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MOBILE INFORMATION SYSTEM ADOPTION AND USE: BELIEFS AND ATTITUDES IN MOBILE CONTEXT

Doctoral Dissertation

Matti Koivisto

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Department of Communications and Networking

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Abstract

During the last decades scholars and practitioners have been interested in the reasons why users either accept or reject Information Systems (IS). Users' perceptions of information technology have mainly been studied from acceptance, success, or usability perspectives. Although these research approaches have provided valuable information, they all have a limited view. Thus, there is a need for an integrated framework that fulfills the gaps between different approaches.

In this study the acceptance and use of mobile systems are analyzed by combining the results of different disciplines. The main result of the study is a new model for Mobile IS Adoption and Use (MISAU). It integrates the elements of technology acceptance, information system success, and usability studies into a single model. As information system acceptance must always be analyzed in context of use, MISAU is based on the mobile service supply chain.

The main differences between stationary and mobile systems can be found in network performance and usability of mobile devices. MISAU serves as a framework for case studies in which the effects of these special characteristics on users' perceptions are analyzed. The results of the study indicate that the ever-increasing transmission speeds of mobile networks are not alone adequate to increase the use of mobile services. Perceived quality of service is an outcome of multiple factors. The successful implementation of a mobile IS requires high quality in all elements of service supply chain (i.e. end-user devices, networks, and services). The small size of mobile devices is a serious threat to usability – especially to text entry and navigation within an application. Further studies are still needed in these sectors.

Keywords mobile devices, mobile information systems, usability, acceptance, success factors

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Työn ohjaaja	Prof. Raimo Kantola

Tiivistelmä

Syyt, joiden perusteella käyttäjät joko hyväksyvät tai hylkäävät tietojärjestelmän, ovat kiinnostaneet alan tutkijoita ja yrityksiä vuosikymmenien ajan. Tutkimuksissa käyttäjien suhtautumista tietotekniikkaan on tarkastelu lähinnä hyväksymisen, menestyksen tai käytettävyyden kannalta. Vaikka kyseiset menetelmät ovat lisänneet merkittävästi ymmärrystämme järjestelmien käyttö- ja hyväksymisprosesseista, ne kertovat kuitenkin vain osatotuuden. Viimeisten vuosien aikana onkin noussut esiin tarve yhdistää eri tarkastelutapoja paremman kokonaiskuvan saamiseksi.

Tässä työssä analysoidaan mobiilitietojärjestelmien käyttöä ja hyväksymistä eri tutkimustraditioita yhdistävästä näkökulmasta. Tutkimuksen keskeinen tulos on uusi malli (MISAU-malli), joka yhdistää teknologian hyväksymis-, tietojärjestelmien menestys- ja käytettävyystutkimuksen keskeisiä tuloksia. Koska tietojärjestelmät ovat aina sidoksissa käyttökontekstiinsa, mallin lähtökohtana on mobiilipalveluille ominainen toimitusketju ja sen laatuominaisuudet.

Keskeisimmät erot kiinteiden ja mobiilien tietojärjestelmien välillä liittyvät tietoverkkojen ominaisuuksiin ja päätelaitteiden käytettävyyteen. MISAU-mallin luo perustan työn empiirisille tutkimuksille, joissa tarkastellaan näiden erityispiirteiden vaikutuksia käyttäjien kokemuksiin. Tutkimusten tulokset osoittavat, että mobiiliverkkojen kasvavat siirtonopeudet eivät yksin riitä lisäämään palvelujen käyttöä. Käyttäjän kokema palvelun laatu on monen tekijän summa ja mobiilipalveluiden menestys edellyttää laatua kaikilta toimitusketjun osilta eli päätelaitteilta, verkoilta ja itse palveluilta. Mobiilipäätelaitteiden pieni koko aiheuttaa haasteita palveluiden käytettävyydelle - erityisesti tekstinsyötölle ja palveluiden sisäiselle navigoinnille. Näiden ominaisuuksien kehittäminen vaatii vielä jatkotutkimusta ja tuotekehitystä.

Asiasanat	mobiililaitteet, mobiilijärjstelmät, käytettävyys, hyväksyttävyys, menestystekijät		
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PREFACE

This thesis stems from a will to understand the dynamics of mobile information system adoption and use that on many occasions seem intriguingly mysterious. The work presented in the thesis has been done during 2002 – 2008 under the supervision of professor Raimo Kantola, Department of Communications and Networking. I am most grateful to him for his support and encouragement.

During the thesis writing project I have had a great opportunity to work with professor Andrew Urbaczewski from the University of Michigan. I have learnt a lot – and not only about mobile information systems – when working with him. I owe him a lot!

I want to thank my employer Mikkeli University of Applied Science (MAMK) for funding my conference trips, two former students of mine Vesa Hartonen and Esa Kyllästinen for implementing two research instruments, my colleague from MAMK Pekka Uotila for introducing me to Social Network Analysis, and all those people taking part in the satisfaction and performance surveys of the thesis. Their help was vital to my work.

Last but absolutely not least I want to thank my wife Tuula not only for her love and patience but also for her help with the intricacies of the English language. As a result of that ☺ I dedicate this work to her and our three beautiful daughters Laura, Pauliina, and Venla.

CONTENTS

LIST OF PUBLICATIONS

This thesis consists of an overview and of two journal articles ([P2] and [P6]) and seven conference papers ([P1], [P3], [P4], [P5], [P7], [P8], and [P9]). Due to the different styles of the conference proceedings and journals the formats and referencing styles of the publications vary to some extent.

[P1] Urbaczewski A., Wells J., Sarker S., and Koivisto M. (2002) Exploring cultural differences as means for understanding the global mobile Internet: A theoretical basis and program of research, Proc. of the 35th Annual Hawaii International Conference on System Sciences, Big Island, HI, USA Nominated for the Best Paper Award.

[P2] Koivisto M. and Urbaczewski A. (2004) The relationship between quality of service perceived and delivered in mobile internet communications, Information Systems and e-Business Management, Vol. 2, No. 4, pp. 309 – 323.

[P3] Koivisto M. (2006) User interface characteristics and network utilization in mobile networks, Proc. of the IASTED Conference on Modelling and Simulation, Montreal, Canada.

[P4] Koivisto M. and Urbaczewski A. (2005) Accuracy metrics in mobile text entry, Proc. of the IASTED Conference on Human-Computer Interaction, Phoenix, AZ, USA.

[P5] Koivisto M. (2007) Mobile text entry metrics for field studies, Proc. of the IASTED Conference on Human-Computer Interaction, Chamonix, France.

[P6] Urbaczewski A. and Koivisto M. (2008) The importance of cognitive fit in mobile information systems, Communications of the Association for Information Systems, Vol. 22, No. 10, pp. 185 – 196.

[P7] Urbaczewski A. and Koivisto M. (2007) Measuring mobile device usability as a second order construct in mobile information systems, Proc. of the 13th Americas Conference on Information Systems, Keystone, CO, USA.

[P8] Koivisto M. (2007) Acceptance and use of mobile phone mediated communication technologies in community communications, Proc. of the 2nd IEEE International Conference on Digital Information Management, Lyon, France.

[P9] Koivisto M. (2007) Development of quality expectations in mobile information systems, Proc. of International Joint Conferences on Computer, Information, and Systems Sciences, and Engineering, University of Bridgeport, CT, USA.

AUTHOR'S CONTRIBUTION

The author of the thesis had an active role in all published papers. Publication [P1] was an outcome of US-European research initiative and a starting point of the thesis. The author co-authored the article and brought the European view to the article. The lead author of this article was professor Andrew Urbaczewski from Washington State University. The author of the thesis co-operated with professor Urbaczewski also in publications [P2], [P4], [P6], and [P7]. At that time, professor Urbaczewski worked at the University of Michigan.

In publication [P2] the author was responsible for the design and implementation of the test environment. As the lead author he also took the main responsibility for writing the final version of the article. Statistical analysis and final editing of the paper was carried out in collaboration with professor Urbaczewski. In this paper the relationship between network performance and perceived quality of service is analyzed in a laboratory experiment.

As the only author of publication [P3] the author was responsible for all stages of the research work. The article creates a framework for studying the effect of user interface characteristics to network utilization especially now when mobile communication is shifting from text to images and video clips.

In publication [P4] the author designed and carried out the data collection process. As the lead author of the paper he wrote the first full version of the article. The final version of the article was created in co-operation with professor Urbaczewski. The article introduces the existing mobile text entry metrics and compares them against each other in a laboratory setting.

The author was the only author of publication [P5] and was responsible for the research work as a whole. In the data collection phase of the test a mobile phone application designed by the author and programmed by Mr. Vesa Hartonen was used. In this paper empirical laboratory and field tests are carried out and new text entry metrics for field studies are developed.

In publication [P6] the author designed and created the test environment and wrote the first full version of the article. The Stock Broker Game used in the data collection of the second test was desiged by the author but implemented by Mr. Esa Kyllästinen. The final formatting was then carried out together with professor Urbaczewski. This article uses the theory of cognitive fit to study the effects of a small screen size to user performance and satisfaction.

In [P7] the author designed the research environment, collected the data and wrote the first version of the article. Professor Urbaczewski was responsible for the statistical analysis, and the final version of the paper was compiled by professor Urbaczewski and the author. In this paper the usability of mobile devices was tested, and multiple existing metrics were used in order to get an overall view of usability as a second order construct.

As the only author of publication [P8] the author was responsible for all steps of the research. This paper develops a model for mobile information system adoption and use based on technology acceptance, user satisfaction, and usability literature. The model is then applied to community communications.

The author was the only author of publication [P9] and he was responsible for all phases of the research work. This paper analyzes the quality expectations and their development in mobile context.

LIST OF ABBREVIATIONS

ASQ	After-Scenario Questionnaire
ACSI	American Customer Satisfaction Index
BPS	Bits Per Second
CPS	Characters Per Second
CFT	Cognitive Fit Theory
CUS	Computer User Satisfaction
CSCW	Computer-Supported Cooperative Work
CER	Corrected Error Rate
CIS	Clinical Information System
CR	Correction Rate
CBA	Cost-Benefit Analysis
CEA	Cost-Effectiveness Analysis
ECSI	European Customer Satisfaction Index
HCI	Human-Computer Interaction
IS	Information System
IT	Information Technology
IDT	Innovation Diffusion Theory
IEEE	Institute of Electrical and Electronics Engineers
IRR	Internal Rate of Return
ISO	International Standardization Organization
ITU	International Telecommunications Union
JAD	Joint Application Design
KC	Keystroke Classification
KSPC	Keystrokes Per Character
LAN	Local Area Network
MSD	Minimum String Distance
MISAU	Mobile Information System Adoption and Use
MMS	Multimedia Messaging Service
NPV	Net Present Value
NET	Network Performance Questionnaire
NCER	Not Corrected Error Rate
PD	Participatory Design
PDA	Personal Digital Assistant
QoBiz	Quality of Business
QoE	Quality of Experience
QoS	Quality of Service
ROI	Return on Investment
TAM2	Revised Technology Acceptance Model
SMS	Short Messaging Service

SSC	Service Supply Chain
SUMI	Software Usability Measurement Inventory
SBG	Stock Broker Game
SUS	System Usability Scale
TTF	Task-Technology Fit
TAM	Technology Acceptance Model
TPB	Theory of Planned Behaviour
TRA	Theory of Reasoned Action
TER	Total Error Rate
UTAUT	Unified Theory of Acceptance and Use of Technology
UMTS	Universal Mobile Telecommunications System
UIS	User Information Satisfaction
UCD	User-Centred Design
WLAN	Wireless Local Area Network
WPM	Words Per Minute
3G	Third Generation Mobile Network

1. INTRODUCTION

1.1. Information System Adoption Research

During the last decades we have witnessed the growth of two new communications technologies – mobile networks and the Internet. The number of users in both technologies are now about 20 times higher than ten years ago reaching 2 685 million mobile subscribers and 1 131 million Internet users in 2006 (ITU, 2007). A lot of applied and theoretical research has taken place in an effort to combine these two successful technologies, but so far the mobile Internet has not become as popular as expected. The success of the mobile Internet and mobile information systems in general depends both on the user's beliefs and attitudes as well as on technological improvements. Technological development opens up new possibilities but finally it is the user who decides whether to accept a service or not.

Information System (IS) researchers have shown a lot of interest in factors and processes affecting users' adoption and use of information technology (IT). They have applied two dominant research approaches in their studies: technology acceptance and information system success (Wixom and Todd, 2005). Both of them try to explain why users accept or reject information systems and how user acceptance is affected by system design features. However, the methods used to achieve this goal are different.

Information technology acceptance research has developed multiple competing models each with a different set of acceptance determinants. Examples of the models include Innovation Diffusion Theory (Rogers, 1995), Technology Acceptance Model (Davis, 1989), and Theory of Reasoned Action (Fishbein and Azjen, 1975). The basic concept underlying these models links individual reactions and intentions to the actual use of the information system (Venkatesh et al., 2003).

In IS success studies the main area of interest has been in the impacts of the system either at an organization or individual level. At the organizational level the success is typically analyzed with economical measures like return on investment or pay-back time. At the individual level many researchers have relied on user satisfaction as an indicator of IS success. A typical user satisfaction study enumerates attributes of the system and analyzes them separately making it a potentially useful diagnostic for system design but user satisfaction is a weak predictor of system use (Wixom and Todd, 2005). As a result of this user satisfaction is not an adequate indicator of information system success, but IS success measurements should combine satisfaction with other success dimensions like system use, system quality, and benefit constructs.

In addition to IS researches Human-Computer Interaction (HCI) professionals have analyzed users' perceptions of the IT including issues of system acceptability and use. Although they admit that system acceptability is a large multidimensional phenomenon (Nielsen, 1993), the key concept in their acceptance studies is usability. The most important difference between IS and HCI practitioners' views is the time factor. IS scientists are typically dealing with implemented products or services whereas usability professionals deal with the process leading up to the implementation of the system. This process – often referred to as usability engineering – includes all steps required to produce usable products (Faulkner, 2000).

1.2. Scope and Contents of the Thesis

The aim of the thesis is to gain an increased understanding of the adoption and use of mobile information systems. Portides (2006) points out that the development of scientific knowledge consists of two major components: theory formulation and theory application. This approach is followed in the study. First, an integrated theoretical framework for the Mobile IS Adoption and Use (MISAU) is developed. The new model integrates the theories of technology acceptance, user satisfaction, and usability into a single framework. The integrated model aims to remove the gap between system characteristics and system use in the mobile context.

Second, the model is used to evaluate the belief and attitude determinants of mobile systems. The unique constraints of mobile context present a number of critical challenges to mobile IS and they can seriously affect the adoption and use processes. These features are analyzed in empirical evaluations conducted both in laboratory and field settings.

The rest of the thesis is organized as follows. In Chapter 2 the classical IT acceptance and satisfaction models are introduced. The presentations are not limited only to the concepts used by the IS scientists but they also introduce the most important HCI related concepts, particularly user-centered design, usability, and usability engineering.

In Chapter 3 the adoption of classical acceptance and success models to mobile context is reviewed. The main aim is to examine the strengths and weaknesses of recent mobile IS adoption and use literature. Special attention is paid to identify the characteristics of mobile IS and their effects on the mobile usability research.

Chapter 4 deals with the development of the MISAU model. The design principles of the model are based on the findings of Chapter 3 and on the special characteristics of mobile IS service supply chain. The MISAU model operates as a solid framework for Chapter 5 which evaluates belief and attitude factors of mobile IS empirically. The studies concentrate on the special characteristics of mobile IS usability identified in Chapter 3. The summary of the thesis can be found in Chapter 6.

1.3. New Scientific Results

The most important scientific results of the thesis are as follows. First, a new model for mobile IS adoption and use (the MISAU model) is developed. The model removes the well-known gap between system characteristics and system use and provides a solid framework for analyzing the factors of mobile IS adoption processes. The model is originally developed in [P8].

Second, several important findings related to the mobile IS acceptance are identified. The findings are based on the special characteristics of the mobile systems and the object-based and behavioral beliefs and attitudes related to them. The four most important results of these studies are listed below:

a) The relationship between network performance and perceived Quality of Service (QoS) is application specific. There is no 1:1 correspondence or even a truly linear relationship between network performance and perceived QoS as recommended by the International Telecommunications Union – Telecommunications (ITU-T, 2001). Applications react differently to network level limitations and the increased network performance does not automatically lead to higher perceived QoS. More details can be found in [P2].
b) Cumbersome text entry methods can have a negative effect on device satisfaction and thus hinder the acceptance of mobile services. In the search for better input methods reliable accuracy metrics are needed. [P4] reveals that it is of vital importance to measure accuracy immediately after the entry process. If the accuracy measurements are postponed, the correlation with text entry method is lost.
c) The theory of cognitive fit (Vessey, 1991) is also applicable to mobile information systems where devices with small displays are used. However, cognitive fit is not as important to the end user performance as menu structures or input methods. See [P6] for more details.
d) Usability of mobile devices is a second order construct predicated by efficiency and device and service satisfaction constructs as shown in [P7]. In contrast, network satisfaction does not have a direct effect on usability.

2. INFORMATION SYSTEM ADOPTION AND USE

Information technology researchers have investigated the factors affecting user perceptions of information systems in great detail. They have tried to explain why users accept or reject information systems, and how user acceptance is affected by system design features. Studies have indicated that there are many factors and processes affecting the system adoption and use. Based on these findings a large number of theories have been created related to innovation diffusion, technology acceptance, information presentation, cognitive fit, impression management, and cultural aspects as explained in [P1]. In this chapter an overview of the basic theories and models of IS adoption and use is presented. However, the topic is far too large to be covered fully within the scope of the thesis. Thus only the three most relevant concepts technology acceptance, IS success, and usability are focused. These three approaches are presented separately in the following sections, and they provide the theoretical foundation for the rest of the thesis. At the end of the chapter the integration of these approaches is also shown.

2.1. Modeling Technology Acceptance

Information technology acceptance research has developed several competing models each with a different set of acceptance determinants. The most distinguished models are Innovation Diffusion Theory (IDT) (Rogers, 1962, 1995), Theory of Reasoned Action (TRA) (Fishbein and Ajzen, 1975), Theory of Planned Behavior (TPB) (Ajzen, 1988, 1991), Technology Acceptance Model (TAM) (Davis, 1989), and Unified Theory of Acceptance and Use of Technology (UTAUT) (Venkatesh et al., 2003). In the following sections these theories are summarized.

2.1.1. Innovation Diffusion Theory

Innovation Diffusion Theory (IDT) (Rogers, 1962, 1995) explains how innovations diffuse through society and how organizations and individuals accept new innovations. Rogers differentiates the adoption process from the diffusion process in that the diffusion process occurs within society, as a group process; whereas the adoption process is related to an individual. The theory is based on the S-shaped diffusion curve (Tarde, 1903) and the classification of users' adoption behavior (Ryan and Gross, 1943).

According to IDT a technological innovation is communicated through particular channels, over time, among the members of a social system. It identifies five characteristics of a technology which determine its acceptance. The characteristics are relative advantage, compatibility, complexity, triability, and observability. Based on these five criteria, individuals perceive an innovation as useful or useless and decide to adopt or reject it.

IDT based studies are primarily concerned with the determinants of the rate, pattern, and extent of technology diffusion (Mahajan, et al., 1990; Mahajan and Peterson, 1985; Parker, 1994). The typical approach here is to gather data on the timing of adoptions in an organization or some population and then to fit a time series of observed cumulative adoptions to some functional form (Fichman, 2000). IDT has been used countless times to explain the assimilation in multiple fields of study including health care (Sanson-Fisher, 2004), e-business (Zhu et al. 2006), and education (Wilson and Stacey, 2003). Some researchers have studied the role of a single factor like gender (Ilie et al., 2005), social network structure (Liu et al., 2005), and culture (Zhu et al., 2006) in the adoption process. Although some critical views exist (e.g. Lyytinen and Damsgaard, 2001), IDT has gained wide popularity also in the IT field. For example Prescott and Conger (1995) found over 70 IDT based IT articles published between 1984 – 1993.

2.1.2. Theories of Reasoned Action and Planned Behavior

The Theory of Reasoned Action (TRA) was developed by Martin Fishbein and Icek Ajzen (1975) to "*organize and integrate research in the attitude area within the framework of a systematic theoretical orientation*". The framework provides a distinction between beliefs, attitudes, subjective norms, intention, and behaviors and the major concern is the relations between these variables. These concepts form a model for the prediction of specific intentions and behaviors (see Figure 2.1).

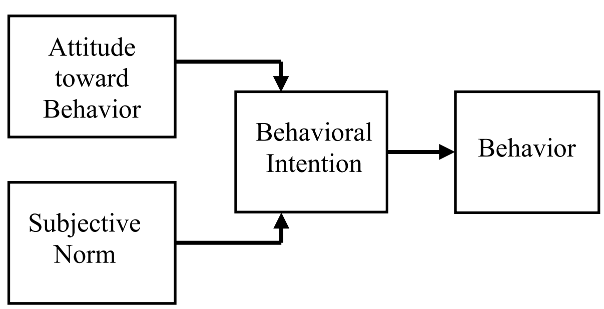

Figure 2.1 TRA model. (Fishbein and Ajzen, 1975)

TRA suggests that an individual's behavior (e.g., acceptance or rejection of technology) is determined by one's intention to perform the behavior, and this intention is influenced both by the individual's attitude and subjective norm. The subjective norm refers to the fact that a person's behavior is susceptible to other people's expectations. (Fishbein and Ajzen, 1975).

TRA has received considerable and, for the most part, justifiable attention within the field of consumer behavior, and it appears to predict consumers' intentions and behaviors quite well. In their meta-analysis examining the application of TRA Sheppard et al. (1988) found that the theory performed extremely well in the prediction of choice among alternatives. They conclude that the theory was exceptionally robust and offered strong predictive utility. The model has been used to predict human choice in situations as diverse as acceptance of expert systems (Liker and Sindi, 1997), teen sexual behavior (Gillmore et al., 2002), and fast food restaurant consumption (Bagozzi et al., 2000).

Theory of Planned Behavior (TPB) of Ajzen (1988; 1991) is the best known successor of the TRA. The original TRA was related to voluntary behavior, and TPB was the result of the discovery that behavior appeared not to be 100 % voluntary. This resulted in the addition of perceived behavioral control as can be seen in Figure 2.2.

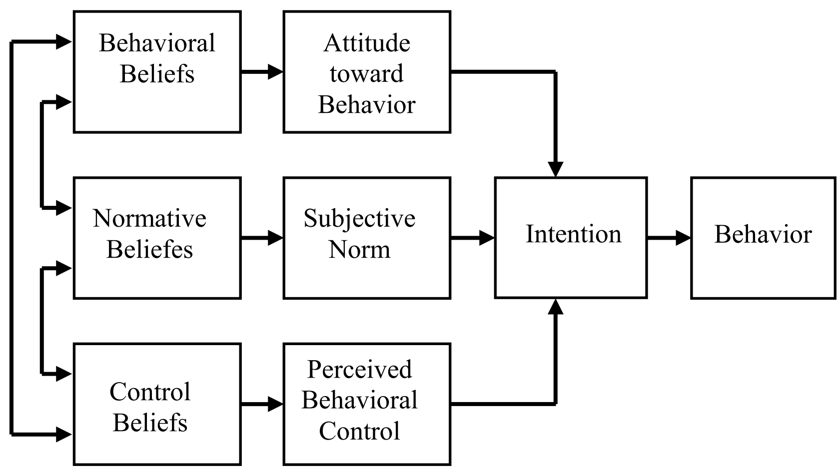

Figure 2.2 TPB model. (Ajzen, 1991)

TPB has also been applied in dozens of studies and in different disciplines such as medical science (Andrykowski et al., 2006), traffic planning (Bamberg, 2006), and environmental engineering (Flannery and May, 2000) to name but a few.

