % | n | % | n | % | n | % | n | % | n | % |
| peou1 | 2 | 1.0 | 5 | 2.5 | 11 | 5.5 | 26 | 13.0 | 45 | 22.5 | 90 | 45.0 | 21 | 10.5 |
| peou2 | 2 | 1.0 | 12 | 6.0 | 18 | 9.0 | 40 | 20.0 | 47 | 23.5 | 68 | 34.0 | 13 | 6.5 |
| peou3 | 2 | 1.0 | 4 | 2.0 | 9 | 4.5 | 41 | 20.5 | 48 | 24.0 | 82 | 41.0 | 14 | 7.0 |
| peou4 | 2 | 1.0 | 6 | 3.0 | 8 | 4.0 | 58 | 29.0 | 46 | 23.0 | 66 | 33.0 | 14 | 7.0 |

Table 6.9: Frequency table showing web survey responses to items measuring perceived ease of use

| Item | N | Min | Max | Mean | Median | Std. Deviation |
|---|---|---|---|---|---|---|
| peou1 | 200 | 1 | 7 | 5.31 | 6.0 | 1.233 |
| peou2 | 200 | 1 | 7 | 4.87 | 5.0 | 1.361 |
| peou3 | 200 | 1 | 7 | 5.16 | 5.0 | 1.182 |
| peou4 | 200 | 1 | 7 | 4.97 | 5.0 | 1.223 |

Table 6.10: Statistical summary of web survey responses to items measuring perceived ease of use

## 6.4 Perceived Enjoyment

This section describes the responses to the items measuring the perceived enjoyment of the application. The respondents in both surveys used a semantic differential with contrasting adjectives at each end to rate these items. The scale used in the street survey was a discrete scale with seven categories while the scale used in the web survey was continuous. The replies from the continuous scale were later on coded into seven categories.

### 6.4.1 Perceived Enjoyment in the Street Survey

Table 6.11 shows the street survey responses to the items relating to perceived enjoyment. These responses are further summarized in table 6.12. It should be noted that there are two missing replies to this question. As a result, the total number of responses in each line adds up to 40 instead 42. The percentages add up to 95.2 instead of 100.

The responses range from 3 to 7. All the items: pe1 (disgusting-enjoyable), pe2 (dull-exciting), pe3 (unpleasant-pleasant), and pe4 (boring-interesting), have means that range between 5.5 and 6.0. Items pe1, pe3, and pe4 all have a median of 6.0 and at least one mode of 7 (item pe3 has two modes: one of 5 and one of 7). Item pe2 have a median of 5.0 and a mode of 5.

| | 1 | | 2 | | 3 | | 4 | | 5 | | 6 | | 7 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | n | % | n | % | n | % | n | % | n | % | n | % | n | % |
| pe1 | 0 | 0.0 | 0 | 0.0 | 1 | 2.4 | 5 | 11.9 | 8 | 19.0 | 12 | 28.6 | 14 | 33.3 |
| pe2 | 0 | 0.0 | 0 | 0.0 | 2 | 4.8 | 5 | 11.9 | 15 | 35.7 | 9 | 21.4 | 9 | 21.4 |
| pe3 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 6 | 14.3 | 12 | 28.6 | 10 | 23.8 | 12 | 28.6 |
| pe4 | 0 | 0.0 | 0 | 0.0 | 1 | 2.4 | 2 | 4.8 | 9 | 21.4 | 12 | 28.6 | 16 | 38.1 |

Table 6.11: Frequency table showing street survey responses to items measuring perceived enjoyment

| Item | N | Min | Max | Mean | Median | Std. Deviation |
|---|---|---|---|---|---|---|
| pe1 | 40 | 3 | 7 | 5.83 | 6.0 | 1.130 |
| pe2 | 40 | 3 | 7 | 5.45 | 5.0 | 1.131 |
| pe3 | 40 | 4 | 7 | 5.70 | 6.0 | 1.067 |
| pe4 | 40 | 3 | 7 | 6.00 | 6.0 | 1.038 |

Table 6.12: Statistical summary of street survey responses to items measuring perceived enjoyment

### 6.4.2 Perceived Enjoyment in the Web Survey

Table 6.13 shows the web survey responses to the items relating to perceived enjoyment. These responses are further summarized in table 6.14. As before, the web survey respondents have used the entire scale to answer the items.

All the items have a mode of 7 and a mean in the range between 5.6 and 6.2. Furthermore, items pe1 (disgusting-enjoyable), pe3 (unpleasant-pleasant), and pe4 (boring-interesting) all have a median of 7.0. Item pe2 (dull-exciting) has a median of 6.5. These values are higher than their street survey counterparts.

| | 1 | | 2 | | 3 | | 4 | | 5 | | 6 | | 7 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | n | % | n | % | n | % | n | % | n | % | n | % | n | % |
| pe1 | 6 | 3.0 | 6 | 3.0 | 5 | 2.5 | 12 | 6.0 | 21 | 10.5 | 24 | 12.0 | 126 | 63.0 |
| pe2 | 15 | 7.5 | 7 | 3.5 | 7 | 3.5 | 15 | 7.5 | 26 | 13.0 | 30 | 15.0 | 100 | 50.0 |
| pe3 | 7 | 3.5 | 3 | 1.5 | 7 | 3.5 | 5 | 2.5 | 22 | 11.0 | 22 | 11.0 | 134 | 67.0 |
| pe4 | 17 | 8.5 | 11 | 5.5 | 5 | 2.5 | 7 | 3.5 | 23 | 11.5 | 22 | 11.0 | 115 | 57.5 |

Table 6.13: Frequency table showing web survey responses to items measuring perceived enjoyment

| Item | N | Min | Max | Mean | Median | Std. Deviation |
|---|---|---|---|---|---|---|
| pe1 | 200 | 1 | 7 | 6.06 | 7.0 | 1.562 |
| pe2 | 200 | 1 | 7 | 5.60 | 6.5 | 1.881 |
| pe3 | 200 | 1 | 7 | 6.17 | 7.0 | 1.514 |
| pe4 | 200 | 1 | 7 | 5.67 | 7.0 | 1.993 |

Table 6.14: Statistical summary of web survey responses to items measuring perceived enjoyment

## 6.5 Intention to Use

This section describes the responses to the items measuring the intention to use the application. As in the scales for perceived usefulness and perceived ease of use, the respondents in both surveys rated these items on a scale from 1 to 7, where 1 was highly disagree and 7 highly agree. The scale used in the street survey was only labeled at the end-points while the scale used in the web survey was fully labeled.

### 6.5.1 Intention to Use in the Street Survey

Table 6.15 shows the street survey responses to the items relating to the intention to use the application. The responses are further summarized in table 6.16. It should be noted that there are two missing replies to item bi1, one missing reply from bi2 and one missing reply for bi3. As a result, the frequencies for these items do not add up to 42 while the percentages do not add up to a 100.

This is the only place in the street survey where the respondents have used the entire scale. The standard deviations range from a low of 0.889 to a high of 1.784.

All the items have at least one mode of 7. Items bi7("I intend to use the app in my hometown") and bi8("I predict that I will use the app in my hometown") have two modes, with the second one being 5. These two items also have a median of 5.0. 47.6% of the respondents rated item bi7 as a 6 or 7 while 45.3% rated item bi8 as a 6 or 7.

