Acceptance-by-Design
Elicitation of Social Requirements for Intelligent Infrastructures

Proefschrift

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To the woman who encouraged her children to continually further their education and broaden their horizons…To my mother…

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Chapter 1 : Introduction

1.1 Background

A critical infrastructure is a term used by governments to describe material assets that are essential for the functioning of a society and economy. Generally, the term encompasses a wide spectrum of fundamental services such as: electricity generation and distribution, telecommunication, water supply, agriculture, food production and distribution, public health, and transportation systems among others. Over the decades the operation of critical infrastructures has witnessed rapid developments in both the quantity and quality of their offered services, and in the way these services are being implemented and delivered to consumers. One of the major transformations in these infrastructures is the adoption of the latest developments in the information and communication technologies. The massive, rapid and ongoing developments over the past decades of information and communication technologies included: computer hardware and software, information management systems, and computer networks topologies and mechanisms. This digital revolution led to the emergence of state-of-the art ICT infrastructures which facilitate the manipulation, storage and transportation of enormous volumes of data and information. The level of ICT involvement in critical infrastructures varies in visibility from back-end systems and underlying infrastructure technologies, to interactive user service end-points.

Today, the incorporation of ICT infrastructures as a vital component supporting critical infrastructures has reshaped the services offered by infrastructure systems to consumers, improved the quality of these services, in addition to the automation of a number of essential services that are part of the daily life of millions of people in The Netherlands. The transformation has turned infrastructure systems into intelligent infrastructure systems that aim to improve the overall quality of daily life. The digitization of infrastructure systems was driven by goals that are either on a national or EU level. Furthermore, this digitization yields advantages for both consumers and other actors who are responsible for governing and operating the infrastructures. Despite the advantages that can be gained from the operation of smart infrastructure systems, a full-scale deployment of such systems was hindered due to inherent properties of their embedded ICT-backbone infrastructure. As a result, intelligent infrastructures could not reach their full potential, nor were they able to fulfill their goals.

Obstacles challenging the deployment of smart infrastructure systems can be attributed to two characteristics of these systems. First, infrastructure systems are socio-technical system. That is, they are systems that mainly consist of two major layers of components: technical and social. The technical layer encompasses physical components of the system, the collective operation of which delivers the intended services to society. The social layer includes the entire social component, i.e. actors, who assume various roles and interact with physical system accordingly. Each component can interact with other components from either the physical or social layer.

Socio-technical systems have received a lot of attention throughout the literature during the past decades, due to their complexity and the inherent challenges associated with many aspects of these systems, such as; the planning, management and development of this class of systems. Each layer is subjected to a different set of rules and laws. For example, the technical layer follows physical laws, e.g. Newton's laws, or Einstein's theory of relativity, whereas the social layer abides by social laws, e.g. legislation, unwritten codes of behavior, or economic contracts. Complexity of socio-technical systems' is due partly to both types of laws influencing the system, in combination with the interaction occurring between the physical and social layer (van Dam 2009). For a more detailed account of socio-technical systems and some of their associated challenges, the reader is referred to (van Dam 2009).

Second, as described earlier in this chapter, infrastructure systems have become ICT-intensive systems, which imply the existence of a new set of vulnerabilities, against which these systems must be made resilient. In general, the combination of the two aforementioned characteristics of socio-technical systems caused the evolution of potential vulnerabilities, which can be classified as follows:

- **Technical vulnerabilities:** weaknesses of physical technical components of a system, which can results from design deficiencies or immanent properties of the technologies used for system implementation. Such vulnerabilities may render the system weak and exposed to external threats. A prominent weakness that is incurred by embedding ICT-infrastructures is information security vulnerabilities, which can lead to information security breaches of the system.

- **Social vulnerabilities:** attitude or a belief adopted by the different social actors who interact with the physical components of the system, which may lead to decisions or actions that could negatively impact the system or the continuation of its operation.

The social vulnerabilities associated with the different actors of a system can take diverse forms and have various impacts on the system; all of which are negative and can prevent reaching the intended goals of the systems. One from of social vulnerabilities that can result from actors affiliated with organizations operating a system is the lack of proper security culture within the organization. That is, interacting with the system -by accessing or processing its data – with an indifferent attitude towards the importance of information security. This lack of awareness or the negligent attitude toward information security can be -and many times is- exploited by attackers. System exploitation can be carried out using many techniques such as: social engineering methods to gain unlawful access to the system and its information assets. Another form of social vulnerabilities is social rejection of systems due to aspects such as: poor information security implementation, health-insecure technical components, or financial costs incurred by the system for which consumers are responsible.

Thus far, research efforts have focused on the technical vulnerabilities of systems, such as information security and privacy risks, and explored possible methods to immunize systems against potential breaches. However, achieving the maximum possible level of information security of a system is not enough to ensure its successful deployment and operation. Attention must be paid to the neglected social components of ICT-intensive infrastructure systems, to identify ingrained vulnerabilities within the social components, and investigate techniques to mitigate the negative impact of such vulnerabilities on the infrastructure system, and ensure a successful deployment and operation.

In the remainder of this thesis, ICT-intensive infrastructure systems are referred to interchangeably as: socio-technical systems, infrastructure systems, systems, or technologies.

1.2 Problem Definition

The development of infrastructure systems mainly conforms to conventional Systems' Development Life-Cycles- SDLC. Current SDLCs are sufficient for information systems, and information technology systems that are being commissioned and used by the same social actor, i.e. system owner is the system user. However, such SDLC are deficient for infrastructure systems for two reasons: first, congenital characteristics of a system that exist due to the system's embedded ICT backbone impact the lives of members of society in a novel manner that has not been exhibited by conventional infrastructure systems. Second, the operation of such systems requires a higher level of consumers' interaction with the technology. Thus, consumers are transformed from passive into active actors of these systems.