2.1.3. Technology Acceptance Model

Technology Acceptance Model (TAM) (Davis, 1989) is a popular theory used to explain the acceptance of technology amongst individuals. TAM is based on the psychological models of TRA (Fishbein and Ajzen, 1975) and TPB (Ajzen, 1988) introduced above. TAM uses TRA as a theoretical basis for specifying the causal linkages between the key features: perceived usefulness and perceived ease of use, and the users' intentions and actual use of the system.

TAM defines perceived ease of use as the degree to which the user believes using the system is free from effort. Usefulness states the degree to which the user believes using the system enhances his or her performance (Davis, 1989). According to TAM perceived ease of use and perceived usefulness are the sole determinants of attitudes towards an innovation, which in turn predicts behavioral intention shown to be a solid predictor of actual behavior as shown in Figure 2.3.

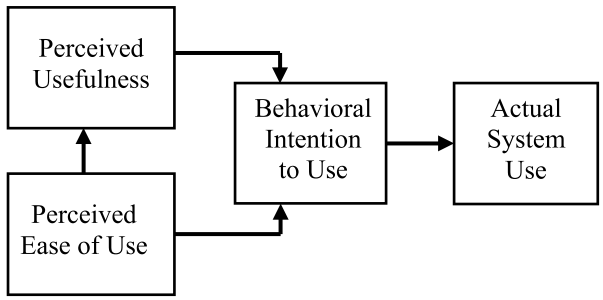

Figure 2.3 Original TAM model. (Davis, 1989)

TAM research is typically conducted in a single time period when the users are exposed to a ready-made system. This makes it useful for choosing between competing technologies at the implementation stage but less applicable at the early stages of design where designers are trying to determine how to design a technology so that it will be accepted (Dillon, 2001). Although TAM is considerably less general than TRA, it has been applied in many contexts including World Wide Web (Lederer et al., 2000), electronic commerce (Pavlou, 2003), online consumer behavior (Koufaris, 2002), cellular telephone adoption (Kwon, 2000), and PDA usage (Liang et al., 2003). Legris et al (2003) demonstrate the popularity of TAM by identifying more than 80 TAM based research papers in the leading IS journals between 1980 and 2001.

Many modifications and enhancements to the model have been suggested. A typical extension suggests a set of determinants for perceived ease of use and perceived usefulness (Pedersen, 2005). Examples of this kind of studies include (Ramayah, 2005; Venkatesh and Davis, 1996; Venkatesh, 2000). Probably the most influential extension to the original model was suggested by Venkatesh and Davis (2000). They extend the original TAM model to explain perceived usefulness and usage intentions in terms of social influence and cognitive instrumental processes. The modified model, referred to as TAM2, adds the concepts of subjective norm, image, job relevance, output quality, result demonstrability, experience, and voluntariness into the original model as presented in Figure 2.4. TAM2 has also been used in a number of studies (e.g. Chismar and Wiley-Patton, 2003, Singletary et al. 2002, Venkatesh and Davis, 2000).

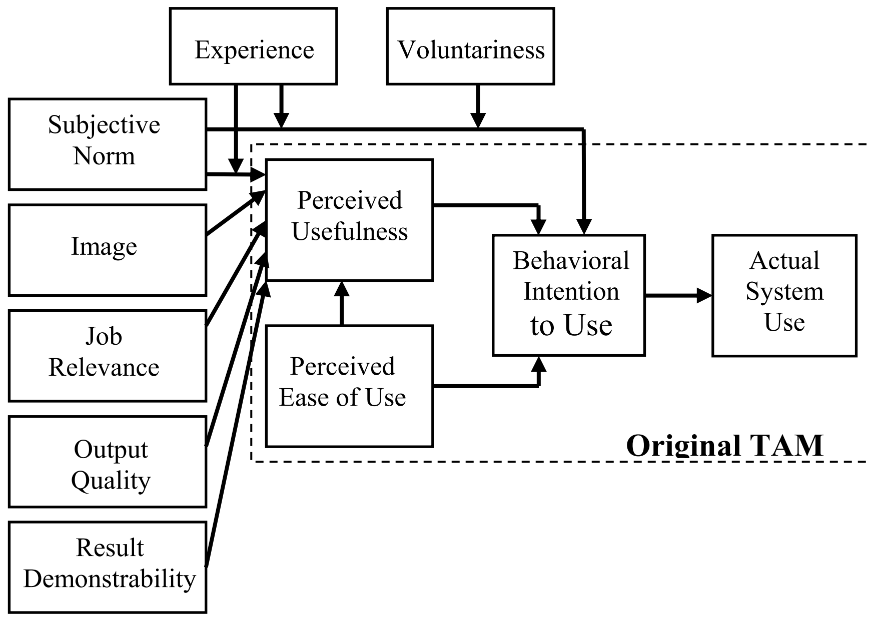

Figure 2.4 Extended TAM2 model. (Venkatesh and Davis, 2000)

2.1.4. Unified Theory of Acceptance and Use of Technology

The Unified Theory of Acceptance and Use of Technology (UTAUT) (Venkatesh et. al., 2003) is one of the latest developments in the field of general technology acceptance models. Like earlier acceptance models, it aims to explain user intentions to use an IS and further the usage behavior. The theory holds that four key constructs (performance expectancy, effort expectancy, social influence, and facilitating conditions) are direct determinants of usage intention and behavior (Venkatesh et. al., 2003). Gender, age, experience, and voluntariness of use are posited to mediate the impact of the four key constructs on usage intention and behavior as indicated in Figure 2.5.

The theory is developed through a review and consolidation of the constructs of eight earlier IS usage models. These models are (Venkatesh et. al., 2003):

- Innovation Diffusion Theory (Rogers, 1962),
- Theory of Reasoned Action (Fishbein and Ajzen, 1975),
- Theory of Planned Behavior (Ajzen, 1988),
- Technology Acceptance Model (Davis, 1989),
- Motivational Model (Vallerand, 1997),
- Combined Theory of Planned Behavior/Technology Acceptance Model (Taylor and Todd, 1995),
- Model of PC Utilization (Thompson et al., 1991), and
- Social Cognitive Theory (Compeau and Higgins, 1995).

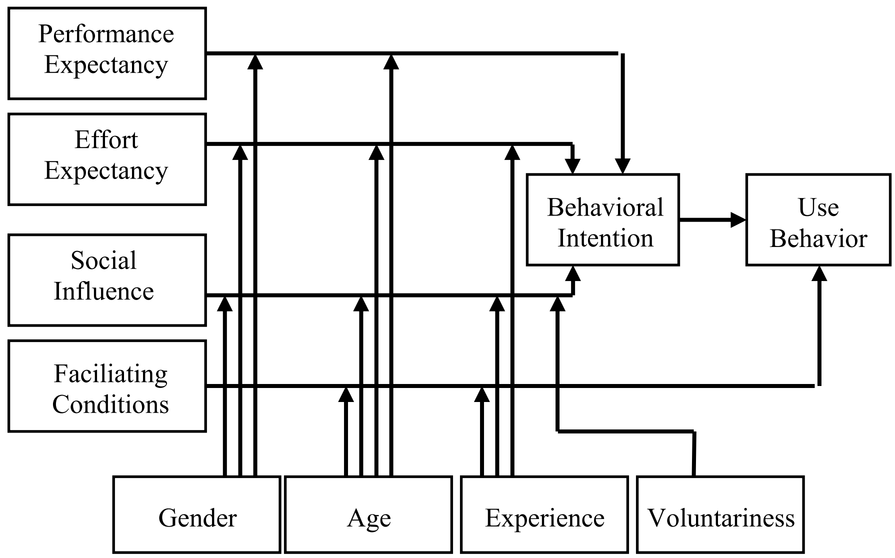

Figure 2.5 UTAUT model. (Venkatesh et. al., 2003)

UTAUT has been used to analyze the adoption of e.g. Wireless LAN technology (Anderson and Schwager, 2004), web system usage (Benslimane et al., 2004), and mobile devices and services (Carlsson et al., 2006). The results indicate that the model can be applied both to voluntary and mandatory use (Venkatesh et. al., 2003).

2.1.5. Summary of Acceptance Models

In the sections above the most influential acceptance models were introduced. Although they have their differences and they use a different set of acceptance determinants, the basic concept underlying these models links individual reactions and intentions to the actual use of the system as shown in Figure 2.6. It should be noted that the actual use of the system has an effect back on the individual reactions and thus on the future intention and use.

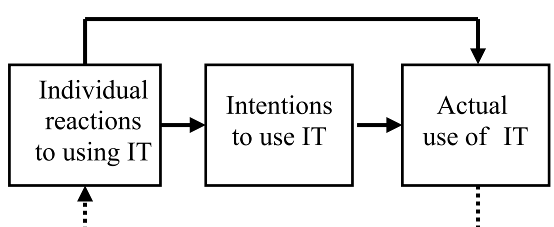

Figure 2.6 Basic concepts of user acceptance models.
(modified from Venkatesh et. al., 2003)

The models presented, although firmly established, still have some limitations. These models use a holistic view and emphasize methods that may be used for predicting the level of acceptance any information technology will attain (Dillon and Morris, 1996). Due to the holistic view information technology acceptance studies provide sound predictions of usage but do not focus on the system characteristics. Thus, they provide only limited guidance about how to influence usage through design and implementation (Wixom and Todd, 2005).

2.2. Measuring Information System Success

Information system success is an alternative approach to study the impacts of IT. In IS success studies impacts are typically analyzed either at an organizational or at a user level. This logic is also followed here, although some additional views on IS success are also mentioned.

2.2.1. IS Success from Organizational Perspective

Organizations and institutions invest large amounts of money and time in various information systems. IS investments are typically justified by the expected increase in economical effectiveness. The success of the investments is a critical concern of both academic and practitioner communities (Sylla and Wen, 2002; Microsoft, 2002). Especially managers are eager to receive detailed information on benefits achieved by IS investments. Many well-known financial measures such as the Return on Investment (ROI), the Net Present Value (NPV), the Internal Rate of Return (IRR), and the pay back time have been used to measure the success of IT investments (Martinsons et al., 1999). There is, however, one big problem related to these methods. Although development, implementation and operational costs of a system are quite easily determined, the IS related benefits are difficult to quantify as many factors affect organizational performance (Kanungo et al., 1999).

Parker et al. (1988) offer an alternative method – information economics – to link the business performance to information technology. Information economics seeks to answer the basic question about the value of information technology with two extended concepts: value and cost. Value describes the effect information technology has on the business performance of a company. Cost refers to the many ways in which information technology investment can negatively affect the organization. The method is closely related to other economic theories like Cost-Benefit Analysis (CBA) (Nas, 1996) and Cost-Effectiveness Analysis (CEA) (McEwan and Levin, 2001), which are typically applied in public sector organizations' effectiveness studies.

Some scholars (including Martinsons et al., 1999; Mills and Mercken, 2004) extend the idea of the IS success by adopting the well-known balanced scorecard method (Kaplan and Norton, 1992) for the strategic management of the IS. The balanced scorecard is a framework that gives top managers a fast but comprehensive view of strategically important indicators. It demonstrates information trends from four different perspectives (the learning and growth perspective, the business process perspective, the customer perspective and the financial perspective). The aim of balanced IS scorecard studies has been to allow managers to see the positive and negative impacts of IS activities on the factors that are important to the organization as a whole.

2.2.2. IS Success from Individual Perspective

In IS success studies, success in not only analyzed at the organizational level but frequently also at the user level. At the user level, IS success is mostly assessed from the point of view of satisfaction or individual performance. User satisfaction based approaches apply the users' perceptions as a key success determinant. User satisfaction is defined by Ives et al. (1983) as "*the extent to which users believe the information system available to them meet their information requirements*". There is a large number of user satisfaction tools and questionnaires available to measure these beliefs. Examples of these are Computer User Satisfaction (CUS) (Bailey and Pearson, 1983), the User Information Satisfaction (UIS) (Baroudi et al., 1986), and Web-Customer Satisfaction (McKinney et al., 2002).

Measuring IS effectiveness with satisfaction is well established in the literature (Bailey and Pearson, 1983) but offers only a limited view. The alternative method measures success with performance gains. But how can IT maximize the performance increases? The literature suggests that a technology is more useful if it provides features that fit the requirements of a task (Culnan 1983; Daft and Macintosh, 1981). For instance the impact of data representation on performance is dependent upon its fitness with the task (Benbasat and Dexter, 1986). Based on the results of earlier studies and their own experiments Vessey and Galetta (1991) developed a theory of Cognitive Fit. The theory proposes that the correspondence between the task and the information presentation format leads to superior task performance for individual users.

Other scholars have developed more general "fit" theories. Especially the Task-Technology Fit (TTF) (Goodhue and Thompson, 1995) is widely accepted. TTF refers to the extent to which technology functionality matches task requirements and individual user abilities (Goodhue and Thompson, 1995). According to TTF, information technology is more likely to enhance individual performance and use if the task and technology characteristics match as shown in Figure 2.7.

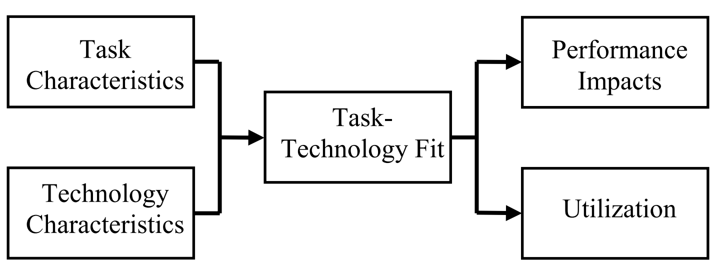

Figure 2.7 TTF model. (Goodhue and Thompson, 1995)

The measure of TTF consists of eight factors: quality, locatability, authorization, compatibility, ease of use/training, production timeliness, systems reliability, and relationship with users. Each factor is measured using between two and six questions with responses on a seven point scale ranging from strongly disagree to strongly agree. TTF model has been adapted in many contexts World Wide Web (D'Ambra and Wilson, 2004), Mobile Business Applications (Gebauer and Shaw, 2004), and Electronic Knowledge Repositories (Kankanhalli et al., 2005) to mention but a few.

2.2.3. Quality Based IS Success Models

DeLone and McLean (1992) combine the elements of organizational and individual level success dimensions in their IS Success Model. This model is one of the most widely cited frameworks for analyzing multiple dimensions of IS success. It is based on Shannon and Weaver's (1949) pioneering work on communication and Mason's (1978) extensions to it. The original model is a comprehensive framework with the following six interrelated dimensions of success: system quality, information quality, system use, user satisfaction, individual impacts, and organizational impacts. The model describes the causal relationships between these dimensions as can be seen in Figure 2.8. Many researchers have tested the causal paths of the model and found them to be broadly valid (Rai et al., 2002; Seddon and Kiew, 1994).

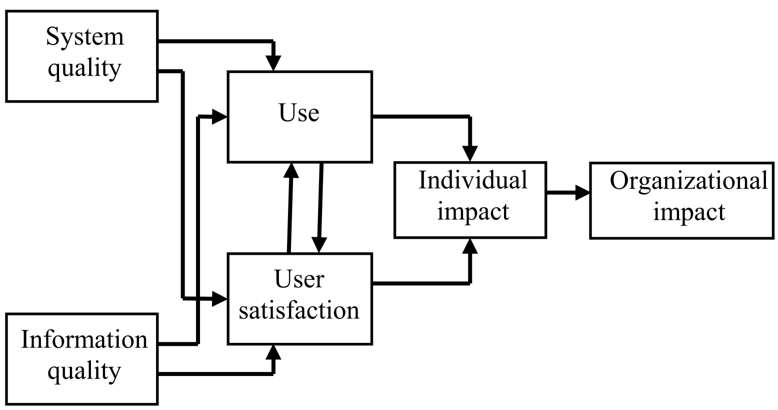

Figure 2.8 Original IS success model. (DeLone and McLean, 1992)

Many modifications and improvements to the model have been suggested (e.g. Seddon, 1997; Wilkin and Hewitt, 1999; Myers et al., 1998), but the original model has been used in a large number of studies.

Ten years after the original model DeLone and McLean (2002) revisited their own model and made minor modifications to it. The modified version of the model is shown in Figure 2.9. According to the reformulated IS success model quality has three major dimensions: information, system, and service quality. System quality describes the technical level characteristics of the information system. Information quality is related to the semantic level and the information product characteristics such as accuracy, meaningfulness, and timeliness (DeLone and McLean, 1992). The new quality concept, service quality, has to do with the information system support level where the focus is not on the product but on the services like end-user support (DeLone and McLean, 2002).

All quality dimensions of the model influence both user satisfaction and intention to use the system. Use and user satisfaction bring certain net benefits that affect the future use and satisfaction either positively or negatively.

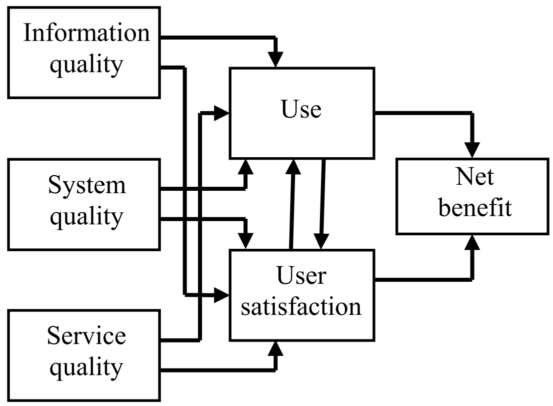

Figure 2.9 Revised IS success model. (DeLone and McLean, 2002)

DeLone and McLean (2002) point out that each of the three quality dimensions of their model have different weights depending upon the level of analysis. When measuring the success of a single system, information quality or system quality may be the most important quality component. For measuring the overall success of the IS department, as opposed to individual systems, service quality may become a more important variable.

2.2.4. Alternative Views to IS Success

Success is very subjective and varies depending on the stakeholder's perspective. Success or failure of an IS looks different from the end-user's than from the CEO's perspective. Unlike managers, end-users are typically more interested in individual impacts like satisfaction or increased performance than economical implications. Some scholars claim that organisation and user level views do not identify all important dimensions of IS success. They suggest increasing the number of stakeholders applied to the success evaluations. In a networked economy success is no longer limited to one single organization but is achieved by a number of co-operating organizations that use information technology efficiently to achieve their common goals. Because one of the main tasks of IT is to connect organizations effectively together, some researchers recommend that the IS success evaluations should include new stakeholders like suppliers (Ragatz et al., 1997) and customers (Tan et al., 1999).

The recent trends in IS development processes also challenge the traditional management centric economical measurement methods. For example, in open source software development projects success cannot be measured in terms of economy. Moreover, the role of management differs remarkably from the classical one. In their study of success in free and open source software development Crowston et al. (2006)

analyze success not only from the users' but also from the software developers' perspective. They argue that developers connect success with concepts like employment opportunities, individual reputation in the community or creation of new knowledge instead of making money.

The different views of success described above indicate that there is no agreement on a single IS effectiveness or success assessment approach. According to DeLone and McLean (1992) this stems from the nature of information. Because there are many steps in the production and dissemination of information, there are also numerous variables to measure IS success. Different dimensions and views of success make it difficult to compare the results of different studies.

Many scholars agree that the measurement of IS effectiveness and success is a highly complex issue (Kanungo et al., 1999; Ferguson et al., 2005; Milis and Vanhoof, 2007), and it cannot be studied with a single variable like productivity, financial impacts or user satisfaction. Some authors regard the triple constraints (time, cost, specification) as a standard measure of success (Wright, 1997; Turner, 1993). This approach concentrates on whether the project was delivered on time, whether it was as budgeted, and whether it met the specifications. No attention is paid to the stakeholders' opinions of both the process and the product (Wateridge, 1998).

There are also researchers who modify the general success models in order to introduce sector specific success frameworks. Examples can be found in Enterprise Planning Systems (Holland and Light, 1999; Scheer and Habermann, 2000; Hong and Kim 2002), e-commerce (Garrity et al., 2005; Kaefer and Bedoly, 2004; Sung, 2006) or web site success evaluations (Belanger et al., 2006; Park, 2007). Typically these models are derived from general success or acceptance models. They identify case specific critical success factors or new success dimensions within a restricted context.

2.3. Developing Usability

2.3.1. User-Centred Design

In IS assessments many evaluation methods have been used to study how well the completed systems meet their pre-defined goals like functionality, safety, cost, and efficiency. In recent years a new focus has emerged: evaluation methods that can be used iteratively during the whole development life cycle with the objective of improving the design and deployment of IS (Kushniruk, 2002). In these formative evaluation methods the processes of design and evaluation are highly inter-related (Kushniruk and Patel, 2004), and the actual users of the system play a central role. This method is called User-Centred Design (UCD) to distinguish it from the traditional system-centred approaches.

The term 'user-centred design' has its origins in the seminal works of Norman and Draper (1986) and Norman (1988). UCD places the user at the centre of the design and the role of the designer is to facilitate the task for the user and to make sure that the user is able to make use of the product as intended and with a minimum effort to learn how to use it.

UCD is a multidisciplinary design approach dealing with the active involvement of users to improve the understanding of user and task requirements, and the iteration of design and evaluation (Mao et al., 2005). The main goal of UCD is to create products that better fulfill the users' needs. UCD is widely considered the means to achieve better product usefulness and usability.

UCD was developed from the original concept of user friendliness in accordance with a variety of disciplines including Human-Computer Interaction (HCI), Computer Supported Cooperative Work (CSCW), Joint Application Design (JAD), and Participatory Design (PD). Although, there are some differences between these approaches, they all share the key element of user-centred design by emphasizing the central role of the user instead of the system or the product.

In the early days of the UCD, the main interest was to assure that users are able to use the product or service. The development of the UCD methods has moved the focus of the UCD field from the simple product assurance testing to integrated product design and development (Karat and Karat, 2003). The modern UCD approach requires designers to analyze and foresee how users are likely to use the product and also to test the validity of their assumptions with actual users. This shift of focus can also be seen in the names referring to usability specialists. Titles like human factor specialist or interface designer are replaced by usability engineers or UCD specialists (Karat and Karat, 2003).