The medians and means of items bi5("I intend to use the app in a city I visit as a tourist") and bi6("I predict that I will use the app in a city I visit as a tourist") are noticeably higher than the medians and means of the other items. Item bi5 has the highest median and the highest mean of all the items in this scale. 83.4% of the respondents rated this item as a 6 or 7. The values for bi6 are slightly lower but still higher than the other items. 78.6% of the respondents rated this item as a 6 or 7.

Items bi1("I intend to use the app on a smartphone") and bi2("I predict that I will use the app on a smartphone") both have a median of 6.0. 66.7% of the respondents rated item bi1 as a 6 or 7 while 64.3% rated item bi2 as a 6 or 7. Their respective means are 5.98 and 5.80. These values are higher than the means and medians of items bi3("I intend to use the app on a tablet") and bi4("I predict that I will use the app on a tablet"). Item bi3 has a mean of 5.22 while bi4 has a mean of 4.81. Both have a median of 5.0. 42.9% of the respondents rated item bi3 as a 6 or 7 while 38.1% rated item bi4 as a 6 or 7.

| | 1 | | 2 | | 3 | | 4 | | 5 | | 6 | | 7 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | n | % | n | % | n | % | n | % | n | % | n | % | n | % |
| bi1 | 0 | 0.0 | 0 | 0.0 | 1 | 2.4 | 4 | 9.5 | 7 | 16.7 | 11 | 26.2 | 17 | 40.5 |
| bi2 | 0 | 0.0 | 0 | 0.0 | 3 | 7.1 | 3 | 7.1 | 8 | 19.0 | 12 | 28.6 | 15 | 35.7 |
| bi3 | 0 | 0.0 | 2 | 4.8 | 4 | 9.5 | 8 | 19.0 | 9 | 21.4 | 5 | 11.9 | 13 | 31.0 |
| bi4 | 2 | 4.8 | 2 | 4.8 | 6 | 14.3 | 9 | 21.4 | 7 | 16.7 | 5 | 11.9 | 11 | 26.2 |
| bi5 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 2 | 4.8 | 5 | 11.9 | 7 | 16.7 | 28 | 66.7 |
| bi6 | 0 | 0.0 | 0 | 0.0 | 2 | 4.8 | 2 | 4.8 | 5 | 11.9 | 13 | 31.0 | 20 | 47.6 |
| bi7 | 2 | 4.8 | 0 | 0.0 | 2 | 4.8 | 4 | 9.5 | 14 | 33.3 | 6 | 14.3 | 14 | 33.3 |
| bi8 | 2 | 4.8 | 1 | 2.4 | 2 | 4.8 | 6 | 14.3 | 12 | 28.6 | 7 | 16.7 | 12 | 28.6 |

Table 6.15: Frequency table showing street survey responses to items measuring intention to use

| Item | N | Min | Max | Mean | Median | Std. Deviation |
|---|---|---|---|---|---|---|
| bi1 | 40 | 3 | 7 | 5.98 | 6.0 | 1.121 |
| bi2 | 41 | 3 | 7 | 5.80 | 6.0 | 1.229 |
| bi3 | 41 | 2 | 7 | 5.22 | 5.0 | 1.557 |
| bi4 | 42 | 1 | 7 | 4.81 | 5.0 | 1.784 |
| bi5 | 42 | 4 | 7 | 6.45 | 7.0 | 0.889 |
| bi6 | 42 | 3 | 7 | 6.12 | 6.0 | 1.109 |
| bi7 | 42 | 1 | 7 | 5.43 | 5.0 | 1.548 |
| bi8 | 42 | 1 | 7 | 5.24 | 5.0 | 1.620 |

Table 6.16: Statistical summary of street survey responses to items measuring intention to use

### 6.5.2 Intention to Use in the Web Survey

Table 6.17 shows the web survey responses to the items relating to the intention to use the application. The responses are further summarized in table 6.18. As in the rest of the web survey, the respondents have used the entire scale.

Items bi3("I intend to use the app on a tablet") and bi4("I predict that I will use the app on a tablet") both have a mode of 4 and a median of 4.0. Furthermore, their means are close together with a value of 4.01 and 3.55. The means, medians and modes of the three other pairs of items are not so similar. 24.5% of the respondents rated item bi3 as a 6 or 7 while 15.0% rated item bi4 as a 6 or 7.

Items bi1("I intend to use the app on a smartphone") and bi2("I predict that I will use the app on a smartphone") both have a mode of 4, but bi1 has a median of 5.0 and a mean of 4.58 while bi2 has a median of 4.0 and a mean of 4.07. 34.5% of the respondents rated item bi1 as a 6 or 7 while 23.0% rated item bi2 as a 6 or 7.

Items bi5("I intend to use the app in a city I visit as a tourist") and bi6("I predict that I will use the app in a city I visit as a tourist") both have a median of 5.0 but bi5 has a mode of 6 and a mean of 5.05 while bi6 has a mode of 4 and a mean of 4.45. 44.5% of the respondents rated item bi5 as a 6 or 7 while 29.0% rated item bi6 as a 6 or 7.

Items bi7("I intend to use the app in my hometown") and bi8("I predict that I will use the app in my hometown") have two modes and two different medians but the means 4.54 and 4.16 are closer together than the means of bi1 and bi2, or bi5 and bi6. 34.5% of the respondents rated item bi7 as a 6 or 7 while 26.0% rated item bi8 as a 6 or 7.

| | 1 | | 2 | | 3 | | 4 | | 5 | | 6 | | 7 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | n | % | n | % | n | % | n | % | n | % | n | % | n | % |
| bi1 | 15 | 7.5 | 18 | 9.0 | 13 | 6.5 | 42 | 21.0 | 43 | 21.5 | 40 | 20.0 | 29 | 14.5 |
| bi2 | 23 | 11.5 | 17 | 8.5 | 20 | 10.0 | 62 | 31.0 | 32 | 16.0 | 33 | 16.5 | 13 | 6.5 |
| bi3 | 24 | 12.0 | 25 | 12.5 | 18 | 9.0 | 54 | 27.0 | 30 | 15.0 | 35 | 17.5 | 14 | 7.0 |
| bi4 | 37 | 18.5 | 21 | 10.5 | 22 | 11.0 | 72 | 36.0 | 18 | 9.0 | 23 | 11.5 | 7 | 3.5 |
| bi5 | 9 | 4.5 | 8 | 4.0 | 13 | 6.5 | 30 | 15.0 | 51 | 25.5 | 53 | 26.5 | 36 | 18.0 |
| bi6 | 19 | 9.5 | 12 | 6.0 | 12 | 6.0 | 51 | 25.5 | 48 | 24.0 | 38 | 19.0 | 20 | 10.0 |
| bi7 | 19 | 9.5 | 16 | 8.0 | 13 | 6.5 | 35 | 17.5 | 48 | 24.0 | 46 | 23.0 | 23 | 11.5 |
| bi8 | 28 | 14.0 | 15 | 7.5 | 14 | 7.0 | 53 | 26.5 | 38 | 19.0 | 35 | 17.5 | 17 | 8.5 |

Table 6.17: Frequency table showing web survey responses to items measuring intention to use

| Item | N | Min | Max | Mean | Median | Std. Deviation |
|---|---|---|---|---|---|---|
| bi1 | 200 | 1 | 7 | 4.58 | 5.0 | 1.760 |
| bi2 | 200 | 1 | 7 | 4.07 | 4.0 | 1.700 |
| bi3 | 200 | 1 | 7 | 4.01 | 4.0 | 1.779 |
| bi4 | 200 | 1 | 7 | 3.55 | 4.0 | 1.695 |
| bi5 | 200 | 1 | 7 | 5.05 | 5.0 | 1.577 |
| bi6 | 200 | 1 | 7 | 4.45 | 5.0 | 1.692 |
| bi7 | 200 | 1 | 7 | 4.54 | 5.0 | 1.779 |
| bi8 | 200 | 1 | 7 | 4.16 | 4.0 | 1.810 |

Table 6.18: Statistical summary of web survey responses to items measuring intention to use

# Chapter 7

# Statistical Analysis of the Results

This chapter presents the assessment and testing of the proposed research model using structural equation modeling. The analysis consists of two steps:

1. Assessing the reliability and validity of the measurement model.

2. Testing the hypotheses in the structural model.

Both a street survey and a web survey were conducted as part of this research. The two surveys were analyzed separately, both times using the statistical software Smart PLS [54]. A bootstrapping procedure was run for each of the data sets in order to determine the significance of the model estimates. The results of the analyses are presented in this chapter.

## 7.1 Statistical Analysis of the Street Survey

### 7.1.1 Results from Assessing the Reliability and Validity of the Street Survey Measurement Model

#### Reliability of the Street Survey Measurement Model

Table 7.1 shows some of the reliability measures calculated with data from the street survey. All four scales reached a composite reliability value of at least 0.85. They are thus well above the 0.70 threshold for composite reliability. The scales also showed high internal consistency with the lowest Cronbachs alpha being 0.80. This is well above the 0.70 threshold for confirmatory research. The Average Variance Extracted (AVE) for behavioral intention (BI) was AVE = 0.495. This is just below the critical value of 0.5 and indicates that slightly less than half the variance in the answers related to this item is caused by a single hypothesized underlying latent variable. The other AVE values are well above the suggested limit.

#### Convergent Validity of the Street Survey Measurement Model

The outer model loadings in table 7.2 are all 0.50 or above (bi5 is 0.4976). This indicates good convergent validity. With the exception of the item loadings from bi5 and bi6, all loadings were significant at the $p < 0.001$ level. The two exceptions were significant at the $p < 0.01$ level.

| | Composite Reliability | Cronbach's Alpha | AVE |
|---|---|---|---|
| BI | 0.884665 | 0.853951 | 0.495266 |
| PE | 0.890407 | 0.835702 | 0.670444 |
| PEOU | 0.885262 | 0.827860 | 0.659051 |
| PU | 0.866968 | 0.798745 | 0.621637 |

Table 7.1: Reliability measures calculated with data from the street survey

| | Loading | t-Statistic |
|---|---|---|
| pu1 ← PU | 0.878011 | 28.893438 |
| pu2 ← PU | 0.748255 | 6.996187 |
| pu3 ← PU | 0.824971 | 12.066230 |
| pu4 ← PU | 0.689333 | 6.139012 |
| peou1 ← PEOU | 0.871496 | 20.505590 |
| peou2 ← PEOU | 0.812519 | 12.278692 |
| peou3 ← PEOU | 0.779001 | 6.406940 |
| peou4 ← PEOU | 0.780811 | 13.335394 |
| pe1 ← PE | 0.800025 | 13.598561 |
| pe2 ← PE | 0.799788 | 7.845999 |
| pe3 ← PE | 0.798202 | 11.749198 |
| pe4 ← PE | 0.874613 | 29.826150 |
| bi1 ← BI | 0.779420 | 5.826057 |
| bi2 ← BI | 0.776958 | 6.124250 |
| bi3 ← BI | 0.685900 | 4.209150 |
| bi4 ← BI | 0.657805 | 4.014688 |
| bi5 ← BI | 0.497613 | 2.778121 |
| bi6 ← BI | 0.573410 | 3.098736 |
| bi7 ← BI | 0.778258 | 6.624290 |
| bi8 ← BI | 0.815902 | 7.143610 |

Table 7.2: Outer model loadings calculated with data from the street survey

#### Discriminant Validity of the Street Survey Measurement Model

Table 7.3 shows the cross loadings between measurement items and constructs. The values in bold at the diagonal shows cross loadings between measurement items and their theoretically assigned factor. These values are consistently greater than the other cross loadings and indicates that the scales might show good discriminant validity.

There is a second test that must be passed for a scale to show good discriminant validity. The square root of the AVE for each latent construct should be much larger than the correlations between the construct and the other constructs in the model [17]. The lowest acceptable value is 0.50 [23].

Table 7.4 shows that all the scales used in the street survey satisfy the requirements mentioned above. The square roots of the AVE-s are shown in bold. The lowest of these values is 0.70. The smallest difference between the square root of an AVE and one of the other correlations is 0.11.

| | BI | PE | PEOU | PU |
|---|---|---|---|---|
| pu1 | 0.328975 | 0.479379 | 0.718143 | **0.878011** |
| pu2 | 0.139513 | 0.392474 | 0.400659 | **0.748255** |
| pu3 | 0.169776 | 0.290322 | 0.404784 | **0.824971** |
| pu4 | 0.269814 | 0.445521 | 0.451192 | **0.689333** |
| peou1 | 0.335885 | 0.585861 | **0.871496** | 0.627224 |
| peou2 | 0.265832 | 0.485846 | **0.812519** | 0.626473 |
| peou3 | 0.368396 | 0.435819 | **0.779001** | 0.308058 |
| peou4 | 0.277384 | 0.601267 | **0.780811** | 0.534994 |
| pe1 | 0.475622 | **0.800025** | 0.521194 | 0.406520 |
| pe2 | 0.366791 | **0.799788** | 0.639142 | 0.379637 |
| pe3 | 0.513090 | **0.798202** | 0.428924 | 0.406883 |
| pe4 | 0.581892 | **0.874613** | 0.555089 | 0.509549 |
| bi1 | **0.779420** | 0.488617 | 0.132908 | 0.220231 |
| bi2 | **0.776958** | 0.476747 | 0.157833 | 0.167867 |
| bi3 | **0.685900** | 0.404528 | 0.382548 | 0.236451 |
| bi4 | **0.657805** | 0.396590 | 0.353949 | 0.182368 |
| bi5 | **0.497613** | 0.251013 | 0.187284 | 0.217162 |
| bi6 | **0.573410** | 0.205295 | 0.204489 | 0.242898 |
| bi7 | **0.778258** | 0.481931 | 0.372709 | 0.273000 |
| bi8 | **0.815902** | 0.497587 | 0.353639 | 0.246764 |

Table 7.3: Cross loadings calculated with data from the street survey

This occurs between the square root of the AVE for BI and the cross-loading between BI and PE. Since the measurement items also loads properly on their theoretically assigned factors, the scales show good discriminant validity.