Although the goal of UCD is clear, there appears to be no agreed-on definition or process for it. However, the principles presented by Gould and Lewis (1985) are widely accepted. Their principles are early focus on users and tasks, empirical measurement, and iterative design. This sort of classification is also supported in ISO 13407 (1999). It identifies the following four principal activities of UCD:

- Understanding and specifying the context of use, including the characteristics of the intended users, the task users are to perform, and the environment in which they are to use the system.
- Specifying the user and organisational requirements in relation to the context of use description.
- Producing design solutions iteratively by employing user feedback.
- Evaluating designs against requirements at all stages of the system life cycle.

2.3.2. Usability, Usability Engineering, and Usability Testing

As stated earlier the main goal of the UCD method is to create products that have high usability. Usability increases customer satisfaction and productivity, leads to customer trust and loyalty, and contributes to tangible cost savings and profitability (Marcus, 2005). But what is usability and how do we define it?

Researchers agree that usability involves many mutually dependent dimensions (Holcomb and Tharp, 1991; Nielsen, 1993). These dimensions have various classifications. According to Dumas and Redish (1999) usability means that "*people that use the product can do so quickly and easily to accomplish their own tasks*". Furthermore, ISO 9241 defines usability as "*the effectiveness, efficiency, and satisfaction with which specified users can achieve specified goals in particular environment*" (ISO 9241-11, 1998). See e.g. [P7] for a more detailed discussion of usability definitions.

One of the most important aspects of the UCD methodology, as mentioned above, is that it is iterative in nature; once user needs are researched, explained, and implemented, the process is evaluated and repeated until it yields usable results. This process is often referred to as usability engineering. As opposed to the UCD, usability engineering has a narrower focus on defining measurable usability goals and testing the product against those goals (Wixon and Wilson, 1997). Tyldesley (1988) defines usability engineering as "*a process whereby the usability of a product is specified quantitatively and in advance*". Wixon and Wilson (1997) clarify the definition of usability engineering as a process for defining, measuring, and thereby improving, the usability of products.

There are a number of methods associated with usability engineering, and foremost among them is usability testing. Usability testing refers to the evaluation of IS by means of testing representative users as they perform representative tasks using an IT system in a particular context (Kushniruk and Patel, 2004). Usability testing fits in as one part of the UCD process. In a usability test, representative users use the system, while observers, including the development staff, watch, listen, and take notes. The purpose of a usability test is to identify areas where the users struggle with the system and recommend improvements.

Usability engineering and usability testing highlight that usability related questions should be analyzed by two main groups: academic researchers and product developers. Shneiderman (1998) describes the difference between these two groups as follows.

"While academics were developing controlled experiments to test hypotheses and support theories, practitioners developed usability testing methods to refine user interfaces rapidly. Controlled experiments have at least two treatments and seek to show statistically significant differences: usability tests are designed to find flaws in user interfaces. Both strategies use a carefully prepared set of tasks, but usability tests have fewer subjects (maybe as few as three) and the outcome is a report with recommended changes as opposed to validation or rejection of hypotheses."

Although it is sometimes difficult to draw the line between these two approaches, diagnostic usability tests are not regarded as research experiments but as a formative evaluation in which the goal is to identify problems and in time fix them (Dumas and Redish, 1999). The main difference between usability testing and customer satisfaction tests is the focus. As mentioned above, the focus in usability testing is on a single product and the manufacturer wants to identify the relative level of its user friendliness. By contrast, a customer satisfaction survey does not analyze a single product but rather the quality of service in general. Despite the different focuses of these two approaches, similar methods for test design and data collection can be used in both of them.

In the thesis the usability related issues are analysed from an academic perspective. Instead of testing individual products or services and identifying their usability problems, the present work aims at more general scientific results. This can be seen in the empirical evaluations in [P2] – [P8].

2.4. Integrating Technology Acceptance, IS Success, and Usability

All approaches discussed earlier have their limitations. Therefore, some scholars suggest the integration of different approaches into a single framework. This section discusses the integration of technology acceptance, IS success, and usability concepts.

2.4.1. Combining Acceptance and Usability Concepts

The first method is to link usability and acceptance together. HCI practitioners share the view that usability is only one dimension in a more complex structure of acceptance. Figure 2.10 shows the hierarchical structure of acceptance defined in Nielsen's seminal work on usability (Nielsen, 1993). The system has two acceptability dimensions – social and practical. Practical acceptability has many determinants including cost, compatibility, reliability, and usefulness. Usefulness can again be broken down into the two categories of utility and usability. Utility concerns the question whether the system functions as expected. Usability deals with the question to what extent the users are able to benefit from the functions.

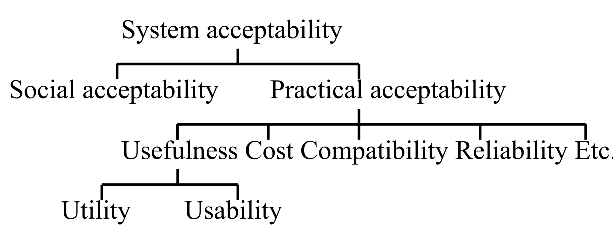

Figure 2.10 Role of usability in system acceptance. (Nielsen, 1992)

Acton et al. (2004) identify usability as an important mediator of acceptance. Based on earlier studies (e.g. Hassenzahl et al., 2001; Schenkman and Jonsson, 2000, Tractinsky, 1997) they point out that user attitudes towards a system's interface are strongly related to apparent usability and may significantly affect the overall system acceptability as shown in Figure 2.11. Especially the aspects of an interface that lead to increased usability can boost the acceptance of the system.

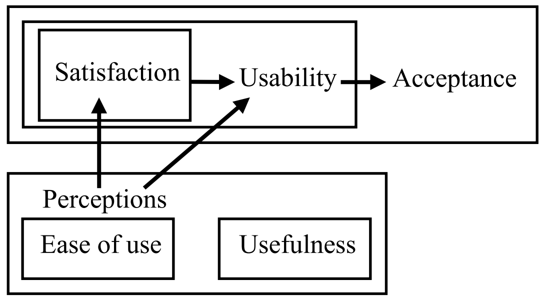

Figure 2.11 Influence of perceptions on mediators of acceptance. (Acton et al., 2004).

2.4.2. Combining Usability and Success Concepts

The second approach is to combine usability and success. One application of this approach has tried to give justification to UCD and usability investments. Many researchers (including Mantei and Teorey, 1988; Donahue, 2001; Mauro 2002; Nielsen-Norman, 2003) introduce a cost-benefit analysis to usability engineering to be able to discuss the broader usability benefits and measure the success of usability investments.

Kuan et al. (2005) use another method in their study. They employ the DeLone and McLean's reformulated model of IS success in an attempt to unify past usability studies and to classify existing usability attributes into DeLone and McLean's IS quality dimensions. Furthermore, their study tests usability dimensions against the intention to purchase. Previous studies simply examined fragmented usability attributes against the outcomes of usability (e.g. satisfaction or effectiveness).

Some scholars also combine TTF with usability. For example, Mathieson and Keil (1998) point out that although many developers focus their attention on the system's interface, perceived ease of use extends beyond the interface. According to the results of their laboratory experiment perceived ease of use is also a function of task-technology fit. When users report that a system is difficult to use, developers should not assume that the interface is the only problem. There may be deeper task-technology fit issues that cannot be corrected by changing the interface.

Likewise, Goodhue et al. (2000) connect TTF with usability, but they concentrate on the effectiveness dimension of usability instead of satisfaction. They focus on user evaluations of task-technology fit for mandatory use systems and develop theoretical arguments for the link between TTF and individual performance.

2.4.3. Combining Acceptance and Success Concepts

A new emerging field of study combines the principles of technology acceptance and IS success within a single framework. The integration of acceptance and satisfaction creates a more comprehensive view of adoption and use by combining quality dimensions, beliefs, attitude, and intentions. Models of this sort enable us to get more reliable results of the adoption and use of new information services.

One of the first contributions in this line of research was made by Dishaw and Strong (1999) when they extended the TAM with task-technology fit constructs. According to them, TAM and TTF overlap in a significant way as both of them are developed to reveal users' choices and evaluations of IT. However, Dishaw and Strong point out that although the outcome variable for both is the actual use of IT or a related variable, they differ in focus. TAM usually focuses on the early phase in the outcome chain (intention to use or actual use), whereas TTF focuses on the later phase (actual use or the individual performance attributable to actual use). The outcome was an integrated model which clarify the choices of IT use.

A similar integration approach is also used by Palm et al. (2006). They create an electronic survey instrument from TAM and IS success models to assess the acceptability of integrated Clinical Information Systems (CIS). The dimensions hypothesized in their model to be determinants of user satisfaction are user characteristics, CIS use, quality, usefulness, and service quality.

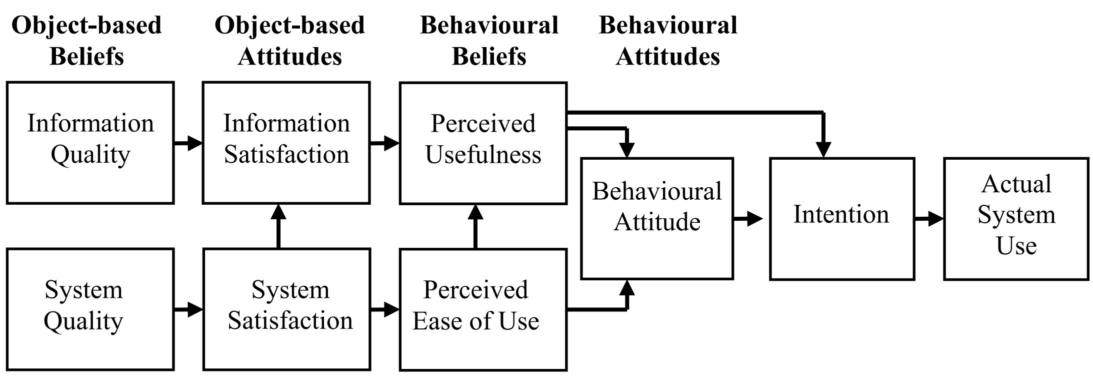

Figure 2.12 Integrated satisfaction and acceptance model. (Wixom and Todd, 2005)

Wixom and Todd (2005) made an important contribution to this stream of research. They combined TAM with satisfaction research and created an integrated model that distinguishes beliefs and attitudes towards the system (i.e., object-based beliefs and attitudes) from beliefs and attitudes towards using the system (i.e., behavioural beliefs and attitudes) as can be seen in Figure 2.12. The core logic of their model was based on the correspondence principle (Fishbein and Ajzen, 1975) which states that beliefs and attitudes towards a specific behaviour (e.g. the use of an IS) are predictive of intention and behaviour.

The main motivation of these integrated models is to build a bridge from design and implementation decisions to system characteristics (the core strength of the user satisfaction literature) as well as to the prediction of usage (the core strength of the technology acceptance literature). This approach is also applied in the development of the theoretical framework of this thesis in Chapter 4 and in [P8].

2.5. Summary

IT researchers have analyzed user perceptions of IS from many different viewpoints. In this chapter the three dominant approaches, namely, technology acceptance, IS success, and usability were introduced. All these methods have they merits, but they deal with IS adoption and use process only superficially. Thus, an integrated approach which combines elements from different methods and models better enables us to understand the main question of the thesis: why users accept or reject information systems and services.

3. ADOPTION AND USE OF MOBILE INFORMATION SYSTEMS

In Chapter 2 three dominant approaches to evaluate user perceptions of IS were introduced. The approaches and the models related were originally developed for stationary systems and contexts. The differences between stationary and mobile systems require that the established adoption and use models are fitted to the mobile context. This kind of work has already started, and established theoretical models of stationary IS are extended to the mobile contexts. This section reviews the adoption and use models for mobile systems.

3.1. Mobile IS Acceptance Models

From all the classical technology acceptance models introduced in Chapter 2 TAM in particular has received a lot of interest in the mobile IS research community, and it has been the dominant approach in mobile adoption studies (AlHinai et al., 2007). Mobile IS researchers have extended the original TAM in various ways by using primarily two approaches. The first method adds new intention determinants to the original model. The second method identifies the determinants of perceived usefulness and perceived ease of use in the mobile context. Section 2.1 introduced a few other models for stationary IS. This review, however, only covers the mobile TAM studies.

3.1.1. Models with New Intention Determinants

As explained in Chapter 2, the original TAM identified two intention determinants, perceived ease of use and perceived usefulness. Some scholars note that in mobile environment new antecedents of intention must be added. This section and [P9] present short reviews of these models.

Pedersen (2003, 2005) applies the results of domestication research in his studies on adoption of the mobile services. Domestication studies look beyond the adoption and use of IS to find out about the meaning of technologies and services and the role they play in people's lives (Haddon 2006). As a result Pedersen (2003) suggest adding perceived self-expressiveness as an independent variable into TAM. Self-expressiveness here means both the social expression of identity and self-identification. Both concepts are considered important elements in the adoption and use of mobile services.

Because mobile information systems are not only used for work but also for entertainment, some scholars propose that the entertaining features should be added into the mobile TAM model. Following this stream of research Cheong and Park (2005) name perceived playfulness as the third determinant of attitude towards the mobile Internet.

Amberg et al. (2004) created the Compass Acceptance Model which is designed especially for the analysis and evaluation of mobile services. The model has four dimensions that focus on subjective perception. The first two perceived usefulness and perceived ease of use come from the original TAM. In addition to them two new dimensions, perceived mobility and perceived cost, are included. They have their origins in concepts of benefits, efforts, service, and the general conditions of service.

In her Ph.D. thesis Kaasinen (2005) introduces a technology acceptance model for mobile services. She suggests that in consumer markets special attention should be paid to the time when users first take the system into use. For this reason, she includes a new construct perceived ease of adoption together with trust into the original TAM. She also claims that perceived usefulness should be replaced with perceived value because it better covers the motivations of acceptance in the consumer market.

Mallat et al. (2006) add three new constructs into their research model: compatibility, mobility, and the use situation. Compatibility is derived from IDT and mobility from the special characteristics of mobile IS. The use situation is treated as a separate construct referring to the specific circumstantial conditions that users meet when they move around and use mobile services.

Nah et al. (2003) include trust and enjoyment as two additional intention factors in their model. The determinants of trust included security, privacy policy, and the characteristics of mobile vendor. Enjoyment on the other hand is determined by perceived congruence of skills and challenges, focused attention, and interactivity. Phuangthong and Malisawan's (2005) list of intention factors was almost similar in their study on the 3G mobile Internet technology. Contrary to Nah et al. they, however, excluded trust.

Again, trust is included in the theoretical framework used for studying factors associated with mobile technology acceptance (Lu et al. 2003). The model extends the original TAM not only by trust but also by three other dimensions, namely system complexity, social influence, and facilitating conditions.

Table 3.1 summarizes the antecedents of attitude used in the mobile TAM models discussed above. Although this review is by no means exhaustive, some conclusions can be drawn. According to Table 3.1 perceived usefulness and perceived ease of use are prevalent in these models, whereas the other intention determinants are less widespread. AlHinai et al. (2007) support these finding as they point out that TAM and its usefulness and ease of use concepts are the most frequently used theories in studies on individuals' voluntary adoption of mobile commerce services.

Although the scholars have used different terms in their extended TAM models, they share some concepts. For example, both playfulness and enjoyment are related to the feeling of pleasure and satisfaction. Similarly, self-expressiveness has a social dimension resembling social influence, but in addition to social expression of identity it includes self-identification as well. Interestingly, a few new attitude determinant candidates can be found also in the usability literature. For example, Nielsen (1993) classified cost, compatibility, and social dimensions in his system acceptability framework.

The new attitude determinants emphasize also the typical usage mode of mobile services. Hassenzahl et al. (2002) define two different modes of IS usage: a goal mode and an activity mode. In goal mode individuals are task oriented and the system is just a mean to reach some predefined goal. In this case pragmatic aspects like ease of use and usefulness are essential attitude determinants. In mobile context the services are often used for entertainment purposes. Then the usage or activity itself is important and goals are defined on the fly. In this kind of activity mode the hedonic dimensions like playfulness and self-expressiveness get a more important role.

Table 3.1 Antecedents of attitude in some mobile TAM models.

Perceived antecedent	**Pedersen (2003)**	**Cheong Park (2005)**	**Amberg et al. (2004)**	**Kaasinen (2005)**	**Mallat (2006)**	**Nah (2003)**	**Phuang-thong Malisawan (2005)**	**Lu (2003)**
Usefulness	X	X	X	X*	X	X	X	X
Ease of use	X	X	X	X	X	X	X	X
Self-expressiveness	X							
Mobility			X		X			
Cost			X					
Ease of adoption				X				
Trust				X		X		X
Playfulness		X						
Compatibility					X			
Use situation					X			
Enjoyment						X	X	
Complexity								X
Social influence								X
Facilitating conditions								X

* Usefulness is renamed as perceived value.

3.1.2. Determinants of Ease of Use and Usefulness in Mobile IS

As stated earlier the second approach which applies TAM in mobile IS aims at finding out the factors affecting perceived usefulness and ease of use in the mobile context. Lee et al. (2002) suggest that the key determinants of ease of use are self-efficacy, facilitating conditions or support, focus, and fun. Usefulness is similarly based on social influence, personal innovativeness, and service quality.

Nah et al. (2003) list four key determinants of perceived ease of use in mobile computing. They are the input device, the output device, navigation, and bandwidth. Perceived usefulness, however, consists of service offering, the degree of mobility, compatibility, coverage, and reliability. In her study on the adoption of 3G mobile multimedia services, Pagani (2004) identifies very similar factors influencing the users' perceived ease of use and usefulness. She replaces Nah et al.'s term navigation by a larger concept of software facilities. In addition to navigation, software facilities also cover commands, symbols, and help functions. According to Pagani usefulness consists of four main factors: service offerings, the degree of mobility, compatibility, and price. The first three were suggested also by Nah et al.

In his research questionnaire Pedersen (2005) measures usefulness of the mobile Internet services with five items of time saving, improvement, efficiency, usefulness, and quality. His ease of use items were derived from the original items of Davis et al. (1989) and adapted to the mobile IS setting.

Table 3.2 Determinants of ease of use in some mobile TAM models.

Determinants	**Lee (2002)**	**Nah (2003)**	**Pagani (2004)**	**Pedersen (2005)***
Self-efficacy	X			
Facilitating conditions	X			
Focus	X			X
Fun	X			
Input device		X	X	
Output device		X	X	
Navigation		X		X
Bandwidth		X	X	
Software facilities			X	
Learnability				X
Ease of interaction				X
General ease of use				X

* Determinants are derived from the questions of the research instrument used in the study.

Table 3.3 Determinants of usefulness in some mobile TAM models.

Determinants	Lee et al. (2002)	Nah (2003)	Pagani (2004)	Pedersen (2005)
Social influence	X			
Personal innovativeness	X			
Service quality	X	X*	X*	X
Degree of mobility		X	X	
Compatibility		X	X	
Coverage		X		
Reliability		X		
Price			X	
Time saving				X
Improvement				X
Efficiency				X
Usefulness				X

*Term offering is used instead of quality but it is related to the quality aspects of the service

Tables 3.2 and 3.3 indicate that there is no common understanding about the determinants of perceived ease of use or usefulness. The only factor found in all studies was the one dealing with quality. This seems to support the author's earlier assumption that quality plays an important role in mobile IS acceptance. Interestingly enough some constructs that were earlier listed as new intention determinants (like mobility and compatibility) are classified here as the determinants of usefulness. Future studies are obviously needed to harmonize the terminology and concepts in this field of study.

3.2. Mobile IS Success Studies

3.2.1. Holistic Success and Satisfaction Studies of Mobile IT Markets

Mobile IS success has been studied from many perspectives. Some scholars have analyzed the success and satisfaction of the mobile IS markets as a whole. A mobile IT market success study has not typically aimed at identifying the success factors of a single system or application but success has been studied from a larger perspective. Such studies examine the national, industry or company level success stories and they primarily focus on explaining why some companies or countries have been more successful in the mobile IT field than others, and what factors lie behind their competitive advantage. Similarly, industry level satisfaction studies analyze the satisfaction from a holistic perspective. A few scholars have applied the cross-company cross-industry national measurement tools like American Customer Satisfaction Index (ACSI) (Fornell et al., 1996) or European Customer Satisfaction Index (ECSI) (ECSI, 1998) for mobile IT markets. Table 3.4 lists examples of holistic success and satisfaction studies on mobile IT markets.

The studies listed in Table 3.4 and their research methods analyze success typically in terms of competitive advantage or strategy and compare the situation in one country or company with others. The aim of the present discussion is to find out why users accept or reject mobile IS. It is also concerned with the processes and determinants underlying acceptance. Thus, it is beyond the scope of the thesis to account for the national, industry, or company level success analyses in detail.

Table 3.4 Mobile IT market success studies.

Study	Focus
Lindmark and Bohlin (2003)	National success factors (Japan)
Leppävuori (2002)	National success factors (Finland)
Carvalho (2006)	National success factors (Portugal)
Cheong and Park (2005)	National success factors (Korea)
Turel and Serenko (2006)	National customer satisfaction ratings (Canada)
Aydin and Özer (2005)	National customer satisfaction ratings (Turkey)
Heng (2004)	General Industry Success Factors
Wallis-Brown and von Hellens (2000)	Company success factors (Nokia Mobile Phones and Ericsson Mobile Communication)
Tariq (2005)	Company success factors (Vodaphone)
Butter and Pogue (2002)	Company success factors (Handspring)

3.2.2. Classical Success Models in Mobile Context

In Section 2.2 two dominant approaches for IS success analysis (TTF and IS success model) were presented. It still remains to be investigated to what extent previous theories of information system use and impacts are applicable to mobile systems (Mylonopoulos and Doukidis, 2003).

Scholars have mapped the classical success models to mobile context in many ways. In some cases the mobile environment is added as a new element into the model. For example Aasheim (2007) extend the original IS success model with contextual features, but Gebauer and Shaw (2002) do not extend the model. Instead, they take an internal view and study the effect of a general trade-off between functionality and portability of the underlying devices on the task-technology fit. They insist that the relationship between information processing requirements and processing capabilities is an important mobile IS success factor. In her more recent studies Gebauer pays special attention to the role of user mobility in TTF (Gebauer and Tang, 2008).

Some scholars have analyzed how mobile context affects quality elements of the IS success model. Cheong and Park (2005) have two quality constructs, content quality and system quality, in their research model of the mobile Internet acceptance. Perceived content quality replaced information quality used by DeLone and McLean because information is often regarded as content in the Internet context. Chae and Kim (2001) also used content quality in their quality framework for the mobile Internet services, together with connection quality, interaction quality, and contextual quality.

All the studies discussed here have revealed two important findings. First, the classical models developed for stationary information systems provide a solid foundation for mobile IS studies. Second, the models must be modified to some extent to fit the special characteristics of mobile IS.

3.3. Mobile IS and Usability

3.3.1. Special Characteristics of Mobile IS Usability

Mobile usability studies have mainly focused on the special characteristics of mobile systems. This is understandable because earlier studies have indicated that the mobile Internet users get disappointed because of the limitations that distinguish mobile devices, networks, and services from conventional desktop PCs (Chae and Kim 2003). Table 3.5 shows the key limitations of mobile devices and networks mentioned in some earlier mobile IS studies. The studies are listed in chronological order.