| | BI | PE | PEOU | PU |
|---|---|---|---|---|
| BI | **0.703751** | 0.000000 | 0.000000 | 0.000000 |
| PE | 0.593207 | **0.818806** | 0.000000 | 0.000000 |
| PEOU | 0.379094 | 0.656936 | **0.811820** | 0.000000 |
| PU | 0.308540 | 0.522397 | 0.664008 | **0.788440** |

Table 7.4: Inter-construct correlations and square roots of AVE calculated with data from the street survey

### 7.1.2 Results from Testing the Hypothesis with Data from the Street Survey

The PLS analysis yielded path coefficients for the structural model shown in figure 7.1. There are three pieces of information in the figure:

1. path coefficients

2. t-statistics showing levels of significance (in parentheses)

3. $R^2$ values (in circles)

The structural model shows that three out of the five hypotheses were supported. The t-statistics for the paths from PU to BI and PEOU to BI indicates that these paths are not significant. Because of this, hypotheses H2 and H3 cannot be confirmed. The model supports hypotheses H1, H4, and H5 with a positive relationship between PEOU and PU, PEOU and PE, and PE and BI. Overall, the model explained about 35% of the variance in usage intentions.

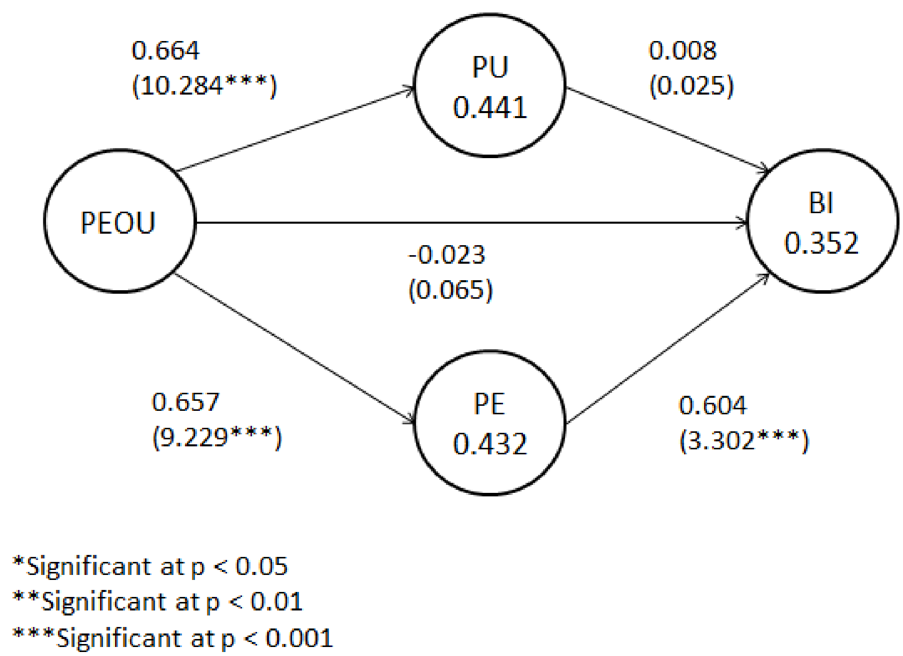



Figure 7.1: Structural model with data from the street survey

## 7.2 Statistical Analysis of the Web Survey

### 7.2.1 Results from Assessing the Reliability and Validity of the Web Survey Measurement Model

#### Reliability of the Web Survey Measurement Model

Table 7.5 shows some of the reliability measures calculated with data from the web survey. All four scales reached a composite reliability value of at least 0.90. They are thus well above the 0.70 threshold for composite reliability. The scales also showed high internal consistency with the lowest Cronbach's alpha being 0.88. This is well above the 0.70 threshold for confirmatory research. The lowest average variance extracted was AVE = 0.74. This is also above the suggested limit of 0.50.

| | Composite Reliability | Cronbach's Alpha | AVE |
|---|---|---|---|
| BI | 0.965362 | 0.958900 | 0.777262 |
| PE | 0.920711 | 0.884843 | 0.744363 |
| PEOU | 0.941507 | 0.917415 | 0.801356 |
| PU | 0.954965 | 0.936713 | 0.841476 |

Table 7.5: Reliability measures calculated with data from the web survey

### Convergent Validity of the Web Survey Measurement Model

All the scales used in the web survey show strong convergent validity. The lowest of the outer model loadings in table 7.6 is 0.79 (pe3 ← PE). This is well above the suggested 0.50 threshold. Furthermore, the t-statistics show that all loadings are significant at the $p < 0.001$ level.

| | Loading | t-statistic |
|---|---|---|
| pu1 ← PU | 0.926213 | 64.221510 |
| pu2 ← PU | 0.935139 | 77.998502 |
| pu3 ← PU | 0.945103 | 91.102232 |
| pu4 ← PU | 0.860424 | 30.446605 |
| peou1 ← PEOU | 0.908824 | 52.735245 |
| peou2 ← PEOU | 0.817128 | 20.944853 |
| peou3 ← PEOU | 0.925712 | 60.412519 |
| peou4 ← PEOU | 0.924567 | 65.358358 |
| pe1 ← PE | 0.918104 | 46.541685 |
| pe2 ← PE | 0.862660 | 29.714637 |
| pe3 ← PE | 0.787257 | 16.512719 |
| pe4 ← PE | 0.877827 | 40.712885 |
| bi1 ← BI | 0.904014 | 49.186558 |
| bi2 ← BI | 0.921667 | 67.628964 |
| bi3 ← BI | 0.828020 | 35.103813 |
| bi4 ← BI | 0.823438 | 30.860872 |
| bi5 ← BI | 0.869359 | 50.323804 |
| bi6 ← BI | 0.885089 | 49.606151 |
| bi7 ← BI | 0.891845 | 48.469552 |
| bi8 ← BI | 0.923669 | 72.548256 |

Table 7.6: Outer model loadings calculated with data from the web survey

### Discriminant Validity of the Web Survey Measurement Model

Table 7.7 shows that the web survey measurement model meets the first criteria for discriminant validity. The cross loadings between measurement items and their theoretically assigned factor are consistently greater than the other cross loadings.

Table 7.8 shows that the second requirement for good discriminant validity is met. The square roots of the AVE-s are shown in bold. The lowest of these values is 0.86. The smallest difference

| | BI | PE | PEOU | PU |
|---|---|---|---|---|
| pu1 | 0.597866 | 0.449985 | 0.702570 | **0.926213** |
| pu2 | 0.612339 | 0.517435 | 0.668218 | **0.935139** |
| pu3 | 0.618642 | 0.497304 | 0.734257 | **0.945103** |
| pu4 | 0.708038 | 0.677822 | 0.679763 | **0.860424** |
| peou1 | 0.575039 | 0.557494 | **0.908824** | 0.737507 |
| peou2 | 0.410511 | 0.363033 | **0.817128** | 0.492686 |
| peou3 | 0.619510 | 0.521342 | **0.925712** | 0.733571 |
| peou4 | 0.600490 | 0.492809 | **0.924567** | 0.713816 |
| pe1 | 0.583141 | **0.918104** | 0.520060 | 0.507164 |
| pe2 | 0.561882 | **0.862660** | 0.483811 | 0.535582 |
| pe3 | 0.427605 | **0.787257** | 0.411915 | 0.430402 |
| pe4 | 0.618901 | **0.877827** | 0.471004 | 0.542744 |
| bi1 | **0.904014** | 0.620246 | 0.576821 | 0.666299 |
| bi2 | **0.921667** | 0.569380 | 0.565597 | 0.617948 |
| bi3 | **0.828020** | 0.534514 | 0.531079 | 0.515030 |
| bi4 | **0.823438** | 0.479973 | 0.493676 | 0.464170 |
| bi5 | **0.869359** | 0.586467 | 0.594700 | 0.696972 |
| bi6 | **0.885089** | 0.533932 | 0.580878 | 0.585802 |
| bi7 | **0.891845** | 0.606239 | 0.533505 | 0.674684 |
| bi8 | **0.923669** | 0.569918 | 0.527586 | 0.624151 |

Table 7.7: Cross loadings calculated with data from the web survey

between a squared AVE and one of the other correlations is 0.14. This occurs between the squared AVE for PEOU and the cross-loading between PU and PEOU.

| | BI | PE | PEOU | PU |
|---|---|---|---|---|
| BI | **0.881625** | 0.000000 | 0.000000 | 0.000000 |
| PE | 0.641166 | **0.862765** | 0.000000 | 0.000000 |
| PEOU | 0.625673 | 0.548832 | **0.895185** | 0.000000 |
| PU | 0.693488 | 0.586745 | 0.760256 | **0.917320** |

Table 7.8: Inter-construct correlations and square roots of AVE calculated with data from the web survey

### 7.2.2 Results from Testing the Hypothesis with Data from the Web Survey

Figure 7.2 shows the structural model calculated with data from the web survey.

The structural model shows that all five hypotheses were supported. With the exception of the path between PEOU and BI, all paths were significant at the $p < 0.001$ level. The path between PEOU and BI were significant at the $p < 0.05$ level.

Overall, the model explained about 57% of the variance in usage intentions.

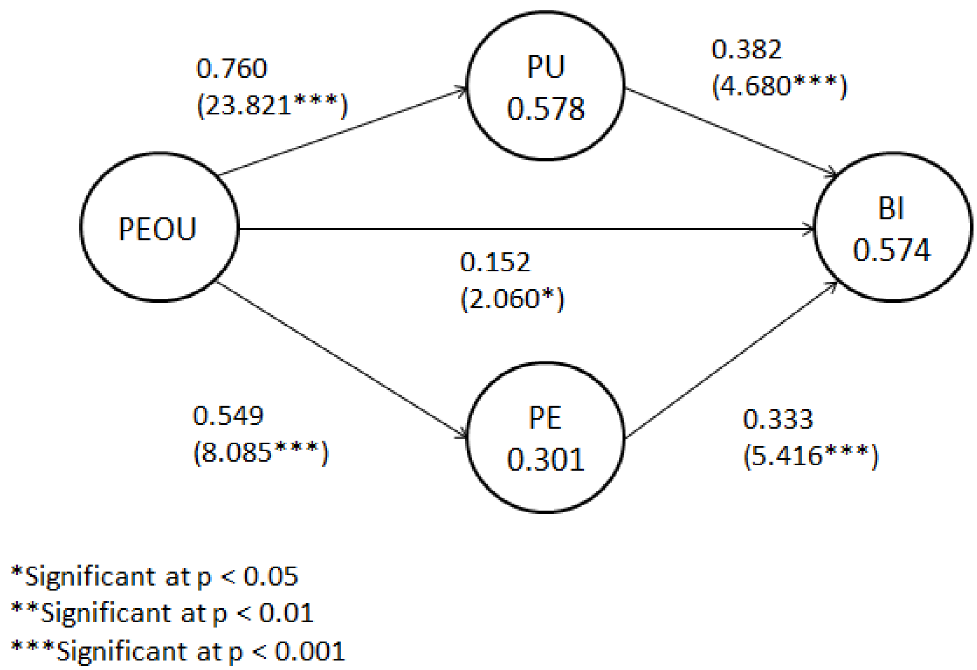



Figure 7.2: Structural model with data from the web survey

# Chapter 8

# Discussion

This research proposed a research model and five research hypotheses that explain users' adoption of mobile augmented reality applications with cultural heritage resources. Two surveys were conducted, and both showed that perceived enjoyment is an important determinant for the intention to use this type of systems. Table 8.1 summarize the rest of the hypothesis test results.

| | Street Survey | | Web Survey | |
|---|---|---|---|---|
| | Estimate | Significance | Estimate | Significance |
| **H1** PEOU $\rightarrow$ PU | 0.664 | Significant at $p < 0.001$ | 0.760 | Significant at $p < 0.001$ |
| **H2** PU $\rightarrow$ BI | 0.008 | Not significant | 0.382 | Significant at $p < 0.001$ |
| **H3** PEOU $\rightarrow$ BI | -0.023 | Not significant | 0.152 | Significant at $p < 0.05$ |
| **H4** PEOU $\rightarrow$ PE | 0.657 | Significant at $p < 0.001$ | 0.549 | Significant at $p < 0.001$ |
| **H5** PE $\rightarrow$ BI | 0.604 | Significant $p < 0.001$ | 0.333 | Significant at $p < 0.001$ |

Table 8.1: Summary of hypothesis test results

## 8.1 Technology Acceptance Model for Mobile Augmented Reality Applications with Cultural Heritage Resources

The technology acceptance model for hedonic systems was found to fit the data. The model was tested with the results from the street survey and the web survey, and accounted for 35% and 57%of the total variance in intention to use, respectively. In comparison, van der Heijden was able to account for 35% of the variance in intention to use in his study [61]. Chesney accounted for 62% of the variance in his study [16].

The results from the street survey and the web survey are significantly different. Both studies show a positive relationship between perceived ease of use and perceived usefulness, perceived ease of use and perceived enjoyment, and perceived enjoyment and intention to use. However, the two remaining relationships were very weak and not statistically significant in the model estimated with data from the street survey. They were statistically significant in the model estimated with data from the web survey. Here, perceived usefulness achieved about the same predictive value as perceived enjoyment on intention to use (38% versus 33%) while perceived ease of use had less of an impact (15%).

A large body of research have previously shown that perceived usefulness is the strongest predictor of user acceptance and that the effect of perceived enjoyment is consistently weaker then the effects of perceived usefulness and perceived ease of use [20, 35, 36]). However, van der Heijden [61] did a study on a pleasure-oriented system and found that perceived enjoyment and perceived ease of use were stronger determinants of intention to use than perceived usefulness. Chesney [16] repeated this research with a dual system that were used for both utilitarian and hedonic purposes and found that perceived usefulness achieved dominant predictive value over perceived enjoyment and perceived ease of use.

The results from this study indicates that mobile augmented reality applications with cultural heritage resources are dual in nature. People want to use this type of applications because they enjoy the experience, but also because it helps them achieve some goal. This also explain the difference between the intention to use the application as a tourist versus the intention to use the application in their hometown. As tourists, many people go on sightseeing and look at historical places. This type of application helps them do that. The users do not feel the same need in their hometown and are thus less interested in the application.