Table 3.5 Review of limitations of mobile devices and networks.

Study	Limitations of mobile devices	Limitations of mobile networks
Joseph et al. (1997)	Unreliable, low battery power, risk to lose data, low computing power	Low bandwidth, high latency, lack of network coverage
Forman and Zahorjan (1999)	Low battery power, risk to data, small display, difficult input methods	Reliability, low bandwidth, bandwidth variability, heterogeneity, security
Siau et al. (2001)	Small screen, small multifunctional keypad, less computational power, complicated input methods, higher risk of data storage and transaction errors, lower display resolution, less surfability, unfriendly user interface, graphical limitations	Less bandwidth, less connection stability, less predictability, lack of standardized protocols, higher cost
Pilioura et al. (2003)	Difficult input methods, less memory, limited processor power, small display, low battery power	Limited bandwidth
Tarasewich et al. (2002)	Smaller screen sizes, lack of color, limited keyboards	Bandwidth constraints
Chae and Kim (2004)	Small screens, limited storage, a short battery life, slow CPU speed, cumbersome input facilities	Low bandwidths
Heath et al. (2005)	Minimal input and output options, small screen size, potential file and system disasters, loss of battery power.	
Qiu et al. (2006)	Limited input and output capabilities, low processor power limited memory	Limited bandwidth

Although the studies in Table 3.5 only constitute a minute fraction of the research carried out during the last decade they still reveal some interesting facts. First, the main device challenges – difficult input methods and small displays – have not changed during the last ten years. Although today's mobile devices have better displays and text entry methods, there is still the physical limitation of making a device that will fit the user's hand and provide a large display and uncomplicated user interface. Second, although mobile network technologies have developed rapidly during the last ten years, the bandwidth constraints are still an important issue in mobile IS. The following sections will discuss these three main characteristics of mobile IS in detail.

3.3.2. Limited Input Methods and Mobile Text Entry

One of the key challenges of mobile device manufacturers is to identify the optimal input method for their devices. The small size of mobile devices prevents the usage of the standard QWERTY keyboards, handheld mice, or other traditional computing input devices. Mobile text entry has also become a flourishing research area. A large number of studies and multiple metrics have been developed for analysing both the performance and the preference of an input method. In performance measurements the aim is to collect objective metrics of system performance. In preference measurements attention is paid to users' subjective preferences and opinions.

System performance can be measured in many ways. According to the International Standardization Organization (ISO, 1998), performance can be divided into two concepts: efficiency and effectiveness. The measures of efficiency reveal how efficiently the resources are used. From the user's point of view, the time and effort spent on the task are the resources s/he consumes. The measures of effectiveness for their part relate the goals or sub-goals of using the system to accuracy and completeness with which these goals can be achieved (Bevan and Mcleon, 1994). In text entry evaluations efficiency is usually measured with input speed or text entry rate metric. The most often used speed metrics are Words Per Minute (WPM) or Characters Per Second (CPS). These metrics are actually identical because the definition of a word for this purpose is five characters, including spaces or any other characters in the text.

In text entry tasks the effectiveness is normally analyzed in terms of accuracy. If the calculations of entry speed are straight forward, accuracy is another matter. Still, the intuitively simple measure "percent errors" is problematic and different methods are used two calculate the error rates. Two recently introduced methods to measure accuracy in text entry evaluations are the Minimum String Distance (MSD) (Soukoreff and MacKenzie, 2001) and the keystroke classification methods (Soukoreff and MacKenzie, 2003, 2004). The MSD method is based on the Levenshtein String Distance Statistic. The algorithm yields the minimum distance between two strings defined in terms of editing primitives. The primitives are insertion, deletion, and substitution. The idea is to find the smallest set of primitives that applied to one string (transcribed text) produces the other (presented text). The number of primitives in the set is the minimum string distance (MSD). Using the

MSD statistic a text entry error rate, given a presented text string (A) and a transcribed text string (B) can be calculated according to Equation 3.1.

$$\textit{MSD Error Rate} = \frac{MSD(A,B)}{Max(|A|,|B|)} \qquad (3.1)$$

The keystroke classification method is based on delineating participants´ keystrokes into the following four classes:

- Correct (C) keystrokes – alphanumeric keystrokes that are not errors,
- Incorrect and Not Fixed (INF) keystrokes – errors that go unnoticed and appear in the transcribed text
- Incorrect but Fixed (IF) keystrokes – erroneous keystrokes in the input stream that are later corrected, and
- Fixes (F) – the keystrokes that perform the corrections (i.e. delete, backspace, cursor movement)

Based on this classification several statistics can be easily calculated as shown in Equations 3.2. – 3.4.

$$\textit{Total Error Rate (TER)} = \frac{(INF + IF)}{(C + INF + IF)} * 100\% \qquad (3.2)$$

$$\textit{Not Corrected Error Rate (NCER)} = \frac{INF}{(C + INF + IF)} * 100\% \qquad (3.3)$$

$$\textit{Corrected Error Rate (TER)} = \frac{IF}{(C + INF + IF)} * 100\% \qquad (3.4)$$

The performance measurements discussed above are objective by nature, as opposed to the preference measurements that are based on subjective data. In ISO’s usability definition, preference measures are related to the basic usability concept of satisfaction. The measures of satisfaction describe the perceived usability of the overall system or some specific aspects of the system (Bevan and Macleod, 1994).

The standard tool for analyzing the users´ perceptions is a preference or usability questionnaire. A number of questionnaires have been developed during the last decades. Some questionnaires like System Usability Scale (SUS) (Brooke, 1986) give one single value for usability as a whole. Others, like Software Usability Measurement Inventory (SUMI) (Kirakowski, 1996), provide multiple scores. Also the number of questions in the questionnaires varies. For example, the After-Scenario Questionnaire (ASQ) (Lewis, 1995) which concentrates on user satisfaction has only three questions, while questionnaires with a broader scope, like SUMI or SUS, have more questions. See for instance, [P7] for more details of the questions used in the questionnaires.

3.3.3. Data Representation and Navigation with Mobile Devices

One of the key characteristics of a mobile device is its small display size. Small displays are not limited only to mobile IS but they are also used in a number of applications in consumer and industrial product environments. Small screens aim to satisfy the need to display information in a restricted space.

The effects of the screen size to user perception have received a lot of scholarly attention, focusing on reading speed (Duchnicky and Kolers, 1983; Dyson and Haselgrove, 2001), comprehension rate (Tombaugh et al., 1985), information retrieval methods (Jones et al., 1999), and information and menu structures (Chae and Kim, 2004). Although there are some differences in the results, they clearly reveal that the small screens decrease user effectiveness (Jones et al., 1999).

Mobile IS researchers have revealed two main reasons for the decreased efficiency, namely, data representation limitations and navigation problems. Small screens create obvious constraints for data representation on handheld devices like smart phones and PDA devices especially in the Internet environment. Most web pages today have been designed with the desktop computer in mind, and are hence too large to fit into the small screen of a mobile device. Consequently, the mobile Internet users are required to manually scroll the window to find the content of interest and position the window properly for reading information. This tedious and time-consuming process negatively influences usefulness of these devices (Chen et al., 2003).

Many adoption methods have been suggested to improve the browsing experience including distilling web objects (Fox et al., 1998), web page reformatting (Hori et al., 2000), re-authoring (Bickmore and Schilit, 1997), text summarization (Buyukkokten et al., 2001), and zooming (Chen et al., 2003). Although these as well as other methods can increase the performance of mobile systems, many studies have indicated that the user experience is quite different from that on desktop PCs. For example, users with small displays tend to use more zooming and scrolling actions while browsing a text (Dillon, 1990) or images (Xie et al., 2005),

Small display sizes affect not only data representation but also user interaction. Although some novel methods like menu translucency (Acton et al., 2005) have been developed for mobile devices, navigating on the small screen is considerably slower than on the normal screen (Gutwin and Fedak, 2004). To increase navigation efficiency studies on the optimal menu designs and navigation structures have been conducted, but the results are still somewhat inconsistent.

3.3.4. Network Performance and Quality of Service

Service quality or Quality of Service (QoS) is typically seen as an important success factor in telecommunication services. It has thus been the main area of interest of network operators and telecommunication organizations like International Telecommunications Union – Telecommunciation (ITU-T). Network related QoS has also received a lot of attention among the mobile IS scientists because bandwidth limitation is considered one of the most important obstacles for mobile IS adoption.

According to the different definitions (e.g. ITU-T, 1994; RACE, 1994), QoS covers both subjective and objective aspects of a service. This means that there are also several viewpoints from which to analyze quality. In recommendation G.1000, ITU-T (2001) presents four viewpoints of QoS as shown in Figure 3.1.

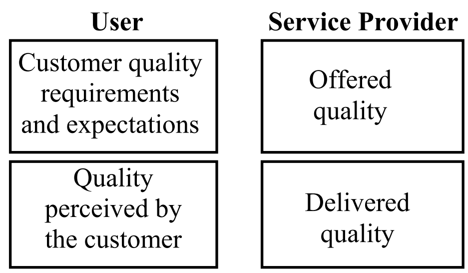

Figure 3.1 Viewpoints of Quality. (modified from ITU-T, 2001)

According to Figure 3.1 quality is a combination of user side (quality requirements/expectations and perceived quality) and system side elements (offered and delivered quality). User satisfaction or high perceived quality can only be achieved when there is a fit between the user and the system side quality constructs. The aspects of quality can further be linked to network performance as shown in Figure 3.2.

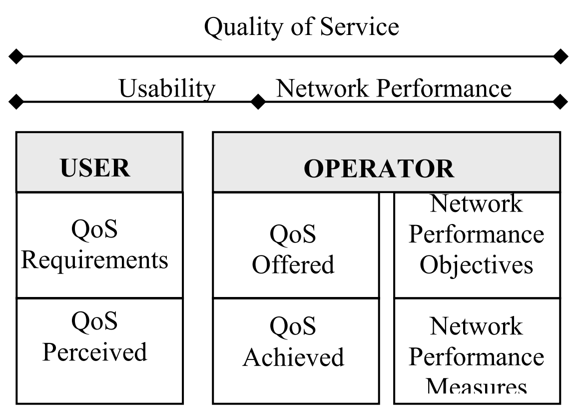

Figure 3.2 Viewpoints of QoS. (Based on ETSI, 1994)

Figure 3.2 shows how QoS combines users and networks. Part of QoS can be addressed under the auspices of usability, while the rest can be more directly measured by the actual network performance. Usability is more in the eyes of the user, while the operator is concerned with the speed and reliability that the network delivers. QoS brings these two concepts together in one model. Some scholars have used terms like Quality of Experience (QoE) (Jain, 2004; Hossfeld et al., 2007) or Quality of Business (QoBiz) (van Moorsel, 2001) instead of QoS when extending the quality beyond the objective network related dimensions. However, in this thesis QoS covers both subjective and objective dimensions of quality.

QoS has been studied intensively on factors such as bandwidth, jitter, and packet loss (see Wood and Chatterjee, 2002 for a review), but little from the user's point of view. Likewise, in mobile systems the technical characteristics identified in Table 3.5 like unpredictable link properties, node mobility, limited battery life, hidden and exposed terminal problems, route maintenance, and security have been the scientists' main areas of interest.

Although network performance has an important role in perceived QoS, they are not the same construct, and by design they are measured differently. Network performance is an absolute that can be measured in terms of bits and seconds, with metrics like bps, delay, and jitter, while user perceptions are psychological constructs that must be measured indirectly using psychological instruments. Thus, one must use different methods to analyze QoS expected and perceived by users.

The two main methods of analyzing QoS from the users' point of view are opinion polls and customer satisfaction surveys. In an opinion poll, anyone is asked for an opinion, and in satisfaction surveys users report their satisfaction levels shortly after they experienced the service. Both methods have their strengths and weaknesses. Therefore, in the empirical test of the thesis both of them are applied.

3.4. Summary

In this chapter mobile IS adoption and use from three different perspectives: technology acceptance, IS success, and usability is examined. The literature review of mobile IS adoption studies revealed three important findings. First, there is one dominant approach to study mobile IS acceptance (TAM), but there are different views about how to adjust it to the mobile context. Second, TTF and the IS success model are most commonly used to analyze IS success at user level. And third, difficult input methods, small displays, and network performance limitations pose the three main challenges for the mobile usability.

4. MODEL FOR MOBILE INFORMATION SYSTEM ADOPTION AND USE

In this chapter and in [P8] an integrated model for mobile IS adoption and use is developed. The model is based on the three research traditions introduced in Chapter 2 (technology acceptance, IS success, and usability) and the special characteristics of mobile systems. The model establishes a solid framework for further studies on the determinants of mobile IS adoption and use.

4.1. Limitations of the Earlier Models

Although one has to acknowledge the merits of previous studies, one has to recognize that they have some important theoretical and practical limitations. First, the current models are typically limited either to satisfaction or acceptance. As discussed in Section 2.4, the integration of different research approaches in stationary context has received some interest among IS scholars and practitioners but it has not been widely accepted in mobile IS studies. However, pioneering work in this field has recently been published (e.g. Gebauer et al., 2007; Pousttchi and Wiedemann, 2007).

Second, the distributed structure of mobile IS Service Supply Chain (SSC) has not received enough attention in the earlier models. SSC is the composition of services adapted to the needs of the user. Typically, it consists of one or several service elements potentially offered by different providers (Fiedler et al., 2007). Mobile IS SSC consists of three distinguishable parts: mobile devices, networks, and information services as shown in Figure 4.1. These components are typically provided separately by creating a multi-vendor and multi-dimensional quality structure.

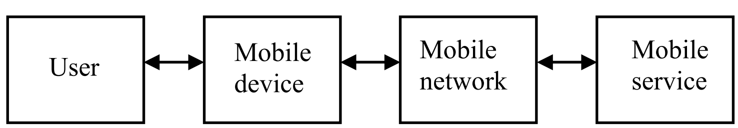

Figure 4.1 Service supply chain of mobile IS.

As discussed in Sections 3.3.2 and 3.3.3, the main limitations of the handheld devices are those of the user interface (small displays and difficult input methods). Input and output facilities of the devices have a vital role in user satisfaction, and mobile device manufactures must continue to develop them even further.

Similar challenges can also be found in the network portion of the mobile service supply chain. We have witnessed a fast development of mobile communication networks during the last two decades. Nonetheless, compared with their wired counterparts they still have serious limitations, including unpredictable link properties, lower network speeds, longer delays, and higher packet loss ratios. These network performance related parameters and QoS of the network affect perceived QoS and user satisfaction as discussed in Section 3.3.4.

Early mobile information services were based on the existing stationary systems, and special devices or gateways converted information of the stationary Internet content servers to formats supported in mobile devices. Such solutions did not fulfill the mobile users' needs. Tasks carried out with mobile devices differ from stationary information system tasks. For example mobile users are more likely to be under time pressure and thus may be more prone to making errors when accomplishing a task (Chae and Kim, 2004). More general mobile contexts differ from desktop-contexts: internal factors such as tasks, needs, and goals are different, as are external factors such as social resources and present objects and events (Oulasvirta, 2004).

4.2. Principles of the New Model

The new model for Mobile IS Adoption and Use (the MISAU model) has the following principles:

a) The theoretical foundation of the model is the original TAM model. Although there has been some criticism against the original TAM, many studies have validated the model in many contexts. TAM has also been the most widely applied acceptance model in mobile contexts as pointed out in Section 3.1.

b) The most important limitation of TAM is its holistic view of the acceptance process. Technology acceptance studies provide sound predictions of usage but do not focus on the system characteristics and thus provide only limited guidance about how to influence usage through design and implementation. To overcome this limitation the traditional TAM model is extended with elements of Delone-McLean's IS success model. The integration of the models is based on the classification of object-based beliefs and attitudes and behavioural beliefs and attitudes as introduced in Section 2.4.3.

c) Only the original intention determinants, perceived ease of use and perceived usefulness, are included into the model. This decision stems from the literature review of extended mobile TAM models (see Section 3.1.1). Although many scholars have suggested new intention determinants like perceived playfulness and trust, scholars disagree on them.

d) The quality and satisfaction constructs of the model follow the structure of the mobile IS supply chain discussed in Section 4.1. Perceived overall quality of mobile IS is affected by all three components of the chain: handheld devices, mobile networks and information services offered to the users. For this reason all of them should be present in the framework of mobile IS adoption and use.

4.3. The MISAU Model

Based on the principles above, an integrated model for Mobile Information System Adoption and Use (MISAU) is developed here and in [P8]. The model is shown in Figure 4.2. In the MISAU model quality and satisfaction are analyzed from three different perspectives of device, network, and information service which together form the service supply chain of mobile IS.

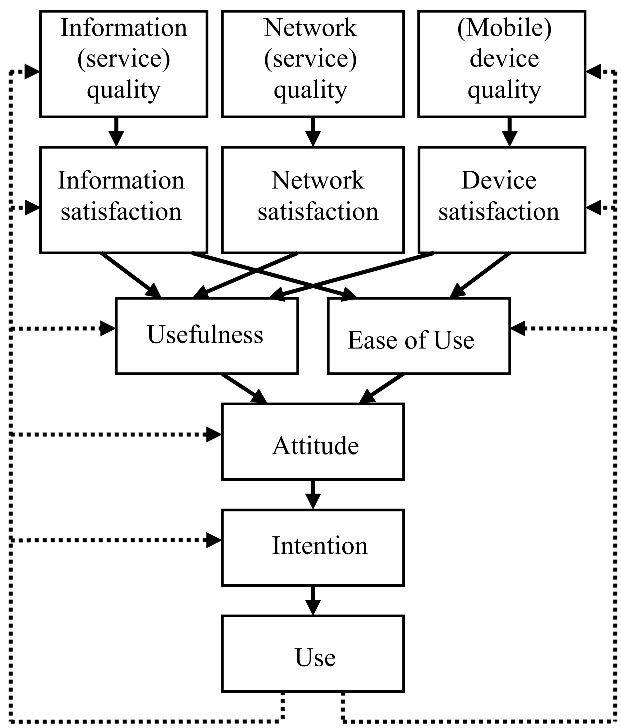

Figure 4.2 MISAU model.

Using the logic presented in Section 2.4.3 quality and satisfaction can be classified as object-based beliefs and attitudes. Moreover, satisfaction concepts influence intention and behaviour through behavioural beliefs and attitudes. The behavioural belief of the MISAU model consists of the original intention determinants of the TAM (i.e. perceived usefulness and perceived ease of use). They are the main determinants of attitude. Attitude then has an impact on intention and eventually the actual use of the system.

According to the model mobile device manufacturers, network operators, and information service companies provide devices and services for mobile IS users. The characteristics of these devices and services influence the perceived quality and satisfaction. Product or service development in one area can improve quality and boost satisfaction.

Although the MISAU model has three separated quality and satisfaction dimensions, the model does not question the holistic nature of the user experience. For the user the interface is the system, and all quality dimensions are communicated to the user through the interface. Users evaluate systems' usefulness and ease of use as a whole rather than separate parts of the service supply chain. For example, a mobile phone with new features and higher quality may increase user satisfaction towards the phone but the problems elsewhere in the supply chain may prevent a similar development in usefulness and ease of use of the mobile IS.

Mobile IS adoption does not happen at once but it is a time consuming process. Every time the system is used the user's experiences have an impact back on all levels of the model including quality, satisfaction, usefulness, ease of use, attitude, and intention.

4.4. MISAU Model and Context of Use

Although it is commonly assumed that quality is an attribute of a product and not affected by the use of the product, earlier studies have revealed the multi-dimensional nature of quality. Quality is not limited only to product-centric dimensions (offered and delivered quality) but it also includes the user-centric dimensions (quality expectations and perceived quality) [P9]. As a result, quality depends on how the product is used (Bevan, 1995) and the adoption and use of the product or service must always be analyzed in the right context. Fishbein and Ajzen (1975) point out that for accurate prediction, beliefs and attitudes must be consistent in time, target, and context.

Usability professionals have applied a concept of context of use in their research. The context of use identifies the intended users of the product, the tasks, the equipment and environment. A number of different sets of contexts of use have been suggested as listed in Table 4.1.

Bevan (1985) emphasizes the importance of device context. In mobile IS the special limitations of mobile devices are vital acceptance factors and must be analyzed in detail. On the other hand the other elements of mobile IS supply chain (network and information service) should also be kept in mind. Therefore Bevan's device context should be replaced by a larger concept of system context, following the principles of UCD mentioned in Section 2.3.1. In mobile IS system context is formed by the three dimensions of mobile supply chain device, network, and information service.

Table 4.1 Suggested sets of context of use.

	Bevan (1985)	**Kirakowski and Cierlik (1999)**	**Maguire (2001)**
User Context	skill and experience, personal traits	job characteristics, role, skill and knowledge, physical attributes, attitude and motivation	type, role, experience knowledge and skills, personal attributes
Task Context	(Task context dimensions not specified in details)	task execution, task flow, task demand on users, task safety	task characteristics
Device Context	general, specifications	(Defined as part of environment context)	(Defined as part of environment context)
Environment Context	technical, physical, organizational, social	technical, physical, organizational, social	technical, physical, organizational

In Figure 4.3 the MISAU model is attached to the context of use framework. System context is the part that information providers, network operators, and device manufacturers implement. According to the UCD principles they gather feedback from the actual use of the system to develop the system further in order to better meet their customers' needs. Perceived quality, satisfaction, usefulness, ease of use, attitude, intention, and use are all related to the specific task that users do in some environment. They are thus analyzed in the user, task, and environment context.

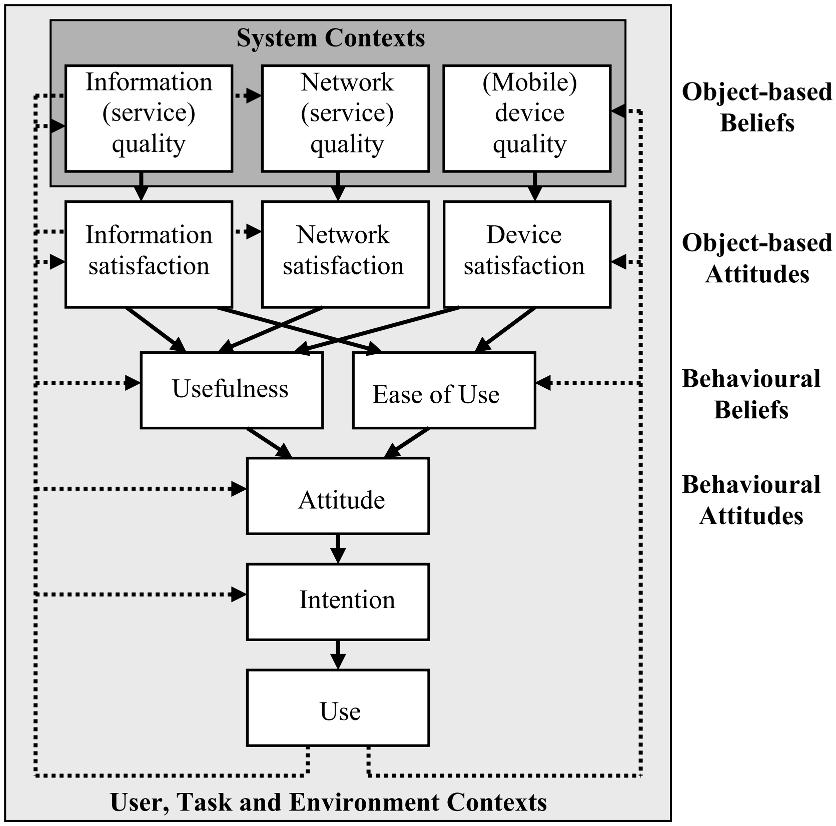

Figure 4.3 MISAU model in context of use. (Koivisto, 2008)

The MISAU model connected to the context of use provides us with a strong framework for analyzing the factors and determinants of the adoption and use of mobile IS. The empirical evaluations of the model reported in Chapter 5 (as well as in [P7] and [P8]) support the structure and causal paths presented.