## 8.2 Interest in Mobile Augmented Reality Applications with Cultural Heritage Information

67% of the respondents in the street survey rated item bi1("I intend to use the app on a smartphone") as a 6 or 7. 35% of the respondents in the web survey replied in the same way by selecting the alternatives "agree" or "highly agree". 43% of the respondents in the street survey rated item bi3("I intend to use the app on a tablet") as a 6 or 7. 25% of the respondents in the web survey did the same.

83% of the respondents in the street survey rated item bi5("I intend to use the app in a city I visit as a tourist") as a 6 or 7. 45% of the respondents in the web survey replied in the same way. The number of respondents that rated item bi7("I intend to use the app in my hometown") as a 6 or 7 is considerably lower. 48% of the street survey respondents and 35% of the respondents in the web survey gave item bi7 this rating.

The values indicate that there is an interest in mobile augmented reality applications with cultural heritage information. The interest depends on the setting of the user and whether the application is available on smartphones or tablets. However, there is a significant difference between the answers in the two surveys. It is possible that this is linked to the users' *knowledge* of the application.

Knowledge is the first stage in Rogers model for adoption of innovations [55]. It occurs when an individual "is exposed to an innovation's existence and gains some understanding of how it functions". Knowledge is not included in the technology acceptance model (TAM). Instead, the model assumes that the user has gained enough knowledge about the system to evaluate the system and their intentions to use it. This is a dubious assumption for innovations at the early stages of their diffusion, such as the case of augmented reality systems. For this reason, the respondents in the street survey got to try the application first. This was not possible in the web survey, so the respondents watched a video instead. It is possible that the video was an inadequate replacement and that knowledge is a missing factor in the acceptance model. This would be in accordance with the findings of Peres et al. who in their study of mobile electronic tourist guides (METG) found that usefulness “is highly influenced by the tourists’ level of knowledge regarding METG” and that there is “a direct significant path between knowledge and behavioural intention, suggesting that good levels of knowledge of the service are a pre-condition for greater of usage of METG” [52].

## 8.3 Implications for the Cultural Heritage Sector

The results of this study can benefit cultural heritage institutions that are considering developing a mobile augmented reality application. The technology acceptance model indicates how this type applications can be made more acceptable to users. The comments and the different results between intention to use depending on context show the importance of selecting the right platform and aiming for the right user groups.

### 8.3.1 Increasing Perceived Usefulness and Perceived Enjoyment

This study showed that both perceived usefulness and perceived enjoyment had a strong positive effect on the intention to use this type of applications. They both achieved dominant predictive value over perceived ease of use. As a result, it is natural to focus on how to increase these two factors.

The participants in the street survey had several suggestions to improve the usefulness and enjoyment of the application. One of the participants suggested adding movies. Others suggested connecting the app to a larger existing tour guide or adding the ability to access ready-made tours. Another group focused on the ability to personalize the application. It was also suggested to link the app to existing physical resources such as plates with historical information or buildings and walls engraved with years.

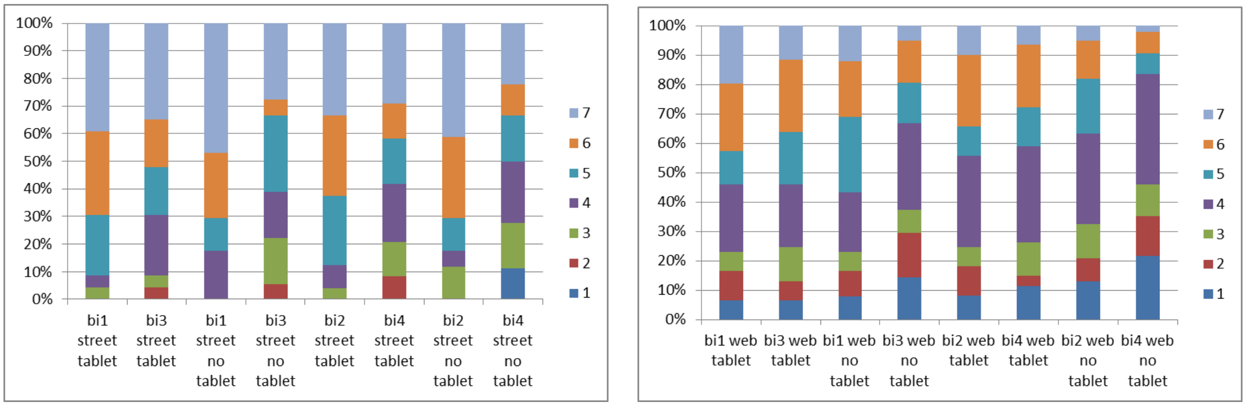
### 8.3.2 Focusing on Perceived Ease of Use

Perceived ease of use had less of a direct impact on intention to use than the other constructs but played an important part in influencing perceived usefulness and enjoyment. Usability was the main focus under the initial development of the application and the replies to the items measuring perceived ease of use still indicates that there is room for improvement. However, the results are better than those achieved under the usability evaluation of the first version of the application. This show the importance of iterative development and evaluation with users as suggested by Nielsen [45], and Gould and Lewis [29].

### 8.3.3 Choosing the Right Platform

The results indicate that a smartphone application is likely to be more popular than a tablet application. The scores on the items measuring the intentions to use the application on a smartphone were higher than the scores on the items measuring the intention to use the application on a tablet.

Figure 8.1 shows how the replies of the tablet owners differ from the replies of the respondents without a tablet. Item bi1 and bi2 are related to use on smartphones while bi3 and bi4 are related to use on tablets. The graphs show that respondents without a tablet had less of an intention to use the application on a tablet than the tablet owners. However, the tablet owners were also slightly




(a) Street survey

(b) Web survey

Figure 8.1: Intentions to use the application on smartphones and tablets

more negative to a tablet application than to a smartphone application. This may be related to the comments about the inconvenience of carrying a tablet downtown.

### 8.3.4 Targeting Multiple User Groups

The participants in both surveys were certainly more positive to using the application in a city they visited as a tourist than they were to using it in their hometown. This indicates that it may be an idea to target tourists as well as locals, and support multiple languages. One of the participants also suggested renting out devices with the application pre-installed.

### 8.3.5 Considering Local Weather Conditions

The most novel part of a mobile augmented reality application is the ability to use the augmented reality functionality out on the street. However, local weather conditions can make this a rather unpleasant experience. Furthermore, most touch-devices should not be used in the rain or below the freezing point (0 °C or 32 °F).

While it is possible to develop an application that only supports the augmented reality functionality, this application would have limited use in areas with cold winters or long periods of rain. There will be many more opportunities to use an application that supports navigation through a list and a map as well, and thus can be used inside. It is also likely that these functionalities will increase the perceived usefulness of the application.

## 8.4 Limitations

There are some limitations of this study. First of all, the results from the street survey and the web survey are remarkably different. The street survey participants were generally speaking more positive to the application than their web survey counterparts. It is possible that part of this is related to an interviewer bias introduced by using untrained personnel for data collection. It can also be because street survey respondents had a more realistic experience of how it is to use the application than those who watched a video instead.