4.5. Limitations of the MISAU Model

Philosophers of science have recognized that theory formulation involves conceptual processes of abstraction and idealization. A useful model must be both complete and parsimonious. It should include the results of earlier studies and cover all important elements of the phenomena it describes. At the same time it should be simple to maintain its explanatory value.

It may be argued that the MISAU model oversimplifies the attitude formulation by limiting its determinants only to perceived usefulness and ease of use. Undoubtedly a lot of valuable work is done to extend the original TAM model with new factors, but the research community has not yet been able to reach a mutual understanding of what the new items should be. Consequently, in the MISAU model only perceived ease of use and perceived usefulness are used.

Moreover, the division of device, network, and information quality into three separate categories may be criticized. It may be claimed that users are unable to distinguish between these characteristics but tend to view quality as an entity. The criticism is in accordance with the results of [P3]. [P3] shows that network utilization and requirements are related to the interaction techniques and user interface characteristics. Now that mobile communications are shifting from text to still images and video clips and mobile devices are becoming more and more sophisticated, mobile networks are faced with new challenges. New communication methods and applications like video sharing require higher transmission speeds. Likewise, the asymmetric structure often used in radio access networks today must be altered. A more detailed analysis of this can be found in [P3] where the relationship between user interface characteristics and network utilization in mobile networks is modelled.

However, in the MISAU model the interaction between different parts of mobile service supply chain are handled at context level. Since devices, networks, and services are typically provided by three different vendors, it is essential that these components are analyzed separately. Then overall quality and satisfaction are analyzed in system, user, task, and environment contexts.

4.6. Summary

The main achievement of this chapter is the development of a new model for Mobile Information System Adoption and Use (MISAU). The MISAU model integrates acceptance, success and usability approaches discussed in previous chapters into a single framework. The model also highlights the importance of the context of use. Thus, the adoption and use of mobile IS are always affected by the system, user, task, and environment contexts.

5. EVALUATIONS OF BELIEF AND ATTITUDE DETERMINANTS

The MISAU model developed in Chapter 4 combines object-based and behavioral beliefs and attitudes, together with intention to use the system and actual use. In this chapter, the belief and attitude determinants of mobile information systems are analyzed in different settings. The experiments are reported in publications [P2], [P4], [P5], [P6], [P7], [P8], and [P9]. Since mobile IS acceptance depends on a large number of factors, the empirical evaluations do not try to cover all dimensions of the MISAU model but only some of them. Table 5.1 shows how the empirical studies of the thesis and the MISAU model are linked.

Table 5.1 Relationships between empirical studies and the MISAU model.

Study	Section	Level of the MISAU model	Publication
Quality expectations in mobile IS	5.1.	Object-based and behavioral beliefs of all parts of mobile IS supply chain	[P9]
Network performance, perceived quality, and satisfaction in mobile IS	5.2	Object-based beliefs and attitudes of the network service	[P2]
Evaluation of text entry methods in mobile IS	5.3	Object-based beliefs and attitudes of the mobile device	[P4]
Text entry methods for field test in mobile IS	5.4	Object-based beliefs and attitudes of the mobile device	[P5]
Data representation and navigation with small displays in mobile IS	5.5	Object-based beliefs and attitudes of the mobile device	[P6]
Usability as a second order construct in mobile IS	5.6	Object-based beliefs and attitudes of the all parts of mobile IS supply chain	[P7]
Acceptance and use of mobile phone mediated communication technologies in community communications	5.7	Behavioural beliefs, attitudes, intention, and use	[P8]

In the empirical studies special attention is paid on the key characteristics of mobile IS and the challenges of mobile IS usability reported in Section 3.3, including text entry, data representation, navigation, and network performance. The aspects of mobile systems are manifold, involving many different applications, devices, and networks. This is taken into account in the experiments which attempt to look at mobile systems from several sides. Table 5.2 details study methods and parameters like the number of test subjects.

Table 5.2 Information about the empirical studies of the thesis.

Study	Study Method	Number of Users	Mobile Device	Wireless Network	Mobile Applications
Quality expectations in mobile IS	Opinion poll	83 (2003) 97 (2007)	-	-	-
Network performance, perceived quality, and satisfaction in mobile IS	Lab study	142	PDA	WLAN 802.11b	Email, bank, and news
Evaluation of text entry methods in mobile IS	Lab study	87	PDA	WLAN 802.11b	Email
Text entry methods for field test in mobile IS	Lab study, field test	15	Mobile Phone	GSM	SMS
Data representation and navigation with small displays in mobile IS	Lab study	82 (test 1) 75 (test 2)	Mobile Phone	Bluetooth	Information retrieval
Usability as a second order construct in mobile IS	Lab study	87	PDA	WLAN 802.11b	Email
Acceptance and use of mobile phone mediated communication technologies in community communications	Field test	21	Mobile Phone	GSM	Calls, SMS, MMS

5.1. Opinion Poll on Quality Expectations in Mobile IS

5.1.1. Aim of the Study

According to the MISAU model introduced in Chapter 4 quality is the key to the acceptance of mobile services. Quality covers both subjective and objective aspects of a service as discussed earlier in section 3.3.4. Previous studies have highlighted the importance of quality expectation in mobile IS (e.g. Chae and Kim, 2003) but quality expectations and especially their development in the long run have received only little interest among scientists.

In this section and in [P9], the development of mobile IS quality expectations during a longer period of time is analyzed. The aim is to find out how users' opinions about the importance of different quality determinants have changed during a four year period. Two surveys were carried out in 2003 and 2007, and the analysis is done according to the mobile IS service supply chain used in the MISAU model.

5.1.2. Research Design

During recent years we have witnessed a fast technological development in mobile IS and cellular networks. The latest features in end-user devices like build-in cameras, mp3 players, navigation applications, and 3G network technologies have created new applications and services. But how have these developments affected the users' quality expectations?

To answer this question data on user quality expectations were gathered in two surveys (the first one in January 2003 and the second one in September 2007). The participants of the surveys were IT students of a Finnish University and the numbers of participants were 83 in 2003 and 93 in 2007. (See [P9] for more details.) In the questionnaire the users were asked to select the two most important quality factors in the different parts of the mobile IS supply chain (i.e. device, network, and information service quality). The network quality factors used in the questionnaire were derived from the UMTS bearer service attributes (3GPP). Service quality factors have their roots in TAM studies, and device quality factors stem from usability studies on mobile devices (Tarasewich et al. 2002). The quality factors are listed in Table 5.3.

Table 5.3 Quality factors of the survey.

Device quality	Network quality	Service quality
Perceived ease of use	Network speed	Perceived ease of use
Display properties	Error rate	Perceived usefulness
Input method	Transmission delay	Perceived playfulness
Type of software	Traffic priority	Perceived security

5.1.3. Results and Discussion

The results of both surveys are shown in Table 5.4. Column *1st* shows how many per cent of the participants considered the feature the most important quality factor in the category. Column *1st + 2nd* shows how many participants listed the feature either as the most or the second most important one.

Table 5.4 Importance of quality factors.

Category	Quality Factors	2003		2007	
		1st	1st+2nd	1st	1st+2nd
Device quality	Perceived ease of use	60.2 %	77.1 %	48.4 %	63.4 %
	Display properties	20.5 %	56.6 %	21.5 %	54.8 %
	Input method	10.8 %	45.8 %	17.5 %	47.3 %
	Type of software	8.4 %	20.5 %	12.9 %	34.4 %
Network quality	Network speed	75.9 %	89.2 %	63.4 %	84.9 %
	Error rate	6.0 %	34.9 %	25.8 %	63.4 %
	Transmission delay	12.0 %	53.0 %	6.5 %	32.3 %
	Traffic priority	6.0 %	22.9 %	4.3 %	20.4 %
Service quality	Perceived ease of use	45.8 %	71.1 %	26.9 %	63.4 %
	Perceived usefulness	32.5 %	66.3 %	50.5 %	74.2 %
	Perceived playfulness	3.6 %	18.1 %	2.2 %	9.7 %
	Perceived security	18.1 %	44.6 %	20.4 %	52.7 %

Table 5.4 suggests that users place a high value on the usability of mobile devices. The problems caused by the small display sizes and cumbersome input methods remain important quality factors and get similar ratings in both studies. In both surveys, users ranked network speed as the dominant network quality parameter.

During the four year period the importance of error rates increased, whereas the importance of delay decreased. In service quality the original intention determinants of TAM (perceived ease of use and perceived usefulness) are regarded as the most important factors. In both surveys perceived playfulness was considered insignificant.

5.1.4. Conclusions

Technological development not only changes systems and services, but it also has an impact on users' expectations. The findings of the study, however, indicate that expectations lag behind technology, so that users mainly value the same quality factors in mobile IS today as they did four years ago.

Because the results of the study are more qualitative than quantitative in nature, one should not draw too strong conclusions from them. They do, however, reveal some interesting trends and signals of development. First, ease of use of mobile devices and services seem to be getting less significant. There is no simple explanation to this but one reason may be that the user-centred design methods and the increased interest in usability have had a positive effect on ease of use.

Second, the results of the study strongly support the constructs of the original TAM model. Ease of use and usefulness are the dominant variables in service quality expectations. The extensions of the model recommended by some scholars did not get similar support. Hence, the theoretical foundation of the MISAU model is discovered valid.

The present study has no doubt some limitations, like the use of a student population and a relatively simple questionnaire. Future research is still needed to enlighten the relationship between quality expectations and acceptance in more detail. The study also reveals that although many scholars have done valuable work analyzing the effect of networks, input methods, and small displays on acceptance and mobile service satisfaction, further studies are required concerning these aspects.

5.2. Network Performance, Perceived Quality and Satisfaction

5.2.1. Aim of the Study

Today mobile network operators offer a wide variety of mobile Internet services to their customers including mobile email, banking, and news services. In the system context of the MISAU model the key factor influencing the acceptance of a new service is the balance between the quality perceived by users and the quality delivered by service providers. In many areas of life, perception and delivery are often different, and there is reason to believe that this is the case also with mobile IS. Disappointing adoption rates of services cause concern and give the motivation for studying whether there is a discrepancy between perceived and delivered quality.

So far the discussion of mobile IS quality has been network centric. User satisfaction has been explained by the network performance and different technical concepts and metrics linked to the network's Quality of Service (QoS). In this section and in [P2] the relationship between QoS perceived by the customer and network performance offered by the service provider is analyzed. The aim of the study is to find out to what extent – if at all – these concepts are interrelated. Although the MISAU model indicates that acceptance of mobile IS is a multi-dimensional phenomenon, this study concentrates on network related issues like connection establishment delay, transmission speed, and connection release delay.

5.2.2. Research Design

According to ITU-T (2001) there would ideally be a 1:1 correspondence between delivered and perceived QoS. The research hypothesis of the experiment is that the relationship between network performance and QoS experienced by the user is not as straightforward as recommended by ITU. QoS perceived by the user is much more complex, affected not only by network performance, but also by context, application type, prior experiences, etc. For this reason the object-based beliefs or perceived quality must be studied in the context of use as suggested by the MISAU model.

In order to test our research hypothesis, a customer satisfaction survey was carried out. Subjects interacted with three different mobile Internet applications (an email application, a banking service, and a news service) in the lab environment where network performance variables (connection establishment delay, bandwidth, and connection release delay) were controlled. These applications were chosen as their domain should be familiar to mobile and Internet users and because they would require different levels of interactivity. Also, these applications were all created by the researchers but appeared to the subjects as if they were actually coming from the Internet. This was done to tightly control the application response times and the actual traffic flow over the network while simulating a real-world Internet experience.

The test users used PDA devices with IEEE 802.11b WLAN connections. Three logical network performance levels (low, medium, and high) were used. The delay and bandwidth parameters of the levels are shown in Table 5.5. It is worth mentioning that bandwidths used in the test were guaranteed speed unlike maximum speed typically advertised by network operators.

Table 5.5 Network performance levels used in the experiment.

Level	**Bandwidth**	**Connection establishment delay**	**Connection release delay**
Low	9,600 bit/s	6 seconds	6 seconds
Medium	56,000 bit/s	3 seconds	3 seconds
High	256,000 bit/s	1 seconds	1 seconds

We used 142 subjects (100 males and 42 females) from the university and vocational school undergraduate population. All of the subjects had used both mobile phones and Internet for several years. More details on the test environment and the participants can be found in [P2].

5.2.3. Results and Discussion

The subjects were asked to answer to questions (shown in Table 5.6) about their experience of using the three services (an email, a banking, and a news service). These questions were drawn from the ITU literature on the dimensions of QoS, and they were directly linked to the variables that were manipulated.

Table 5.6 Network performance questions used in the study.

Number	Question
Q1	Evaluate Quality of Service in connection establishment phase
Q2	Evaluate Quality of Service in data transfer phase
Q3	Evaluate Quality of Service in connection release phase
Q4	Evaluate general Quality of Service

Based on the statistical analysis reported in [P2] two main results were found. First, users do not see that network performance consists of many factors like connection establishment time, bandwidth, and release time. Instead, they consider it a single factor. Second, the relationship between network performance and perceived QoS is application specific.

The first finding derives from the fact that about 60 % of the subjects gave the same value to all four questions concerning network performance and the strength of the factor analysis. They were not able to detect any difference between the effect of connection establishment delay, bandwidth, and connection release delay on the general quality of the service. What is the explanation for these findings? Engineers use network performance terms like delay, jitter, bandwidth, and packet loss when dealing with QoS. Users do not share the network model of the engineers, and they define the quality with reference to a particular user activity (Bouch and Sasse, 2001).

According to the second finding, perceived QoS vary with the application being used as can be seen in Figure 5.1.

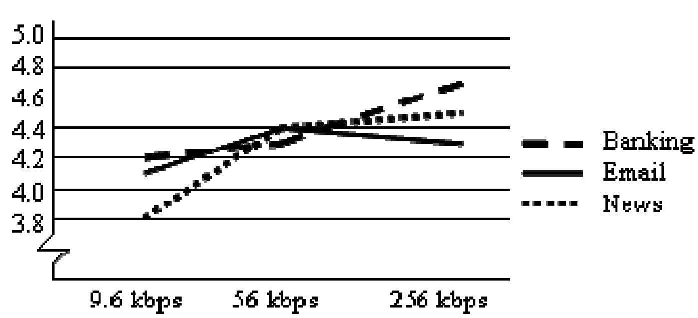

Figure 5.1 QoS perceived and delivered for the three applications.

We did not find a direct linear relationship between delivered and perceived QoS that was suggested by ITU. Rather, we found a general upward trend, but the users' definition and expectation of QoS depends on what their goals are. The acceptable network performance level is different across applications.

5.2.4. Conclusions

The acceptance of the mobile Internet services is heavily dependent on quality of service experienced by the user. So far the discussion of QoS has been network centric and network performance has been the main criterion of user satisfaction.

As mentioned above, the results of our study indicate that there is no 1:1 correspondence between network performance and perceived QoS as recommended by the ITU-T, but the relationship varied from application to application. This leads us to a new question – why does perceived QoS vary with the application being used? One alternative could be found in the stress and discomfort created by the application to the user (see Bouch et. al., 2001). Our study indicated that perceived QoS for the email application did not correlate with the network performance like it did in the case of mobile banking and news service. If the stress level is accepted as an indicator of perceived QoS there must have been some other and stronger source of stress than network delay in email service.

Stress could be caused by the input method or typing of the message. The amount of characters typed in each tested application varied from 0 (news) to 47 (banking) to 110 (email). Because 96 % of the subjects have never before used PDA devices with touch screens, it is very likely that the subjects found it stressful to type the message with the stylus pen. However, the idea of stress and text entry as its source still requires further study. Therefore, in the following sections text entry methods and metrics used in mobile text entry studies are analyzed in greater detail.

5.3. Evaluation of Different Text Entry Methods

5.3.1. Aim of the Study

The results of previous empirical studies and the literature review in section 3.3 pointed out that mobile text entry is one of the most important quality determinants of mobile devices. To improve the quality of mobile devices we must be able to collect reliable performance and preference data concerning the main features of the device. Several metrics are utilized to ascertain the relative merits of human-computer interaction. In the field of text entry, the Minimum String Distance (MSD) and the Keystroke Classification (KC) methods are both used to measure text entry usability. The definitions of the methods and metrics used in them can be found in Section 3.3.2. In the following two empirical tests the methods and metrics of mobile text entry are discussed. This section and [P4] examine text entry in the laboratory settings and in the next section and [P5] the evaluation methods are extended to the field tests.

The aim of the first text entry study reported fully in [P4] was to compare accuracy metrics of MSD and KC methods statistically against each other in order to analyse their quality. In addition to that the relative importance of accuracy data against the efficiency related information is also analyzed.

5.3.2. Research Design

In our experiment we collected metrics used in both MSD and Keystroke Classification methods. A group of test users wrote email messages with three different input methods (stylus pen, multi tap, and reduced QWERTY keyboard). Earlier text entry studies (e.g. Soukoreff and MacKenzie (2003), Clarkson et al. (2005), Oniszczak and MacKenzie (2004)) have clearly pointed out that the used input method affects both text entry speed and accuracy. For more details see [P4] and [P5]. The device used was a PDA with a WLAN connection.

We also used three different message lengths (21, 63, and 197 characters) to study if the number of characters is of any significance. To be able to collect the required information for performance metrics calculations (like presses of backspace, etc.) the PDA's standard input methods and systems like soft keyboards were bypassed and replaced with our test software that provided all user interaction. More details of the input methods used can be found in [P4].

The data collection took place in a laboratory study in which undergraduate students of a Finnish university wrote email messages in a controlled environment. The number of subjects in the study was 87 (64 male, 23 female). Because each participant used three different input methods, the total number of the cases was 261. Four cases were removed from the analysis because the test failed for some reason (e.g. the mobile phone of the test user rang during the test). The Latin square technique was used in organizing the order of the input methods and message length to avoid a learning effect tainting the subjects and the results.

The data collected was then analyzed with the discriminant analysis to provide classification rules that classify cases back to three different groups. The basic concept underlying the discriminant analysis is fairly simple. Linear combinations of the independent variables are formed, and they are used for classifying cases into one of the predefined groups. The discriminant analysis is often used to predict the outcome of the new case by comparing the characteristics of the case to those cases whose success or failure is already known. In our case the discriminant analysis was used differently. We knew, of course, the used input method in all cases, but we wanted to study the clustering capabilities of different accuracy metrics. Separate classification rules were created for all collected metrics, and the classification rule that minimized the probability of misclassification was considered superior.

5.3.3. Results and Discussion

Table 5.7 shows the percentages of correctly grouped cases with different classification rules both for MSD and KC methods. The first two rules are based only on one measured value (either on the not corrected or the corrected error metric). Then the classification capacity of the rule that combines both of them is represented. In the last two rules the text entry speed is included into the analysis. In both methods the text entry speed was measured with WPM (Words Per Minute).

Table 5.7 Percentages of correctly grouped cases.

	MSD method		**KC method**	
	Value	**Metric(s)**	**Value**	**Metric(s)**
Not corrected errors metric only	36.6%	MSD	37.4 %	NCER
Corrected errors metric only	70.8%	KSPC	47.9%	CER
Accuracy metrics together	61.5%	MSD+ KSPC	50.2%	NCER+CER
Speed metric only	61.9 %	WPM	61.9%	WPM
Accuracy and speed metric together	86.4%	WPM+ MSD+ KSPC	63.4%	WPM+NCER+ CER

Table 5.7 indicates that the metrics measuring uncorrected errors (MSD and NCER) are equally weak in classifying the cases into the right groups. Their values (36.6% and 37.4%) are so close to a random classification result (33.3 % with three groups) that they are practically worthless in identifying the input method. For corrected error metrics the situation is the opposite. Both CER and KSPC give a higher success rate, but KSPC has a much higher grouping capability compared to CER. Its strength makes the MSD method in general a better classifier, reaching a result of 86.4 % when used together with the speed metric WPM.

The results of the experiment suggest that from the two accuracy measurement methods studied here, the metrics used in the MSD method are stronger and better. However, we are not ready to make that conclusion for two reasons. First of all, the two suggested metrics for uncorrected errors (MSD error rate and NCER) have equally weak clustering capability, and the two methods differ solely because KSPC and CER are unlike each other. Secondly, we disagree with Soukoreff and MacKenzie (2003) as they suggest KSPC as a metric for corrected errors. It is no doubt a strong metric but the evidence confirms, that it is an efficiency metric, not an accuracy metric. KSPC measures the effort made by a user (the number of keystrokes) needed to type a character, which is the task he or she is doing in text entry. Therefore, it measures efficiency instead of accuracy.

More importantly the test results indicate that special attention should be paid when accuracy is measured. In this unconstrained text entry study the users were free to correct errors or to leave them uncorrected. This divided the text entry task into two overlapping processes: initial entry and correction process (see Figure 5.2). From accuracy metrics analyzed in this study only CER measures the error rate during entry

(entry process metric), and MSD and NCER measure the error rate of the transcribed or corrected string.

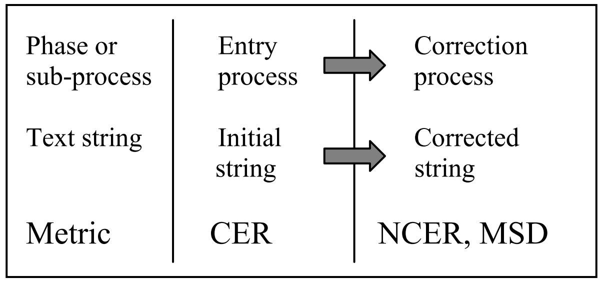

Figure 5.2 Sub-processes of text entry task.

Our results suggest that if accuracy is measured after the correction process, the accuracy measure is no longer equivalent to the input method used. If accuracy is measured before the correction process, the equivalence between accuracy and input method still exists. Wobbrock et al. (2004) also support the classification of accuracy metrics into two categories.

In Table 5.8 the correlations between the initial and corrected string error metrics are shown. NCER and MSD correlation is significant at the 0.01 level. But CER does not correlate with either NCER or MSD. This clearly indicates that even though they both measure accuracy they do it at different levels.

Table 5.8 Correlation of the accuracy metrics.

	CER	**NCER**	**MSD**
CER	1	-0.009	-0.033
NCER		1	0.829**
MSD ERR			1

** Correlation is significant at the 0.01 level

5.3.4. Conclusions

It is too early to draw final conclusions about the quality of different metrics used in text entry studies. Further studies are still needed to examine the relationships between different usability aspects in more detail. However, the results suggest that in text entry, task efficiency related information is more valuable than accuracy data. For this reason WPM should not be used as the only efficiency metric but it should be used together with other efficiency metrics like KSPC.

When evaluating the accuracy of mobile text entry it is very important to know when accuracy is measured. In this study the text entry was divided into two overlapping sub-processes: initial entry and correction process. If accuracy is measured before the error correction process, the input method used can be identified and there is a correlation between accuracy and the input method. If accuracy is measured after the error correction process, accuracy and the input method no longer correlate. In the latter case, the results are not measuring the accuracy of the input method but participants' precision level or conscientiousness.

The results of our experiment propose that accuracy is an attribute of both the user and the device. For this reason we do not regard NCER or MSD as suitable tools for comparing the accuracy of different input methods against each other but recommend CER instead. NCER and MSD can, however, be used when user accuracy is the main interest. When the results are analyzed according to the MISAU model, it becomes obvious that CER measures accuracy in the system context, where as NCER and MSD also involve the user context.

5.4. Text Entry Evaluation Methods for Field Tests

5.4.1. Aim of the Study

Typically text entry studies have been carried out in a laboratory environment where precise measurement methods and established accuracy and efficiency metrics can be applied. One example of this kind of study was reported in the previous section. Laboratory settings provide a high level of control but they have one serious limitation – the lack of realism. Field studies, on the other hand, provide a more realistic research environment, but the established methods and metrics developed for laboratory settings cannot always be applied in them. In this section and in [P5] the metrics used in laboratory based text entry studies are analyzed. The aim of the study is to develop new accuracy metrics for field based evaluations. These new metrics link the mobile text entry studies better to the environment context of the MISAU model. The study is limited only to accuracy metrics because evaluations of the earlier text entry studies in [P5] pointed out that in text entry studies efficiency is measured with some kind of speed metric. Speed can be measured either on character, word or task level but actually all of them can easily be converted to the same unit (e.g. Words Per Minute). Text entry speed is thus a logical efficiency metric also for field based text entry studies.

5.4.2. Research Design

The development of new accuracy metrics for field based mobile text entry studies started with a small scale experiment. In the experiment test users wrote text messages both in controlled laboratory settings and in the field. In the field test part of the experiment test users were asked to send some text messages with the application provided. The numbers of messages, contents or receivers were not limited in any way. In the laboratory test the users wrote predefined sentences with the same application.

The total number of users in this experiment was 15. They represented three different age groups: early teenagers (13 – 16 years), young adults (23 – 26 years), and middle aged people (40 – 49 years). Each group had five users, and all users were familiar with mobile phones and active users of text messages,sending them every day or several times a week as explained in [P5].

A special SMS program for Symbian mobile phones was used to keep the users unaware of the data collection. What the users regarded as a normal SMS application was in fact a program that collected text entry related data during the message creation process. This way the data collection did not jeopardize unbiased results. The automatically collected metrics were the length of the message, the time to write the message and the amount of correction key presses.

5.4.3. Results and Discussion

The results of the field and laboratory studies are shown in Table 5.9. According to the results the text entry speed was significantly slower in the field test as opposed to the lab test. The obvious reason for this was that in the laboratory all sources of disturbance were minimized and the participants could concentrate on their tasks only. In real environments, the test users were for various reasons often distracted away from what they were doing. This, of course, affected their performance. The users also made more corrections in the field than in the laboratory, but here the difference was not as significant as in speed.

Table 5.9 Speed and correction rates in the laboratory and in the field test.

	Lab test	**Field test**	**T-test value**	**Sign. level**
Text entry speed (WPM)	5.59 (1.79)	4.66 (1.73)	2.68	> 0.99
Correction rate (corrections per character)	4.3 % (0.073)	6.5 % (0.067)	1.55	0.88

The accuracy metric used in Table 5.9 is Correction Rate (CR) which is the ratio between the number of correction characters and the total number of characters. The reason why the correction rate was used instead of some established error rate metric like (MSD, NCER or CER) is simple. The error rate metrics can be applied to lab messages but not to the field test ones because we do not have the reference text that can be used in error calculation. When people type text messages in a real environment, they create the content of the message during the writing process instead of copying it from somewhere as is typically done in laboratory experiments.

Although the correction rate can give us valuable information about corrected errors, it does not tell us anything about the errors that are not corrected. In order to evaluate the uncorrected errors as well, some kind of reference text is needed. Because reference strings do not exist in field tests, we must create them. In laboratory tests the reference string is the starting point, and the transcribed text is derived from it. For field tests we suggest a reverse method in which the reference is created afterwards from the transcribed text.

There are two main approaches in the reverse reference creation: the objective or the subjective method. In the objective method the reference does not depend on personal preferences, whereas the subjective criteria are derived from individual quality judgements. In this study the objective reference was the spell checker of Microsoft Word 2003 (Finnish version). The messages were transferred from the mobile phone to Word. As known, Word underlines all the misspelled words with a red zigzag line. In our experiment the necessary corrections were made to fulfill the spelling requirements of the spell checker. This string accepted by Word was our reference and then the Minimum String Distance between it and the original string was calculated. In the MSD calculation all errors suggested by Word in names, abbreviations, and greetings were ignored.

The subjective error criteria were based on the writer's own evaluations. The messages written in the field test were shown to the users afterwards, and they were asked to identify all spelling mistakes in their own messages. The MSD values were calculated now between the original and the subjectively corrected messages.

The average MSD values for the three different user groups (teenagers, young adults, and middle aged users) are shown in Table 5.10. The subjective MSD values seem to be quite similar in all three groups in both settings. Objective values, in contrast, show remarkable differences. Interestingly, the high objective MSD values in field tests are typical of teenage users.

Table 5.10 Measured objective and subjective MSD values.

	Field test		**Lab test**	
Group	Objective MSD	Subjective MSD	Objective MSD	Subjective MSD
Teenagers	15.2 %	0.51 %	0.27 %	0.27 %
Young adults	2.93 %	0.19 %	0.00 %	0.00 %
Middle aged	1.72 %	0.00 %	0.27 %	0.27 %

5.4.4. Conclusions

Mobile text entry has been a flourishing research area. Different kinds of methods and metrics have been developed to compare input systems against each other. These methods are targeted for laboratory evaluations, and the lack of original texts prevents the use of these metrics in field tests. The accuracy metrics used in laboratory studies classify the errors into two categories: corrected and not corrected errors. The same logic can also be used in field experiments.

According to the results of the study CR is a good candidate metric for corrected errors in the field environment, but what about not corrected errors? To measure not corrected errors some kind of reference must be used. In this study both objective and subjective reference strings were created, and corresponding MSD values were calculated. The subjective MSD values were quite similar in all cases but the objective values indicated clear differences between age groups. Teenagers seem to have a much higher objective error rate than other groups.

The high objective MSD values for teenagers reveal the weakness of the objective reference strings. In this case the higher error rates are not a result of typing errors but the use of different registers of language. At least in Finland adult users tend to use standard written language in their messages. The younger generation uses more colloquial spoken language instead. It can thus be said that Finnish teenagers "talk" with text messages as their parents "write" them. Therefore, the objective MSD method does not give reliable results under all circumstances. Better results can be reached with the subjective MSD method. However, it is important to note that subjective evaluations should be done by someone belonging to the same demographic group with the test users. For example a middle aged researcher may totally fail to correctly analyze the errors in teenagers' messages.

5.5. Data Representation and Navigation with Small Displays

5.5.1. Aim of the Study

In Section 3.3 three main limitations of mobile IS were revealed. Some aspects of network performance and input methods were covered in the previous sections. In this section and in [P6] the main focus is on the small display size and its effects on data presentation as well as decision quality and performance in mobile information systems. Special attention is paid to the effect of small displays on the efficiency of and satisfaction on mobile IS.

Until now mobile information services have mainly been text-based. The development of relevant hardware and software for mobile devices has now made it possible to also use other data representation forms like graphs, images or even video in mobile phones and PDA devices. As mobile communications are shifting from voice and text messages to images and video clips, it is more important than ever to understand how data representations affects quality and the success of information systems.

Mobile information systems are in a similar development phase today as personal computer applications were 15 years ago. In the late 80s and early 90s, the presentation of data in the form of graphs became a viable alternative to tabular formats on desktop devices. Several studies were carried out at that time to compare the quality of decision making with graphs and tables. The results, however, were inconsistent, and there was no common understanding of the phenomenon until Vessey (1991) developed the theory of cognitive fit (CFT). According to CFT the correspondence between task and information presentation format leads to superior task performance for individual users.

In this study we have two main aims. First, we intend to verify the theory of cognitive fit also in mobile devices with small displays. Second, we seek to analyze the relative importance of cognitive fit. Data representation and its interpretation form only one part of the information retrieval task. Typical mobile applications include other subtasks as well, like navigation and data entry which are not directly affected by the representation.

5.5.2. Research Design

Mobile devices are typically characterized by small display sizes. The effects of screen size have been studied from multiple viewpoints as discussed earlier. Although researchers have been interested in the question of information presentation on a small screen, they have not combined problem representation with problem solving tasks and mental representation as suggested in the theory of cognitive fit.

The goal of our study was to find out if cognitive fit is applicable to mobile devices with small displays. We, therefore repeated the original Vessey-Galletta study, but conducted the tasks this time with mobile phones. The original Vessey and Galletta test used two data representations (line graphs and tables) together with two types of tasks: symbolic and spatial. Tables are considered more suitable for solving symbolic tasks which involve extracting precise data values from the shown information. Spatial tasks require subjects to make associations such as comparison of trends, and they are better solved by means of graphs.

Both the original and our experiment require the participants to respond to problems regarding deposits and withdrawals of bank accounts over a 12-month period. Using the same task setting enabled us to compare our results with those of other scholars. Eighty-two volunteer undergraduate students participated in the experiment. All participants answered 20 questions (10 spatial and 10 symbolic). The data were represented in 10 cases in table format and in 10 cases in graph format.

The details of the first experiment are not discussed here but reported in [P6]. The main result of the experiment was that the theory of cognitive fit also applied to mobile IS where devices with small displays were used. According to our data, the theory of cognitive fit was fully supported for symbolic tasks and partially for spatial tasks in mobile IS. Interestingly enough, this was exactly the same outcome Vessey and Galetta had in their original study with stationary IS.

In their study, Vessey and Galletta suggested that the research of cognitive fit should be extended to encompass more complex problem solving tasks. Other scholars have also pointed out that experiments with basic tasks have failed to reveal the real effects of user interface characteristics on performance (Chae and Kim, 2004; Han and Kwankh, 1994). We followed these recommendations in our second experiment where users were playing the Stock Broker Game (SBG). SBG was played with a HTML browser running on a mobile phone, and the connection to the server was implemented with Bluetooth. The aim of the game was to carry out as many brokerage tasks as possible in a limited time. Each task consisted of three subtasks that are shown in Figure 5.3.

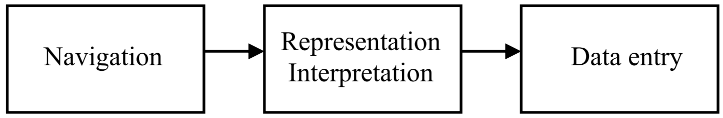

Figure 5.3 SBG subtasks.

Each task began with a task description that included the name of a company. In the navigation phase, data about the company was searched from the system. There were twenty companies altogether, but only the first ten names or lines of the menu fitted the display of the mobile phone. Because the amount of information exceeded the space available, the last ten names were accessible only by scrolling down the menu. The presence of more options in a single menu than a user can process immediately is called crowding (Chae and Kim, 2004).

After the right company was selected, the information about the stock value history of the company was shown either in table or graph format. The player then made a decision to keep, buy, or sell stocks and entered the answer with the mobile phone's keyboard. If the decision was to keep, the player simply selected that option from the menu. If the decision was to buy or sell, the player entered also the number of stocks to be traded.

There were seventy-five students participating in the second experiment. They were divided into two groups. The first group (n = 37) played the game using tables only and the second one (n = 38) using graphs only. The playing time was limited to 10 minutes. The players were encouraged to pay attention to both accuracy and efficiency. They thus gained points by giving correct answers. Moreover, the faster they could give the right answer, the higher they scored. After the game, the users evaluated the usability of the system with a System Usability Scale (SUS) questionnaire (Brooke 1996).

5.5.3. Results and Discussion

The results of the second test were studied in two ways. First, we analyzed performance and preference differences between the two test groups. There were no overall performance or preference differences between tables and graphs. The users spent an almost identical average time per question in both formats (about 48 sec), and the error rates were almost identical (about 8 %). The preference ratings of the two representations were alike as well.

Second, the findings were tested at the subtask level against the following three null hypotheses.

$H1_0$: *Crowding does not have an effect on user performance.*
$H2_0$: *Cognitive fit does not have an effect on user performance.*
$H3_0$: *The amount of input or the number of data entry fields has no effect on user performance.*

The results presented in Table 5.11 indicate that both crowding and additional text entry increased the average time spent on the task, so $H1_0$ and $H3_0$ could be rejected. This result was not surprising, but the high observed significance levels suggested that menu and input structures are critical to mobile information system performance. Cognitive fit seems to boost performance, but because of the low observed significance level, $H2_0$ could not be rejected. Despite the fact that the null hypothesis could not be rejected we cannot go so far as to claim that cognitive fit does not affect performance. Rather, this study failed to reject the null hypothesis.

Table 5.11 Results of the hypotheses tests (N = 75).

		N	Average Time	Stdev	t-value	Observed significance level	Hypothesis rejected
$H1_0$	Without crowding With crowding	75 75	42.31 55.13	9.18 15.73	6.10	> 0.99	yes
$H2_0$	Without cog fit With cog fit	75 75	49.56 46.75	12.78 11.98	1.39	0.84	no
$H3_0$	Without text entry With text entry	75 74 *	33.42 51.63	8.40 11.91	10.82	> 0.99	yes

* N in condition with text entry is 74 because one participant did not reach the first text entry task in limited time

5.5.4. Conclusions

In this study we carried out two laboratory experiments regarding cognitive fit on mobile devices. The first experiment was identical to the original Vessey and Galletta (1991) study. Since our results were almost identical to those of Vessey and Galletta, cognitive fit is verified in mobile and stationary information systems alike.

Our second experiment tested the relative importance of cognitive fit in mobile IS with more complicated tasks. Our subtask level analyses of SBG revealed that the need to scroll in the navigation phase and the number of fields in the text entry phase significantly lengthened the time spent on the task. On the other hand, the cognitive fit of data and task representations did not have a similar effect.

Our experiments supported the findings of other scholars who have found out that small screens cause problems not only in data representation, but also in navigation (e.g. Han and Kwanhk, 1993; Acton et al., 2004). Our results revealed that the users considered the small screen size inconvenient even in very simple navigation tasks. The need for scrolling to the right menu selection caused by crowding was enough to seriously affect system performance. After the users had found the right path to the information, it was noticed that higher representation quality in the form of cognitive fit did not have a significant effect on efficiency or accuracy.

We regard these findings as important characteristics of mobile information systems. From the users´ point of view, the main differences between the PC and mobile devices are network speeds, input methods, and screen sizes. Although mobile devices are in the process of rapid development, the display and keyboard sizes will remain relatively small due to the need for portability. Therefore, these topics will be in focus of UCD specialists in the future as well.

5.6. Usability as a Second Order Construct

5.6.1. Aim of the Study

Ease of use or usability is critical to the success of mobile devices and systems. But what is usability and how should it be measured? Researchers agree that usability involves many mutually dependent dimensions (Holcomb and Tharp, 1991; Nielsen, 1993), but these dimensions have been classified in many different ways. Consequently, there are numerous models of usability and instruments to measure it. Some instruments measure satisfaction constructs, and others evaluate the efficiency and effectiveness side of usability.

In this section and in [P7] the usability of the mobile devices is tested by means of several existing metrics in order to get an overall view of usability as a second order construct. The aim of our study is to gain a greater understanding of the phenomenon of usability and to establish how to measure usability with mobile devices.

5.6.2. Research Design

In our experiment we collected different kinds of metrics to measure overall usability. The research environment and setting used in this study is the same as in Section 5.3 Evaluation of Different Text Entry Methods. As explained earlier, the test users wrote three predefined email messages by different input methods.

The collected metrics were efficiency metrics (WPM, KSPC), effectiveness metrics (NCER, CER), and preference or satisfaction metrics. The preference metrics collected were System Usability Scale (SUS) (Brooke, 1986), After-Scenario Questionnaire (ASQ) (Lewis, 1995), and Network Performance Questionnaire (NET) [P2].

5.6.3. Results and Discussion

In data analysis we adopted a two-step approach in which we first established a valid and reliable measurement model prior to testing the hypothesized second-order factor model (Anderson and Gerbing, 1982). The measurement model development started with statistical validity and reliability tests with all five constructs (efficiency, effectiveness, SUS, ASQ, and NET). The statistical analysis revealed that one of the two items (NCER) prespecified to load on the effectiveness construct did not pass the standardized factor loading test. Thus the measurement model was prespecified by eliminating the effectiveness construct. See [P7] for details of the statistical methods used in the model development.

After determining that the prespecified measurement model was sufficiently valid and reliable, the second-order factor model with efficiency, SUS, ASQ, and NET was tested. The purpose was to determine whether all four primary dimensions can be viewed as appropriate indicators of mobile IS usability. Table 5.12 presents the standardized parameters and t-values resulting from the testing and indicates that three of the four constructs – efficiency, SUS, and ASQ – are dimensions of the second-order factor mobile IS usability. However, the results do not support the inclusion of NET as a dimension.

Table 5.12 Tests of hypothesized relationships for second-order factor model.

	Standardized Parameter Estimate*	**t-value**	**Conclusion**
Efficiency directly influences usability	.482	7.099	Supported
SUS directly influences usability	.928	9.345	Supported
ASQ directly influences usability	.958	13.352	Supported
NET directly influences usability	.078	1.080	Not supported

Goodness of Fit Results: Chi-square of 145.051, df 92; CFI=.971
* Significant at $p < .01$

Based on the empirical results, we elected to eliminate the path between usability and NET. All measures of model fit improved with this model prespecification and the three construct structure did improve upon the initially proposed four-construct second-order factor conceptualization of usability as Tables 5.12 and 5.13 indicate.

Table 5.13 Tests of hypothesized relationships for re-specified model.

	Standardized Parameter Estimate*	**t-value**	**Conclusion**
Efficiency directly influences usability	.476	7.475	Supported
SUS directly influences usability	.931	9.424	Supported
ASQ directly influences usability	.960	13.404	Supported

Goodness of Fit Results: Chi-square of 72.006, df 45; CFI=.977
* Significant at $p < .01$

5.6.4. Conclusions

This project did not seek to identify an "optimal" model of input or output. This was a project designed rather to study the phenomenon of usability, defining its subconstructs, and assisting others in identifying proper measures for usability. While ISO 9241 defines usability in general, this paper confirmed that usability for mobile devices is not radically different from other types of system usability.

This experiment to measure usability from efficiency, effectiveness, and satisfaction perspectives has resulted in many important findings. First of all, it confirmed that usability is indeed a second order construct, made up of many smaller constructs.

Furthermore, it appears that KSPC, long theorized as a measure of effectiveness (Soukoreff and MacKenzie 2004), is really a measure of efficiency. KSPC loaded with WPM on a single construct and was a significant contributor to the construct. It is possible this is a unique factor to the mobile world, which can rely on multi-tap devices to generate a character.

According to the MISAU model, satisfaction can be divided into three different components: device, network, and information satisfaction. The results of the study indicate that network satisfaction measured with NET does not directly influence usability unlike the two other satisfaction metrics SUS and ASQ. The results also showed that SUS and ASQ measure different constructs. It was presumed that both instruments were proxies for the same usability construct. The confirmatory factor analysis showed that these are indeed different constructs. A review of the purified measures seemed to indicate that the SUS may concern to the device characteristics (device satisfaction) whereas the ASQ may be closely connected to the actual task being completed (information satisfaction). However, this idea still requires further studies.

5.7. Acceptance of mobile communication technologies in student communities

5.7.1. Aim of the study

The MISAU model is applicable to the study of the adoption and use of all kinds of mobile information systems. In this section and in [P8] it is applied to mobile communication technologies used in community communications, and the acceptance of mobile communication technology in a student community (undergraduate students in a Finnish university) is analyzed. The special area of interest is to evaluate the effect of culture on the adoption and use of mobile communication services in community context. Wenger et al. (2002) identify three levels of culture in communities of practice: national, organizational, and professional. A similar classification is used also by other scholars (e.g. Dubé et al., 2005). In our analysis we pay attention only to national culture.

5.7.2. Research Design

As mentioned above our study was conducted among students in a Finnish University. Our student community consisted of three sub-communities: Spanish exchange students, Chinese exchange students, and Finnish permanent students. Both exchange student groups were studying for one academic year at the Finnish university, and they had studied two or three years in their home universities before their exchange year. The Finnish students were second or third year students. The students of all three sub-groups were taking some courses together but every student had an individual curriculum.

The communication methods studied were cellular phone calls, text messages, and multimedia messages. Because we wanted our test to be as realistic as possible all participants used their own mobile phones and they paid all communication costs themselves. We believed that introducing a new kind of device or paying their bills would have given biased results. Thus different kinds of mobile phones were used. However, all of them had built-in cameras, 12 key keyboards for text entry and the possibility to send text and multimedia messages.

We analyzed the acceptance of communication methods used for inter-community communication as follows. First, we used a questionnaire to find out the participants' opinions about the ease of use, usefulness, attitude, and intention related to all three communication methods. We used simple questions with a five point Likert scale to measure the participants´ subjective opinions of the ease of use, usefulness, and intention. Attitude was measured with real use of mobile calls, SMS, and MMS messages for other purposes than intra-community communications. See details in Table 5.14.

Table 5.14 Questions used in the study.

Dimension of the MISAU model	**Question**	**Scale**
Ease of use	I find text messaging easy to use.	1 = strongly disagree 5 = strongly agree
Usefulness	I find text messaging useful.	1 = strongly disagree 5 = strongly agree
Attitude	How often do I send text messages?	5 = 6 – 7 days a week 4 = 5 – 4 days a week 3 = 3 – 2 days a week 2 = less frequently 1 = never
Intention	I intend to use text messaging within my group.	5 = 6 – 7 days a week 4 = 5 – 4 days a week 3 = 3 – 2 days a week 2 = less frequently 1 = never

Six weeks later, we collected data on the real use of mobile calls, text, and multimedia messages during a period of two weeks. Data was collected from the logs of the participants' mobile phones. The real use of services was graded using a similar five point scale as with intention and attitude earlier.

5.7.3. Results and Discussion

Average values (underlined) and standard deviations for the collected metrics are shown in Table 5.15 for each sub-group.

Table 5.15 Measured values.