The web survey participants rated the application higher on the scale for perceived enjoyment. It is likely that this is due to the different format that was used for this scale in the web survey. The company that collected the data used a continuous slider to program this question instead of having seven different categories. The answers were afterwards mapped into seven categories. It is possible that this format encourages the respondents to use the end-points of the scale. That would at least explain the high number of top-scores in this scale compared to the others.

The format of the other scales also differed. The web survey used fully labeled Likert scales while the street survey used partially labeled scales. This may have had an effect on the results. It is also possible that the use of testers without formal training introduced an interviewer bias into the data from the street survey.

The number of participants in the street survey was also rather small compared to the number of participants in the web survey. While 42 participants is more than the suggested lower limit of 10 times the number of items in the most complex construct [6] it is possible that more data would have resulted in all the relationships in the model being significant.

Another limitation of the study is the translation of the items. This is especially clear in the scale measuring intention to use where the odd-numbered items start with “I intend to use...” while the even-numbered items start with “I predict that I will use...”. In both surveys, the responses to the even-numbered items are consistently lower than the responses to their odd-numbered counterparts. This is not a common trend in acceptance research. However, the comments from some of the street survey respondents provide an explanation for the difference. When answering whether they intended to use the application, they actually answered how much they wanted to use it. When answering whether they predicted they would use the application, they also considered external factors such as the fact that they did not own a tablet.

# Chapter 9

# Conclusion and Further Work

## 9.1 Conclusion

This project used a technology acceptance model for hedonic systems to examine the determinants of intention to use a augmented reality application with historical information and pictures. A prototype application was built and used to demonstrate the concept for the participants in the street survey that was conducted as part of the project. A questionnaire was used for data collection. The same questionnaire was also used in the second survey, conducted online. The participants in this survey watched a video presentation of the application to get an introduction to the concept before answering the questionnaire. A partial least square analysis was conducted on the data to estimate a structural equation model for the acceptance of this type of application.

Two research questions guided the work during the project:

1. Is there an interest for using augmented reality applications with historical pictures and information?

2. Do the previously established relationships between the constructs in the technology acceptance model (TAM) extended with perceived enjoyment hold for augmented reality applications with historical pictures and information?

The results show that there is an interest in mobile augmented reality applications with cultural heritage resources. The relationships between the constructs in the acceptance model holds, but the predicative strength of the paths are different. Both perceived usefulness and perceived enjoyment are important determinants of intention to use augmented reality application with historical information and pictures. This finding suggests that institutions developing this type of programs can benefit from focusing on both the fun and the useful aspect of their applications.

## 9.2 Further Research

This study used a tablet prototype while the results indicate that this type of application would be most popular on a smartphone platform. It could be useful to examine this further by building and testing a smartphone prototype. Another approach would be to look into the possibility of personalizing the application or provide support for user-generated content.

The results also indicate that the most likely users will be people visiting another place as tourists. Future studies could investigate this by testing with a larger audience consisting of both locals and tourists. The audience could be segmented into two groups and it could be evaluated whether the conclusion was independent of the characteristics of each group.

The difference between the two survey results indicate that knowledge about the application might be a missing factor in the model. Future studies could examine this further by expanding the model and testing the users' knowledge of the application's functionality.

The prototype application is on the wish from the owners of the picture material being made generally available. This opens up the possibility of longitudinal studies and studies that look into the actual usage of the application. In-depth interviews with actual users could provide useful feedback and give ideas for improving this application and other applications of this type.

## Appendix A

# Street Survey (in Norwegian)

## Spørreundersøkelse om den historiske turguiden

*Ved å svare på undersøkelsen og oppgi e-postadresse blir du med i trekningen av en iPad 2. E-postadressen vil ikke bli brukt til andre formål.*

| | Sterkt uenig | | | | | | Sterkt enig |
|---|---|---|---|---|---|---|---|
| | ☐ 1 | ☐ 2 | ☐ 3 | ☐ 4 | ☐ 5 | ☐ 6 | ☐ 7 |
| Ved å bruke appen finner jeg raskt og enkelt historiske bilder og informasjon | ☐ 1 | ☐ 2 | ☐ 3 | ☐ 4 | ☐ 5 | ☐ 6 | ☐ 7 |
| Ved å bruke appen lærer jeg mer om historie i Trondheim | ☐ 1 | ☐ 2 | ☐ 3 | ☐ 4 | ☐ 5 | ☐ 6 | ☐ 7 |
| Ved å bruke appen kan jeg raskt finne ut om det finnes historiske bilder og informasjon om steder i nærheten | ☐ 1 | ☐ 2 | ☐ 3 | ☐ 4 | ☐ 5 | ☐ 6 | ☐ 7 |
| Ved å bruke appen er det større sannsynlighet for at jeg finner historiske bilder og informasjon som interesserer meg | ☐ 1 | ☐ 2 | ☐ 3 | ☐ 4 | ☐ 5 | ☐ 6 | ☐ 7 |

| | Sterkt uenig | | | | | | Sterkt enig |
|---|---|---|---|---|---|---|---|
| Jeg synes appen er klar og forståelig | ☐ 1 | ☐ 2 | ☐ 3 | ☐ 4 | ☐ 5 | ☐ 6 | ☐ 7 |
| Å bruke appen krever ikke mye konsentrasjon | ☐ 1 | ☐ 2 | ☐ 3 | ☐ 4 | ☐ 5 | ☐ 6 | ☐ 7 |
| Jeg synes appen er lett å bruke | ☐ 1 | ☐ 2 | ☐ 3 | ☐ 4 | ☐ 5 | ☐ 6 | ☐ 7 |
| Jeg synes det er lett å få appen til å gjøre det jeg vil den skal gjøre | ☐ 1 | ☐ 2 | ☐ 3 | ☐ 4 | ☐ 5 | ☐ 6 | ☐ 7 |

Å bruke appen er:

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | |
|---|---|---|---|---|---|---|---|---|
| Grusomt | | | | | | | | Underholdende |
| Ensformig | | | | | | | | Spennende |
| Utrivelig | | | | | | | | Hyggelig |
| Kjedelig | | | | | | | | Interessant |

| Jeg har lyst til å bruke appen hvis jeg får tilgang til den: | Sterkt uenig | | | | | | Sterkt enig |
|---|---|---|---|---|---|---|---|
| på mobil | ☐ 1 | ☐ 2 | ☐ 3 | ☐ 4 | ☐ 5 | ☐ 6 | ☐ 7 |
| på nettbrett | ☐ 1 | ☐ 2 | ☐ 3 | ☐ 4 | ☐ 5 | ☐ 6 | ☐ 7 |
| i en by der jeg er som turist | ☐ 1 | ☐ 2 | ☐ 3 | ☐ 4 | ☐ 5 | ☐ 6 | ☐ 7 |
| i byen der jeg bor | ☐ 1 | ☐ 2 | ☐ 3 | ☐ 4 | ☐ 5 | ☐ 6 | ☐ 7 |

| Jeg kommer til å bruke appen hvis jeg får tilgang til den: | Sterkt uenig | | | | | | Sterkt enig |
|---|---|---|---|---|---|---|---|
| på mobil | ☐ 1 | ☐ 2 | ☐ 3 | ☐ 4 | ☐ 5 | ☐ 6 | ☐ 7 |
| på nettbrett | ☐ 1 | ☐ 2 | ☐ 3 | ☐ 4 | ☐ 5 | ☐ 6 | ☐ 7 |
| i en by der jeg er som turist | ☐ 1 | ☐ 2 | ☐ 3 | ☐ 4 | ☐ 5 | ☐ 6 | ☐ 7 |
| i byen der jeg bor | ☐ 1 | ☐ 2 | ☐ 3 | ☐ 4 | ☐ 5 | ☐ 6 | ☐ 7 |

Kjønn: ☐ mann ☐ kvinne

Alder:____________

Jeg har kjøpt og/eller lest en bok om lokalhistorie: ☐ Ja ☐ Nei

Jeg har erfaring med nettbrett: ☐ Ja ☐ Nei

Jeg har erfaring med lignende apper: ☐ Ja ☐ Nei

Hvis ja, navn på appen: ______________________________

Kommentarer: ____________________________________________________________

____________________________________________________________

____________________________________________________________

# Appendix B

# Web Survey (in Norwegian)

Under vises en film som starter automatisk. Det kan ta litt tid avhengig av hvilken internettforbindelse du har. Sørg for at høyttalerene dine er slått på. Dersom filmen ikke vises, kan du se den ved å klikke på en av lenkene nedenfor:

- Vis filmen i Media Player format (åpnes i nytt vindu)
- Vis filmen i QuickTime format (åpnes i nytt vindu)

Kunne du se og høre filmen?

- Ja, den vistes direkte på skjermen.
- Nei, kunne ikke se og høre den.

Er du...

- Mann
- Kvinne

Hva er din alder?
Nedenfor ser du noen utsagn om appen i videoklippet du akkurat så. Vennligst ta stilling til disse på en skala fra 1 til 7 der 1 er sterkt uenig og 7 er sterkt enig.

- Ved å bruke en slik app vil jeg raskt finne historiske bilder og informasjon
- Ved å bruke en slik app vil jeg lære mer om historie
- Ved å bruke en slik app vil jeg raskt finne historiske bilder og informasjon om steder i nærheten
- Ved å bruke en slik app vil jeg finne historiske bilder og informasjon som interesserer meg

Nedenfor ser du noen flere utsagn om appen i videoklippet du akkurat så. Vennligst ta stilling til disse på en skala fra 1 til 7 der 1 er sterkt uenig og 7 er sterkt enig.

- Jeg synes appen virker klar og forståelig
- Å bruke en slik app vil ikke kreve mye konsentrasjon

- Jeg synes appen virker lett å bruke
- Jeg synes det virker lett å få appen til å gjøre det jeg vil den skal gjøre

Vennligst ta stilling til utsagnene nedenfor ved å bruke adjektivene i hver sin ende av skalaen.

- grusomt - underholdende
- ensformig - spennende
- utrivelig - hyggelig
- kjedelig - interessant

Nedenfor ser du noen utsagn som om handler bruk av appen. Vennligst ta stilling til i hvilken grad disse gjelder for deg.

- Jeg har lyst til å bruke en slik app på en smarttelefon
- Jeg kommer til å bruke en slik app på en smarttelefon
- Jeg har lyst til å bruke en slik app på et nettbrett
- Jeg kommer til å bruke en slik app på et nettbrett
- Jeg har lyst til å bruke en slik app i en by jeg besøker som turist
- Jeg kommer til å bruke en slik app i en by jeg besøker som turist
- Jeg har lyst til å bruke en slik app i byen der jeg bor
- Jeg kommer til å bruke en slik app i byen der jeg bor

Har du du lest en eller flere bøker om lokalhistorie?

- Ja
- Nei
- Vet ikke/husker ikke

Har du et nettbrett?

- Ja
- Nei
- Vet ikke/husker ikke

Har du en smarttelefon?

- Ja
- Nei
- Vet ikke/husker ikke

Har du erfaring med lignende apper som den vist i videoklippet?

- Ja
- Nei
- Vet ikke/husker ikke

*Hvis brukeren svarte ja på spørsmålet ovenfor:* Hva er navnet på appen?

# Appendix C

# Comments (in Norwegian)

- Bra initaitiv! Lykke til!
- Virka som en flott og grei app. God ide.
- Veldig kreativ og god ide, kan hjelpe både kjentfolk og turister på en brukervennlig måte. Kanskje den kunne kobles mot en større turistguide?
- Jeg synes denne appen virker lovende, og jeg har villet bruke denne appen aktivt. Tror mange ville blitt interessert
- Bra oppfinnelse! Er det mulig å velge hva slags informasjon man får? For eksempel kun info om kirker?
- Kjempegøy med bilder. Kan man legge inn film?
- Vil gjerne ha informasjon koblet til skilt på hus og årstall i mur på hus. Ta gjerne med navn på byggene også.
- Ville brukt den selv om den hadde kostet penger.
- Synes den ikke er komplisert, ganske enkel å bruke
- Eg måtte ha opplæring for å finne ut av det - da var det lett - men jeg har lite erfaring med app'er så det er noe av grunnen til svarene
- Spennende app å bruke på sightseeing! En virtuell guide =) Foreslår en litt kortere og tydeligere forklaring for appen på info-knappen: vis symbolet du skal trykke på i stedet for å skrive "listeknappen" etc. Lykke til!
- Liker ideen og tror dette kan bli en app mange bruker. Lykke til!
- Synes den også kan opplyse om historiske steder/bygninger selv hvis disse er blitt revet og erstattet med nye bygg.
- Store muligheter her gitt. Vil ha koblet app mot en større reiseguide, gps-rutevarsler, lonely planet, større kartapplikasjon eller lignende. Kult =)
- Med mobil som turist og nettbrett der jeg bor

- Genialt påfunn og veldig interessant! Hadde vært veldig praktisk på kjente feriemål eller de mest besøkte turistbyene på flere språk. I en by der jeg er som turist hadde vært genialt!
- Knall!
- Lærerik! Veldig interessant og virker spennende å bruke. Mye spennende læring om gammel historie som er viktig å ta vare på.
- Kunne vært spennende å få opp en ferdiglaget gåtur som er basert på mine interesser (religion/kunst/politikk) med kart og opplegg
- Spennende, men litt usikker på hvor stor målgruppen er. Kanskje mest eldre og turister. Klart spennende om det er en gratisapp!
- Kunne gies/lånes bort til folk på Hurtigruta! Virker ikke så bra i solskinn, dessuten regner det en del i trondheim...
- Bra app!
- Kanonspennende!

# Appendix D

# Digital Attachments

This report is accompanied with a zip archive containing the raw data from the two surveys, the source code and a video demonstration of the project.

## D.1 Raw Data

The raw data from the two survey are included in the folder Surveys. The folder contains four files:

- StreetSurvey.xls
- WebSurvey.xlsx
- StreetSurvey.sav
- WebSurvey.sav

## D.2 Source Code

The source code for the system is included in the folder Cecar. It is open source and can also be downloaded from GitHub at `https://github.com/anneceh/The-Historical-Tour-Guide`.

## D.3 Video Demonstration

A video demonstration presenting the functionality of the Historical Tour Guide is included with this report. This is the video used in the web survey and is therefore in Norwegian. The file is in the Windows Media Video format and has the file name presentation.wmv.

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