Dimension of the MISAU model	**Spanish exchange students**			**Chinese exchange students**			**Finnish permanent students**		
	calls	SMS	MMS	calls	SMS	MMS	calls	SMS	MMS
Ease of use	4.7 (0.5)	2.7 (1.0)	2.7 (1.0)	4.6 (0.5)	3.0 (1.0)	3.0 (1.0)	4.9 (0.4)	2.4 (0.8)	2.4 (0.8)
Usefulness	4.3 (0.8)	3.9 (0.9)	1.9 (1.1)	3.9 (0.7)	3.7 (1.1)	2.0 (1.0)	3.7 (0.5)	3.6 (1.0)	1.9 (0.9)
Attitude	5.0 (0.0)	4.0 (0.6)	1.0 (0.0)	5.0 (0.0)	4.0 (1.4)	1.0 (0.0)	4.9 (0.4)	3.6 (1.4)	1.0 (0.0)
Intention	4.3 (0.8)	4.1 (0.7)	1.0 (0.0)	4.0 (1.0)	2.7 (1.1)	1.1 (0.4)	4.9 (0.4)	4.0 (0.8)	1.3 (0.5)
Use	3.3 (1.1)	2.0 (1.3)	1.0 (0.0)	4.0 (1.0)	3.0 (1.9)	1.0 (0.0)	3.0 (0.6)	1.6 (1.0)	1.0 (0.0)

Table 5.15 indicates that there was no statistically significant differences between the nationalities in any measured dimension. Our results thus suggest that university students from all three countries share ease of use and usefulness opinions as well as attitudes and intentions towards basic mobile communications services. It is also worth mentioning that although calls and text messages are actively used within sub-communities multimedia messaging is totally rejected.

Table 5.16 shows the correlations between the metrics of the MISAU model. The results support the model as the correlations suggested by the model have higher values than the not suggested ones. However, there is one exception. The model does not include the direct path from usefulness to intention, but the results indicate a high correlation here. The high correlation is understandable due to the very high usefulness-attitude and attitude-intention correlations.

Table 5.16 Measured correlation coefficients.

	Usefulness	**Ease of Use**	**Attitude**	**Intention**	**Use**
Usefulness	1	0,64	**0.98**	0,88	0,59
Ease of Use		1	**0.70**	0,64	0,51
Attitude			1	**0.94**	0,64
Intention				1	**0.73**
Use					1

Attitude and the intention to use the service were closely linked. Although there was a clear correlation between intention and use it was not as strong as between attitude and intention. One explanation for the weaker correlation could be the time of measurement. It is important to bear in mind that the actual use was measured six weeks later than other metrics. During that period of time the participants might have changed their minds about how they intended to communicate with other members in their sub-community.

5.7.4. Conclusions

The correlations between behavioural beliefs, behavioural attitudes, intentions, and actual use fully supported the structure of the MISAU model. The results of the study indicated similar acceptance patterns of mobile communication technologies in all three sub-communities.

Further analysis based on the social networks revealed interesting cultural differences in how the mobile communication technology was used. Finnish students studying in their home country naturally had the largest social networks, and they were not strongly tied to their fellow students. The Chinese students, on the contrary, were committed to their own community and relatives. This 'Chinatown effect' means that the Chinese students did not integrate with others to the extent the Spanish students did. This can partly be explained by the fact that Spanish and Finnish cultures, both being European, resemble each other, whereas Chinese culture is distinctly different. The combination of our results with Hofstede's dimensions of a national culture (Hofstede, 2001) also lead to this conclusion. See (Koivisto, 2008) for more details.

5.8. Summary

The empirical evaluations reported in this chapter analyzed belief and attitude determinants of mobile IS in different settings. The results of the studies were in concordance with the structure of the MISAU model and the importance of usefulness and ease of use in mobile IS adoption. Although mobile device manufacturers and service providers have already paid special attention to the challenges of mobile IS usability, our experiments revealed many limitations in the mobile human-computer interaction, especially in text entry, navigation, and data representation.

6. SUMMARY

User perceptions of information systems have been studied from many different perspectives including technology acceptance, IS success, and usability. The main interest of technology acceptance studies has been to explain why users accept or reject applications or systems. IS success researchers have analyzed the determinants of individual and organizational performance or preference impacts of information systems. Usability research focuses on the processes of developing products that are easy to use. Although all the above mentioned approaches are fully justified, they alone fail to deal with the adoption and use of IS as a whole. Hence, there have been attempts to combine these approaches into one single framework.

Technology acceptance, IS success, and usability theories have their origins in stationary systems. Still, they have also been applied to mobile context. The literature review on mobile IS studies in Chapter 3 revealed that there is one dominant approach in mobile IS acceptance studies (TAM), two main methods to analyze IS success at user level (TTF and IS success model) and three important limitations in mobile IS usability (cumbersome input methods, small display sizes, and network performance).

Usability limitations have hindered the acceptance of mobile services, and will continue to do so in the future. Although mobile devices have developed rapidly during the last two decades and are expected to do so in the years to come, the minuscule physical size of mobile devices prevents the use of full scale keyboards and displays. Similarly, wireless networks will never be able to reach the same performance levels as the wired ones because of the limitations posed by the radio spectrum. Since stationary and mobile contexts are widely divergent, research models developed for desktop systems cannot without alteration be used for mobile systems and applications. Many modifications and extensions to the original acceptance and success models have been suggested, but none of them are commonly accepted. Thus new frameworks are needed to better explain the adoption and use processes of mobile systems.

One of the main contributions of the present thesis is the development of a new framework: an integrated model for Mobile Information System Adoption and Use (MISAU). The MISAU model integrates acceptance, success, and usability approaches into a single framework by combining quality dimensions, satisfaction, behavioral beliefs, attitudes, and intentions. The structure of the model was tested and verified empirically in [P7] and [P8].

The usability limitations of mobile devices, networks, and services were analyzed in context of use according to MISAU. MISAU lists a large number of factors affecting mobile IS acceptance. Therefore, none of the empirical studies reported in the thesis covered all dimensions of MISAU but dealt with only a few of them. The empirical evaluations of network performance revealed that users consider network speed the most important network satisfaction factor, but that the relationship between network performance and satisfaction is application specific. There is no 1:1 correspondence or even a truly linear relationship between network performance and perceived QoS as recommended by the International Telecommunications Union – Telecommunications (ITU-T).

Most of the studies in the thesis were concerned with user interface characteristics of mobile devices. The results indicated that cumbersome text entry methods can negatively affect device satisfaction and thus be an obstacle for the acceptance of mobile services. The studies revealed also some problems in the current accuracy measurement methods like the role of measurement time, the misinterpretation of KSPC as an accuracy metric and difficulties of measuring accuracy in field studies.

Our data representation experiments proved that the theory of cognitive fit is also applicable to mobile information systems where devices with small displays are used. However, small displays pose data presentation and especially navigation problems. The test users considered the small screen size inconvenient even in very simple navigation tasks. System performance deteriorated drastically when the users needed to scroll down the menu. After the users had found the right information, higher representation quality in the form of cognitive fit did not have a significant effect on efficiency or accuracy.

The acceptance of mobile devices, networks, and services is a multidimensional phenomenon. The thesis provides some new, relevant, and practicable contributions to a better understanding of the mobile IS success factors. The experiments included in the thesis, however, have their limitations and leave some open questions. For example, in some cases larger sample sizes and the use of a set of measurement items instead of a single one could have provided more reliable results. Also a more detailed analysis of measured variables like delays and bandwidths in Study 2 could reveal new interesting findings. Future research should better address these issues.

One of the most important areas of future research is the identification of the quality determinants of the MISAU model. The current model does not list the quality determinants related to the different parts of mobile IS service supply chains. Future studies are needed to extend the model to cover these determinants. This extension is essential for mobile device manufacturers, network operators, and information service providers in their search for higher quality and satisfaction for their products and services. Although not yet studied in detail, quality factors of devices, networks, and information services can be expected to be different. Especially the role of traditional and additional quality aspects like hedonics and aesthetics is likely to vary in different parts of the supply chain.

Mobile usability is a topic of growing importance. System analysts, hardware manufacturers, and software developers benefit enormously from the feedback they get from mobile usability researchers. Only if usable systems can be created, will mobile information systems be accepted and used in the giant proportions as predicted.

REFERENCES

Aasheim K. (2007) Adapting the DeLone and McLean IS success model – A PDA impact study in Norwegian home health care, Proc. of the 30th Information Systems Research Seminar in Scandinavia, Tampere, Finland.

Acton T., Golden W., Gudea S., and Scott M. (2004) Usability and acceptance in small screen information systems, Proc. of 9th European Collaborative Electronic Commerce Technology and Research Conference, Guildford, Surrey, UK.

Acton T., Golden W., and van der Heijden H. (2005) Effects of see-through interfaces on user acceptance of small-screen information systems, Proc. of 13th European Conference on Information Systems, Regensburg, Germany.

Ajzen I. (1988) Attitudes, personality, and behavior, Milton-Keynes, England: Open University Press and Chicago, USA: Dorsey Press.

Ajzen, I. (1991) The theory of planned behavior, Organizational Behavior and Human Decision Processes, Vol. 50, No. 2, pp. 179 – 211.

AlHinai Y., Kurnia S., and Johnston, R. (2007) Adoption of mobile commerce services by individuals: A meta-analysis of the literature, Proc. of the 6th International Conference on the Management of Mobile Business, Toronto, Ontario, Canada.

Amberg M., Hirschmeier M., and Wehrmann J. (2004) The compass acceptance model for the analysis and evaluation of mobile services, International Journal of Mobile Communications, Vol. 2, No. 3, pp. 248 – 259.

Anderson J. and Gerbing D. (1982) Some methods for respecifying measurement models to obtain unidimensional construct measures, Journal of Marketing Research, Vol. 19, No. 4, pp. 453 – 460.

Anderson J. and Schwager P. (2004) SME adoption of wireless LAN technology: Applying the UTAUT Model, Proc. of the 7th Annual Conference of the Southern Association for Information Systems, Savannah, GA, USA.

Andrykowski M., Beacham A., Schmidt, J., and Harper, F. (2006) Application of the theory of planned behavior to understand intentions to engage in physical and psychosocial health behaviors after cancer diagnosis. Psycho-Oncology, Vol. 15, No. 9, pp. 759 – 771.

Aydin S. and Özer G. (2005) National customer satisfaction indices: An implementation in the Turkish mobile telephone market, Marketing Intelligence & Planning, Vol. 23, No. 5, pp. 486 – 504.

Bagozzi R., Wong N., Abe S., and Bergami M., (2000) Cultural and situational contingencies and the theory of reasoned action: Application to fast food restaurant consumption, Journal of Consumer Psychology, Vol. 9, No. 2, pp. 97 – 106.

Bailey J. and Pearson, S. (1983) Development of a tool for measuring and analysing computer user satisfaction, Management Science, Vol. 29, No. 5, pp. 530 – 545.

Bamberg S. (2006) Is a residential relocation a good opportunity to change people's travel behavior? Results from a theory-driven intervention study, Environment and Behavior, Vol. 38, No. 6, pp. 820 – 840.

Baroudi J., Olson, M., and Ives, B. (1986) An empirical study of the impact of user involvement on system usage and information satisfaction, Communications of the ACM, Vol. 29, No. 3, pp. 232 – 238.

Belanger F., Fan W., Schaupp L., Krishen A., Everhart J., Poteet D., and Nakamoto K. (2006) Web site success metrics: addressing the duality of goals, Communications of the ACM, Vol. 49 , No. 12, pp. 114 – 116.

Benbasat I. and Dexter A. (1986) An investigation of the effectiveness of color and graphical information presentation under varying time constraints, MIS Quarterly, Vol. 10, No. 1, pp. 59 – 83.

Benslimane Y., Plaisent M., and Bernard P. (2004) Using web systems for e-procurement: An extension of the unified theory of acceptance and use of technology, Proc. of European Conference on Information Systems (ECIS), Turku, Finland.

Bevan N. and Mcleon N. (1994) Usability measurement in context, Behaviour and Information Technology, Vol. 13, No. 1, pp. 132 – 145.

Bevan N. (1995) Measuring usability as quality of use, Journal of Software Quality, Vol. 2, No. 4, pp. 115 – 150.

Bickmore, T. and Schilit, B. (1997) Digestor: Device independent access to the World Wide Web, Proc. of the 6th WWW Conference, Santa Clara, CA, USA.

Bouch A. and Sasse M. (2001) Designing QoS and charging mechanisms: He who pays the service shapes the design, Proc. of Workshop on Advanced Internet Charging and QoS Technology, Vienna, Austria.

Bouch A., Wilson G., and Sasse M. (2001) A 3-dimensional approach to assessing end-user quality of service, Proc. of London Communications Symposium, London, UK.

Brooke, J. (1986) System usability scale, Digital Equipment Corporation.

Butter A. and Porgue D. (2002) Piloting Palm: The inside story of Palm, Handspring, and the birth of the billion-dollar handheld industry, New York, USA: John Wiley and Sons.

Buyukkokten O., Garcia-Molina H., and Paepcke A. (2001) Seeing the whole in parts: Text summarization for web browsing on handheld devices, Proc. of 10th World Wide Web Conference, Hong Kong, China.

Carlsson C., Carlsson J., Hyvönen K., Puhakainen J., and Walden P. (2006) Adoption of mobile devices/services - Searching for answers with the UTAUT, Proc. of the 39th Annual Hawaii International Conference on System Sciences, Big Island, HI, USA.

Carvalho A. (2006) Diffusion of mobile phones in Portugal: Unexpected success? Proc. of International ProACT Conference on Innovation Pressure, Tampere, Finland.

Chae M. and Kim J. (2001) Information quality for mobile internet services: A theoretical model with empirical validation, Proc. of the International Conference on Information Systems, New Orleans, LA, USA.

Chae M. and Kim J. (2003) What's so different about the mobile Internet? Communications of the ACM, Vol. 46, No. 12, pp. 240 – 247.

Chae M. and Kim J. (2004) Do size and structure matter to mobile users? An empirical study of the effects of screen size, information structure, and task complexity on user activities with standard web phones, Behaviour and Information Technology, Vol. 23, No. 3, pp. 165 – 181.

Chen Y., Ma W., and Zhang H. (2003) Detecting web page structure for adaptive viewing on small form factor devices, Proc. of the 12th International World Wide Web Conference, Budapest, Hungary.

Cheong, J. and Park M-C. (2005) Mobile internet acceptance in Korea, Internet Research, Vol. 15, No. 2, pp. 125 – 140.

Chismar W. and Wiley-Patton S. (2003) Does the extended technology acceptance model apply to physicians, Proc. of the 36th Annual Hawaii International Conference on System Sciences, Big Island, HI, USA.

Clarkson E., Clawson J., Lyons K., and Starner T., (2005) An empirical study of typing rates on mini-QWERTY keyboards, Proc. ACM Conf. on Human Factors in Computing Systems, Oregon, USA.

Compeau D. and Higgins C. (1995) Computer self-efficacy: Development of a measure and initial test, MIS Quarterly, Vol. 19, No. 2, pp. 189 – 211.

Crowston K., Howison J., and Annabi, H. (2006) Information systems success in free and open source software development: Theory and measures, Software Process – Improvement and Practice, Vol. 11, No. 2, pp. 123 – 148.

Culnan M. (1983) Environmental scanning: The effects of task complexity and source accessibility on informational gathering behavior, Decision Sciences, Vol. 14, No. 2, pp. 194 – 206.

Daft R. and Macintosh N. (1981) A tentative exploration into the amount and equivocality of information processing in organizational work units, Administrative Science Quarterly, Vol. 26, No. 2, pp. 207 – 224.

D'Ambra J. and Wilson, C. (2004) Use of the World Wide Web for international travel: Integrating the construct of uncertainty in information seeking and the task-technology fit (TTF) model, Journal of the American Society for Information Science and Technology, Vol. 55, No. 8, pp. 731 – 742.

Davis F. (1989) Perceived usefulness, ease of use, and user acceptance of information technology, MIS Quarterly, Vol. 13, No. 3, pp. 319 – 340.

Davis F., Bagozzi R., and Warsaw P. (1989) User acceptance of computer technology: A comparison of two theoretical models, Management Science, Vol. 35, No. 8, pp. 982 – 1002.

DeLone W. and McLean, E. (1992) Information systems success: The quest for the dependent variable, Information Systems Research, Vol. 3, No. 1, pp. 60 – 95.

DeLone W. and McLean, E. (2002) Information systems success revisited, Proc. of the 35th Annual Hawaii International Conference on System Sciences, Big Island, HI, USA.

Dillon A., Richardson J., and McKnight C. (1990) The effect of display size and text splitting on reading lengthy text from the screen, Behavior and Information Technology, Vol. 9, No. 3, pp. 215 – 227.

Dillon A. and Morris M. (1996), User acceptance of information technology: theories and models, Annual Review of Information Science and Technology, Vol. 31 pp. 3 – 32.

Dillon A. (2001) User acceptance of information technology, in Karwowski and Waldemar (Eds.) Encyclopedia of Human Factors and Ergonomics, London, UK: Taylor and Francis.

Dishaw M. and Strong M. (1999) Extending the technology acceptance model with task–technology fit constructs, Information and Management, Vol. 36, No. 1, pp. 9 – 21.

Donahue G. (2001) Usability and the bottom line, IEEE Software, Vol. 18, No. 1, pp. 31 – 37.

Dubé L., Bouhis A., and Réal J. (2005) The impact of structuring characteristics on the launching of virtual communities of practice, Journal of Organizational Change Management, Vol. 18, No. 2, pp. 145 – 166.

Duchnicky J. and Kolers P. (1983) Readability of text scrolled on visual display terminals as a function of window size, Human Factors, Vol. 25, No. 6, pp. 683 – 692.

Dumas J. and Redish J. (1999) A practical guide to usability testing (2nd ed.), Portland, USA: Intellect.

Dyson M. and Haselgrove M. (2001) The influence of reading speed and line length on the effectiveness of reading from screen, International Journal of Human-Computer Studies, Vol. 54, No. 4, pp. 585 – 612.

ECSI Technical Committee (1998), European customer satisfaction index, foundation and structure for harmonized national pilot projects, Report Prepared for the ECSI Steering Committee, ECSI document No. 005.

Faulkner X. (2000) Usability engineering, New York, USA: Palgrave.

Ferguson S., Hider P., and Kelly T. (2005) Information systems evaluation and the search for success: lessons for LIS research, The Australian Library Journal, Vol. 54, No. 3.

Fichman R. (2000) The diffusion and assimilation of information technology innovations, in Zmud (Ed.) Framing the domains of it management research: glimpsing the future through the past, Cleavland, USA: Pinnaflex Publishing.

Fiedler M., Eliasson C., Chevul S., and Eriksén S. (2007) Quality of experience and quality of service in a service supply chain, Proc. of EuroFGI IA.7.6 Workshop on Socio-Economic Aspects in Next-Generation Internet, Santander, Spain.

Fizbein M. and Ajzen I. (1975) Belief, attitude, intention, and behavior: An introduction to theory and research. Reading, USA: Addison-Wesley.

Flannery B. and May D. (2000) Environmental ethical decision making in the U.S. metal-finishing industry, Academy of Management Journal, Vol. 43, No. 4, pp. 642 – 662.

Forman G. and Zahorjan J. (1999) The challenges of mobile computing, in Douglis, Milojicic, and Wheeler (Eds.) Mobility: processes, computers, and agents, Boston, USA: Addison-Wesley.

Fornell C., Johnson M., Anderson E., Cha J., and Bryant B. (1996) The American customer satisfaction index: Nature, purpose and findings, Journal of Marketing, Vol. 60, No. 4, pp. 7 – 18.

Fox A., Gribble S., Chawathe Y., and Brewer, E. (1998) Adapting to network and client variation using infrastructural proxies: Lessons and perspectives, IEEE Personal Communication, Vol. 5, No. 4, pp. 10 – 19.

Garrity E, Glassberg B., Kim Y., Sanders G., and Shin S. (2005) An experimental investigation of web-based information systems success in the context of electronic commerce, Decision Support Systems, Vo. 39, No. 3, pp. 485 – 503.

Gebauer J. and Shaw M. (2002) A theory of task/technology fit for mobile applications to support organizational processes, Proc. of the 1st Workshop on E-Business, Barcelona, Spain.

Gebauer J. and Shaw M. (2004) success factors and impacts of mobile business applications: Results from a mobile e-procurement study, International Journal of Electronic Commerce, Vol. 8, No. 3, pp. 19 – 41.

Gebauer J., Shaw, M., and Subramanyam, R. (2007) Once built well, they might come: A study of mobile e-mail, University of Illinois at Urbana-Champaign, College of Business Working Paper. Retrieved January 2008 from the World Wide Web: http://www.business.uiuc.edu/Working_Papers/papers/07-0117.pdf

Gebauer J. and Tang Y. (2008) Applying the theory of task-technology fit to mobile technology: The role of user mobility, International Journal of Mobile Communications, Vol. 6, No. 3, pp. 321 – 344.

Gillmore M., Archibald M., Morrison D., Wilsdon A., Wells E., Hoppe, M., Nahom D., and Murowchick E. (2002) Teen sexual behavior: Applicability of the theory of reasoned action, Journal of Marriage and Family, Vol. 64, No. 4, pp. 885 – 897.

Goodhue D. and Thompson R. (1995) Task-technology fit and individual performance, MIS Quarterly, Vol. 19, No. 2, pp. 213 – 236.

Goodhue D., Klein B., and March S. (2000) User evaluations of IS as surrogates for objective performance, Information and Management, Vol. 38, No. 2, pp. 87 – 101.

Gould J. and Lewis C. (1985) Designing for usability: Key principles and what designers think, Communications of the ACM, Vol. 28, No. 3, pp. 300 – 311.

Gutwin C. and Fedak C. (2004) Interacting with big interfaces on small screens: A comparison of fisheye, zoom, and panning techniques, Proc. of Graphics Interface Conference, London, Ontario, Canada.

Haddon L. (2006) The contribution of domestication research to in-home computing and media consumption, The Information Society, Vol. 22, No. 4, pp. 195 – 203.

Han S. and Kwankh J. (1994) Design of a menu for small displays presenting a single item at a time, Proc. of the 38th Annual Meeting of Human Factors and Ergonomics Society, Nashville, TN, USA.

Hassenzahl M., Beu A. and Burmester, M. (2001) Engineering Joy, IEEE Software, Vol. 18, No. 1, pp. 70 – 76.

Hassenzahl M., Kekez R., and Burmester M. (2002) The importance of a software's pragmatic quality depends on usage modes, Proc. of the 6th International Conference on Work with Display Units, Berchtesgaden, Germany.

Heath B., Herman R., Lugo G., Reeves J., Vetter R., and Ward C. (2005) Developing a mobile learning environment to support virtual education communities, Technological Horizons in Education, Vol. 32, No. 8, p. 33 – 41.

Heng S. (2004) Mobile telephony – cooperation and value-added are key to further success, Deutsche Bank Research Economics Working Paper, No. 42.

Hofstede G. (2001) Culture's consequences: International differences in work-related values (2nd ed.), London, UK: Saga Publications.
Holcomb R. and Tharp A. (1991) What users say about software usability? International Journal of Human-Computer Interaction, Vol. 3, No. 1, pp. 49 – 78.
Holland C. and Light B. (1999) A critical success factors model for ERP implementation, IEEE Software, Vol. 16, No. 3, pp. 30 – 36.
Hong K. and Kim Y. (2002) The critical success factors for ERP implementation: an organizational fit perspective, Information and Management, Vol. 40, No. 1, pp. 25 – 40.
Hori M., Kondoh G., Ono K., Hirose S., and Singhal S. (2000) Annotation-based web content transcoding, Proc. of the 9th International World Wide Web Conference, Amsterdam, Holland.
Hossfeld T., Tran-Gia P., and Fiedler M. (2007) Quantification of quality of experience for edge-based applications, Proc. of International Teletraffic Congress, Ottawa, Canada.
Ilie V., van Slyke C., Green G., and Lou H. (2005) Gender differences in perceptions and use of communication technologies: A diffusion of innovation approach, Information Resources Management Journal, Vol. 18, No. 3, pp. 13 – 31.
ISO (1998) Ergonomic requirements for office work with visual display terminals (VDTs) – Part 11: Guidance on usability, International Organization for Standardization, Standard 9241-11.
ISO (1999) Human-centred design processes for interactive systems, International Organization for Standardization, Standard 13407.
ITU (2007) World telecommunication/ICT indicators database (11th ed.), International Telecommunication Union.
ITU-T (1994) Terms and definitions related to quality of service and network performance including dependability, International Telecommunication Union, Telecommunication Standardization Sector (ITU-T), Recommendation E.800
ITU-T (2001) Communications quality of service: A framework and definitions, International Telecommunication Union, Telecommunication Standardization Sector (ITU-T), Recommendation G.1000
Ives B., Olson M., and Barioudi J. (1983) The measurement of user information satisfaction, Communications of the ACM, Vol. 26, No. 10, pp. 785 – 793.
Jain R. (2004) Quality of experience, Multimedia IEEE, Vol. 11, No. 1, pp. 96 – 97.
Jones M., Marsden G., Mohd-Nasir N., Boone, K., and Buchanan, G. (1999) Improving web interaction on small displays, Computer Networks, Vol. 31, No. 11, pp. 1129 – 1137.
Joseph A., Tauber J., and Kaashoek M. (1997) Mobile computing with the Rover toolkit, Transactions on Computers, Vol. 46, No. 3, pp. 337 – 352.
Kaasinen, E. (2005) User acceptance of mobile services – value, ease of use, trust and ease of adoption, Espoo, Finland: VTT Information Technology.
Kaefer F. and Bedoly E. (2004) Measuring the impact of organizational constraints on the success of business-to-business e-commerce efforts: A transactional focus, Information and Management, Vol. 41, No. 5, pp. 529 – 541.

Kankanhalli A., Tan B., and Wei, K. (2005) Understanding seeking from electronic knowledge repositories: An empirical study, Journal of the American Society for Information Science and Technology, Vol. 56, No. 11., pp. 1156 – 1166.

Kanungo S., Duda S., and Srinivas Y, (1999) A structured model for evaluating information systems effectiveness, Systems Research and Behavioural Science, Vol. 16, No. 6, pp. 495 – 518.

Kaplan R. and Norton D. (1992) The balanced scorecard: Measures that drive performance, Harvard Business Review, Vol. 70, No. 1, pp. 71 – 79.

Karat J. and Karat C. (2003) The evolution of user-centered focus in the human-computer interaction field, IBM Systems Journal, Vol. 42, No. 4, pp. 532 – 541.

Kirakowski J. (1996) The software usability measurement inventory: Background and usage, in Jordan, Thomas, Weerdmeester, and McClelland (Eds.) Usability evaluation in industry, London, UK: Taylor and Francis.

Kirakowski J. and Cierlik B. (1999) Context of use: Introductory notes. Retrieved August 2007 from the World Wide Web: ftp://ftp.ucc.ie/hfgr/baseline/CoU20.rtf

Koivisto M. (2008) Acceptance of mobile communication technologies in student communities, to appear in special issue on Dynamic virtual communities in the information society: Technologies, methodologies, and tools, International Journal of Web Based Communities, Vol. 4, No. 3.

Koufaris M. (2002) Applying the technology acceptance model and flow theory to online consumer behavior, Information Systems Research, Vol. 13, No. 2, pp. 205 – 223.

Kuan H., Bock G.-W., and Vathanophas V. (2005) Comparing the effects of usability on customer conversion and retention at e-commerce websites, Proc. of the 38th Annual Hawaii International Conference on System Sciences, Big Island, HI, USA.

Kushniruk A. (2002) Evaluation in the design of information systems: Applications of approaches from usability engineering, Computers in Biology and Medicine, Vol. 32 , No. 3, pp.141 – 149.

Kushniruk A. and Patel V. (2004) Cognitive and usability engineering methods for the evaluation of clinical information systems, Journal of Biomedical Informatics, Vol. 37, No. 1, pp. 56 – 76.

Kwon H. (2000) A test of the technology acceptance model: the case of cellular telephone adoption", Proc. of the 33rd Annual Hawaii International Conference on System Sciences, Big Island, HI, USA.

Lederer A., Maupin D., Sena M., and Zhuaong Y. (2000) The technology acceptance model and the World Wide Web, Decision Support Systems, Vol. 29, No. 3, pp. 269 – 282.

Lee W., Kim T., and Chung J. (2002) User acceptance of the mobile Internet, Proc. of the 1st International Conference on Mobile Business, Athens, Greece.

Legris P., Ingham J., and Collerette P. (2003) Why do people use information technology? A critical review of the technology acceptance model, Information and Management, Vol. 40, No. 3, pp. 191 – 204.

Leppävuori I. (2002) Analysis of the Finnish mobile cluster – any potential in mobile services, Publication of the Ministry of Transport and Communications, Finland, No. 28.

Lewis J. (1995) IBM computer usability satisfaction questionnaire: Psychometric evaluation and instructions for use, International Journal of Human-Computer Interaction, Vol. 7 No. 1, pp. 57 – 78.

Liang H., Xue Y., and Byrd T. (2003) PDA usage in healthcare professionals: Testing an extended technology acceptance model, International Journal of Mobile Communications, Vol. 1, No. 4, pp. 372 – 389.

Liker J. and Sindi A. (1997) User acceptance of expert systems: A test of the theory of reasoned action, Journal of Engineering and Technology Management, Vol. 14, No. 2, pp. 147 – 173.

Lindmark S. and Bohlin, E. (2003) What are the lessons from Japan's mobile internet success story? Implications from a comparative study, Proc. of the 2nd International Conference on Mobile Business, Vienna, Austria.

Liu, B., Madhavan, R, and Sudharshan, D. (2005) DiffuNET: The impact of network structure on diffusion of innovation, European Journal of Innovation Management, Vol. 8, No. 2, pp. 240 – 262.

Lu J., Liu C., Yu C., Yao J. (2003) Exploring factors associated with wireless internet via mobile technology acceptance in mainland China, Communications of the International Information Management Association, Vol. 3, No. 1, pp. 101 – 120.

Lyytinen K. and Damsgaard J. (2001) What's wrong with the diffusion of innovation theory? Proc. of the 4th Working Conference on Diffusing Software Products and Process Innovations, Banff, Canada.

Maguire M. (2001) Context of use within usability activities, International Journal of Human-Computer Studies, Vol. 55, No. 4, pp. 453 – 483.

Mahajan V. and Peterson R. (1985) Models for innovation diffusion, Beverly Hills, USA: Sage Publications.

Mahajan V., Muller E., and Bass F. (1990) New product diffusion models in marketing: A review and directions for research, Journal of Marketing, Vol. 54, No. 1, pp. 1 – 26.

Mallat N., Rossi M., Tuunainen V., and Oorni A. (2006) The impact of use situation and mobility on the acceptance of mobile ticketing services, Proc. of the 39th Annual Hawaii International Conference on System Sciences, Big Island, HI, USA.

Mantei M. and Teorey T. (1988) Cost/benefit analysis for incorporating human factors in the software lifecycle, Communications of the ACM, Vol. 31, No. 4, pp. 428 – 439.

Mao J-Y, Vredenburg K., Smith P. and Carey T. (2005) The state of user-centered design practice, Communications of the ACM, Vol. 48, No. 3, pp. 105 – 109.

Marcus A, (2005) User interface design’s return of investment: Examples and statistics, in Bias and Mayhew (Eds.) Cost-justifying usability: An update for an internet age, San Francisco, USA: Morgan Kaufmann.

Martinsons M., Davidson R., and Tse D. (1999) The balanced scorecard: a foundation for the strategic management of information systems, Decision Support Systems, Vol. 25, No. 1, pp. 71 – 88.

Mason R. (1978) Measuring information output: A communication systems approach, Information and Management, Vol. 1, No. 5, pp. 219 – 234.

Mathieson K. and Keil M. (1998) Beyond the interface: Ease of use and task/technology fit, Information and Management, Vol. 34, No. 4, pp. 221 – 230.
Mauro C. (2002) Professional usability testing and return on investment as it applies to user interface design for web-based product and services, White Paper, MauroNewMedia.
McEwan P. and Levin H. (2001) Cost-Effectiveness Analysis: Methods and Applications, London, UK: SAGE Publications.
McKinney V., Yoon K., and Zahedi F. (2002) The measurement of web-customer satisfaction: An expectation and disconfirmation approach, Information Systems Research, Vol. 13, No. 3), pp. 296 – 315.
Microsoft (2002) Measuring success of IT investment: Army looks at REJ to make effective technology decisions, Frontlines, Microsoft Government.
Milis K. and Vanhoof K. (2007) Analysing success criteria for ICT projects, International Journal of Nuclear Knowledge Management, Vol. 2, No. 4, pp. 449 – 455.
Mills K. and Mercken R. (2004) The use of the balanced scorecard for the evaluation of information and communication technology projects, International Journal of Project Management, Vol. 22, No. 2, pp. 87 – 97.
van Moorsel A. (2001) Metrics for the Internet age: Quality of experience and quality of business, Technical report no: HPL-2001-179.
Myers B., Kappelman, L., and Prybutok V. (1998) A comprehensive model for assessing the quality and productivity of the information systems function: Toward a theory for information systems assessment, in Garrity and Sanders (Eds.), Information Systems Success Measurement. Hershey, USA: Idea Group.
Mylonopoulos N. and Doukidis G. (2003) Introduction to the special issue: Mobile business: Technological pluralism, social assimilation, and growth, International Journal of Electronic Commerce, Vol. 8, No. 1, pp. 5 – 22.
Nah F., Zhu W., and Zhao F. (2003) Factors influencing users' adoption of mobile computing, in Mariga (Ed.) Managing e-commerce and mobile computing technologies, Hershey, USA: IGI Publishing.
Nas T. (1996) Cost-benefit analysis: Theory and application, Thousand Oaks, USA: SAGE Publications.
Norman, D. and Draper, S. (1986) User-centered system design: New perspectives on human-computer interaction, Hillsdale, NJ, Lawrence Earlbaum Associates.
Norman, D. (1988) The psychology of everyday things, New York, USA, Basic Books.
Nielsen J. (1993) Usability engineering, Boston, USA: Academic Press.
Nielsen-Norman Group (2003), Return on investment for usability (2nd ed.), Nielsen-Norman Group Report.
Oniszczak A. and MacKenzie S. (2004) A comparison of two input methods for keypads. Proc. of NordiCHI´04, Tampere, Finland.
Oulasvirta A. (2004) Human–computer interaction in mobile context: A cognitive resources perspective, Licentiate Thesis, Department of Psychology, University of Helsinki.

Pagani M. (2004) Determinants of adoption of third generation mobile multimedia services, Journal of Interactive marketing, Vol. 18, No. 3, pp. 46 – 59.
Palm J-M, Colombet I., Sicotte C., and Degouleta P. (2006) Determinants of user satisfaction with a clinical information system, In Proc. of AMIA Annual Symposium, Washington D.C., USA.
Park Y. (2007) Success factors for destination marketing web sites: A qualitative meta-analysis, Journal of Travel Research, Vol. 46, No. 1, pp. 46 – 63.
Parker M., Benson R., and Trainer H. (1988), Information economics: Linking business performance to information technology, Englewood Cliffs, NJ: Prentice-Hall.
Parker P. (1994) Aggregate diffusion forecasting models in marketing: A critical review, International Journal of Forecasting, Vol. 10, No. 2, pp. 353 – 380.
Pavlou P. (2003) Consumer acceptance of electronic commerce: Integrating trust and risk with the technology acceptance model, International Journal of Electronic Commerce, Vol. 7, No. 3, pp. 101 – 134.
Pedersen P. (2003) Usefulness and self-expressiveness: Extending TAM to explain the adoption of a mobile parking service, Proc. of the 16th Bled Electronic Commerce Conference, Bled, Slovenia.
Pedersen P. (2005) Adoption of mobile internet services: An exploratory study of mobile commerce early adopters, Journal of Organizational Computing and Electronic Commerce, Vol. 15, No. 3, pp. 203 – 222.
Phuangthong D. and Malisawan S. (2005) A study of behavioral intention for 3G mobile internet technology: Preliminary research on mobile learning, Proc. of the 2nd International Conference on eLearning for Knowledge-Based Society, Bangkok, Thailand.
Pilioura T., Tsalgatidou A., and Hadjiefthimiades S. (2003) Scenarios of using Web Services in m-services, ACM SIGECOM Exchanges, Vol. 3, No. 4, pp. 28 – 36.
Portides D. (2006) Abstraction, induction and abduction in scientific modeling, Proc. of the 17th European Conference on Artificial Intelligence, Riva del Garda, Italy.
Pousttchi K. and Wiedemann D. (2007) What influences consumers´ intention to use mobile payments? Proc. of the 2007 LA Global Mobility Roundtable. Los Angeles, CA, USA.
Prescot M. and Conger S. (1995) Information technology innovations: A classification by IT locus of impact and research approach, ACM SIGMIS Database, Vol. 26, No. 2 – 3, pp. 20 – 41.
Qiu M., Zhang K., and Huang M. (2006) Usability in mobile interface browsing, Web Intelligence and Agent Systems, Vol. 4, No. 1, pp. 43 – 59.
RACE (1994) UMTS system structure document, Issue 1.0 RACE 2066 Mobile Networks (Monet), CEC Deliverable No: R2066/LMF/GA1/DS/P/052/b1
Ragatz G., Handfield R., and Scannell T. (1997) Success factors for integrating suppliers into new product development, The Journal of Product Innovation Management, Vol. 14, No. 3, pp. 190 – 202.
Rai A., Lang S., and Welker, R. (2002) Assessing the validity of IS success models: An empirical test and theoretical analysis, Information Systems Research, Vol. 13, No. 1, pp. 50 – 69.

Ramayah T. (2005) Doing e-research with e-library: determinants of perceived ease of use of e-library, International Journal of Technology, Knowledge and Society, Vol. 1, No. 4, pp. 71 – 82.

Rogers E. (1962) Diffusion of innovations, New York, USA: The Free Press.

Rogers E. (1995) Diffusion of innovations (4th ed.), New York, USA: The Free Press.

Ryan B. and Gross N. (1943) The diffusion of hybrid seed corn in two Iowa communities, Rural Sociology, Vol. 8, No. 1, pp. 15 – 24.

Sanson-Fisher R. (2004) Diffusion of innovation theory for clinical change, Medical Journal of Australia, Vol. 180, No. 6 (Supplement), pp. S55 – S56.

Scheer A. and Habermann F. (2000) Enterprise resource planning: Making ERP a success, Communications of the ACM, Vol. 43, No. 4, pp. 57 – 61

Schenkman B. and Jonsson F. (2000) Aesthetics and preferences of web pages, Behaviour & Information Technology, Vol. 19, No. 5, pp. 367 – 377.

Seddon P. and Kiew K. (1994) A partial test and development of the DeLone and McLean's model of IS success, Proc. of the 15th International Conference on Information Systems, Vancouver, Canada.

Seddon P. (1997) A respecification and extension of the DeLone and McLean model of IS success. Information Systems Research, Vol. 8, No. 3, pp. 240 – 253.

Shannon C. and Weaver W. (1949) The mathematical theory of communication, Urbana, USA: University of Illinois Press.

Sheppard B., Hartwick J., and Warshaw P. (1988) The theory of reasoned action: A meta-analysis of past research with recommendations for modifications and future research, Journal of Consumer Research, Vol. 15, No. 3, pp. 325 – 343.

Shneiderman B. (1998) Designing the user interface: Strategies for effective human-computer interaction (3rd ed.), Reading, USA: Addison-Wesley.

Siau K., Lim E., and Shen Z. (2001) Mobile commerce: Promises, challenges and research agendas, Journal of Database Management, Vol. 12, No. 3, pp. 3 – 10.

Singletary L., Akbulut A., and Houston A. (2002) Innovative software use after mandatory adoption, Proc. of the 8th Americas Conference on Information Systems, Dallas, TX, USA.

Soukoreff W. and MacKenzie S. (2001) Measuring errors in text entry tasks: An application of the Levenshtein string distance statistic, Proc. of the ACM Conference on Human Factors in Computing System, New York, NY, USA.

Soukoreff W. and MacKenzie S. (2003) Metrics for text entry research: An evaluation of MSD and KSPC, and a new unified error metric, Proc. of the ACM Conference on Human Factors in Computing Systems, New York, NY, USA.

Soukoreff W. and MacKenzie S. (2004) Recent developments in text entry error rate measurements, Proc. of the ACM Conference on Human Factors in Computing Systems, New York, NY, USA.

Sung T. (2006) E-commerce critical success factors: East vs. West, Technological Forecasting and Social Change, Vol. 73, No. 9, pp. 1161 – 1177.

Sylla C. and Wen J. (2002) A conceptual framework for evaluation of information technology investments, International Journal of Technology Management, Vol. 24, No. 2/3, pp. 236 – 261.

Tan K., Kannan V., Handfield R., and Ghosh S. (1999), Supply chain management: An empirical study of its impact on performance', International Journal of Operations & Production Management, Vol. 19 No. 9 – 10, pp. 1034 – 1052.

Tarasewich P., Nickerson R., and Warkentin M. (2002) Issues in mobile e-commerce, Communications of the Association for Information Systems, Vol. 8, pp. 41 – 64.

Tarde G. (1903) The laws of imitiation, (E. C. Parsons, Trans.), New York, USA: Holt.

Tariq R. (2005) Vodaphone's business strategies for success in the third generation (3G) mobile communication", MBA Thesis, University of Bradford.

Taylor S. and Todd P. (1995) Understanding information technology usage: A test of competing models, Information Systems Research, Vol. 6, No. 4, pp. 144 – 176.

Thompson R., Higgins C., and Howell J. (1991) Personal computing: Toward a conceptual model of utilization, MIS Quarterly, Vol. 15, No. 1, pp. 124 – 143.

Tombaugh J., Arkin M., and Dillon R. (1985) The effect of VDU text-presentation rate on reading comprehension and reading speed, Proc. of the ACM Conference on Human Factors in Computing System, San Francisco, CA, USA.

Tractinsky N. (1997) Aesthetics and apparent usability: Empirically assessing cultural and methodological issues, Proc. of the ACM Conference on Human Factors in Computing Systems, Atlanta, GA, USA.

Turel O. and Serenko A. (2006) Satisfaction with mobile services in Canada: An empirical investigation, Telecommunications Policy, Vol. 30, No. 5 – 6, pp. 314 – 331.

Turner, J. (1993) The handbook of project-based management. London, UK: McGraw-Hill.

Tyldesley D. (1988) Employing usability engineering in the development of office products, Computer Journal, Vol. 31, No. 5, pp. 431 – 436.

Vallerand R. (1997) Toward a hierarchical model of intrinsic and extrinsic motivation, in Zanna (Ed.) Advancesin Experimental Social Psychology, New York, USA: Academic Press.

Venkatesh V. and Davis F. (1996) A model of the antecedents of perceived ease of use: Development and test, Decision Sciences, Vol. 27, No. 3, pp. 451 – 481.

Venkatesh V. (2000) Determinants of perceived ease of use: Integrating control, intrinsic motivation, and emotion into the technology acceptance model, Information Systems Research, Vol. 11, No. 4, pp. 342 – 365.

Venkatesh V. and Davis F. (2000) A theoretical extension of the technology acceptance model: Four longitudinal field studies, Management Science, Vol. 46, No. 2, pp. 186 – 204.

Venkatesh V., Morris M., Davis G., and Davis F. (2003) User acceptance of information technology: Toward a unified view, MIS Quarterly, Vol. 27, No. 3, pp. 425 – 478.

Vessey I. (1991) Cognitive fit: A theory-based analysis of the graphs versus tables literature, Decision Sciences, Vol. 22, No. 2, pp. 219 – 240.
Vessey I. and Galletta D. (1991) Cognitive fit: An empirical study of information acquisition, Information Systems Research, Vol. 2, No. 1, pp. 63 – 84.
Wallis-Brown P. and von Hellens L. (2000) The secret of the global success of Nokia Mobile Phones and Ericsson Mobile Communications, Proc. of the Academia/Industry Working Conference on Research Challenges, Buffalo NY, USA.
Wateridge J. (1998) How can IS/IT projects be measured for success? International Journal of Project Management, Vol. 16, No. 1, pp. 59 – 63.
Wenger E., McDermott R., and Snyder W. (2002) Cultivating communities of practice, Boston, USA: Harvard Business School Press.
Wilkin C. and Hewitt B. (1999) Quality in a respecification of DeLone and McLean's IS success model, Proc of the 10th Information Resources Management Association International Conference.
Wilson G. and Stacey E. (2003) online interaction impacts on learning: Teaching the teachers to teach online, Proc. of the 20th Annual Conference of the Australasian Society for Computers in Learning in Tertiary Education. Adelaide, Australia.
Wixom B. and Todd P. (2005) A theoretical integration of user satisfaction and technology acceptance, Information Systems Research, Vol. 16, No. 1, pp. 85 – 102.
Wixon D. and Wilson C. (1997) The usability engineering framework for product design and evaluation, in Helander, Landauer, and Prabhu (Eds.) Handbook of Human-Computer Interaction (2nd ed.), Amsterdam, The Netherlands: North-Holland.
Wobbrock J., Myers B., Aung H., and LoPresti E. (2004) Text entry from power wheelchairs: EdgeWrite for joysticks and touchpads, Proc. of the 6th ACM Conference on Computers and Accessibility, Atlanta, GA, USA.
Wood S. and Chatterjee S. (2002) Network quality of service for the enterprise: A broad overview, Information Systems Frontiers, Vol. 4, No. 1, pp. 63 – 84.
Wright J. (1997) Time and budget: The twin imperatives of a project sponsor, International Journal of Project Management, Vol. 15, No. 3, pp. 181 – 186.
Xie X., Liu H., Goumaz S., and Ma W. (2005) Learning user interest for image browsing on small-form-factor devices, Proc. of the SIGCHI conference on human factors in computing systems, Portland, OR, USA.
Zhu K., Kraemer K., and Xu S. (2006) The process of innovation assimilation, Management Science, Vol. 52, No. 10, pp. 1557 – 1576.

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