An example of this class of systems is the smart metering infrastructure, which is used as a main case study for this research. The system is part of the smart grid in the energy domain in The Netherlands. The roll-out of the smart metering system was challenged by consumers' rejection due to a number of factors such as: perceived health risks and perceived financial cost among others. However, one of the main causes for consumers' concerns is poor level of information security of the system, which in turn is feared to cause violation of the privacy of consumers' personal information.

Consumers' acceptance of smart meters is a crucial matter in order to reach goals such as demand response, to reduce amounts of electricity used and shift times of consumption. To achieve such goals consumers are expected to interact with the system and utilize it. Attention needs to be paid to vulnerabilities stemming from the social component that may negatively impact the roll-out and operation of the system. Furthermore, investigating means of increasing consumers' acceptance of smart meters becomes essential considering the current state of the smart metering legislation in The Netherlands. In April 2009 the Dutch Senate – upper house of parliament- rejected a mandatory smart metering roll-out across The Netherlands, due to a report produced by the University of Tilburg and commissioned by Consumentebond, a consumer organization in The Netherlands (Cuijpers and Koops 2008). The report stated that from a legal standpoint smart meters pose a legal dilemma since the frequent readings of the meter are considered a breach of article 8 –right to respect for private and family life- from the Convention for the Protection of Human Rights and Fundamental

Freedoms (Council of Europe 2003, Garcia and Jacobs 2010). In September 2010, a revised smart metering legislation was introduced again to the Senate. The new legislation allows electricity consumers voluntary adoption of smart meters via a number of choices:

- Refuse the installation of a smart meter.
- Accept the installation of a smart meter, with setting the meter to "administrative off".
- Accept the installation of a smart meter, and accept remote reading of the meter and detailed energy bills.

Administrative off is an option that allows consumers to disable remote meter reading and remote disconnection, while it enables consumers to access detailed meter reading locally via port P1. This poses problems on different levels. First, if consumers reject a smart meter entirely or opt for administrative off, then this will negatively impact the business case. A cost-benefit analysis part of a financial analysis and policy advice report presented by KEMA in July 2010 stated that the business case is negatively affected if approximately 20% of consumers refuse a meter or choose to set the meter to administrative off (van Gerwen, Koenis et al. 2010). Second, consumers choosing for administrative off have the opportunity to access detailed reading of the meter locally via port P1, which means they have no incentive to switch the meter online -and make it available for remote reading and disconnection- to receive detailed bills.

Hence, to ensure a higher level of social acceptance of a technology, it is imperative to adopt a consumer-centric approach in the development of these systems, which can be achieved by taking public opinion into account when designing and implementing such systems. The need to consider public opinion in systems' development calls for the necessity to alter conventional system development life-cycles to cater for a social requirements engineering process.

1.3 Research Objectives

The goal of this research is to increase the level of social acceptance of infrastructure systems, by introducing an Acceptance-by-Design framework for systems' development that should be aligned with the overall system development life-cycle. The proposed framework promotes consumer involvement in the development process of infrastructure systems, by adopting a consumer-centric approach for systems' development. The framework presents a social requirements engineering process that aims to elicit and verify social requirements of a system.

The process begins with investigating possible system-related factors and public values of society, which can potentially influence the social acceptance of the system, and mapping these acceptance determinants into social requirements. Following such approach ensures that systems are designed and implemented by taking into account social requirements that are specific for both the systems, and the society in which it is intended to be deployed. Applying the Acceptance-by-Design framework will result in systems that are socially highly accepted, which consequently allows the realization of goals set by the different actors of the system.

1.4 Research Questions

The main question this research aims to answer is: How can social requirements of ICT-intensive infrastructure systems be elicited to increase the acceptance level of these systems?

To help answer this question, the following list of sub-questions should be answered:

1- What are the limitations of existing technology acceptance theories in predicting acceptance of infrastructure systems?

2- What are the inherent characteristics of infrastructure systems that can influence the lives of members of society?

3- What are the public values of society that can be influenced by infrastructure systems?

4- How does the identified public values and systems' characteristics influence acceptance of infrastructure systems?

5- How do infrastructure systems differ from conventional IT systems?

6- How can the system development life cycle of infrastructure systems be altered to account for social requirements?

1.5 Audience and Relevance

This works provides a framework to investigate social requirements of systems, which in addition to functional and non-functional requirements should be accounted for during systems' design and development. The smart metering technology acceptance model is deemed beneficial by electricity grid operators, as it can aid them in shedding light on public opinion and perception of smart meters within the Dutch society. The recommendations are directed at change agents, i.e. stakeholders of the smart metering system in particular -and ICT-intensive infrastructures in general- to incur change within the system's development, policies and strategies. The changes are intended to lead to a higher level of social acceptance of smart meters among the Dutch population.

1.6 Thesis Outline

The remaining chapters of this thesis are organized as follows: in Chapter 2 a number of technology acceptance theories and models are presented as a theoretical foundation of this work. The smart metering and OV-Cipkaart systems are presented as two case studies of this work in chapters 3 and 4 respectively. In Chapter 5, a comprehensive technology acceptance model is presented in the context of the smart metering system. In Chapter 6 the statistical process applied to identify the comprehensive model is presented, whereas the process of how the compressive model can be extensible across systems from different domains is discussed in Chapter 7 along with the process of elicitation of social requirements. In Chapter 8 a panel of experts' interviews is presented as an overview of experienced actors' outlook on the proposed research method. Finally, in Chapter 9 a set of smart metering system-specific recommendations, recommendations for future ICT-intensive infrastructure systems are given based on the results of model identification, in addition to overall conclusions and recommendations for future work. The research plan of this work is illustrated in Figure 1.1.

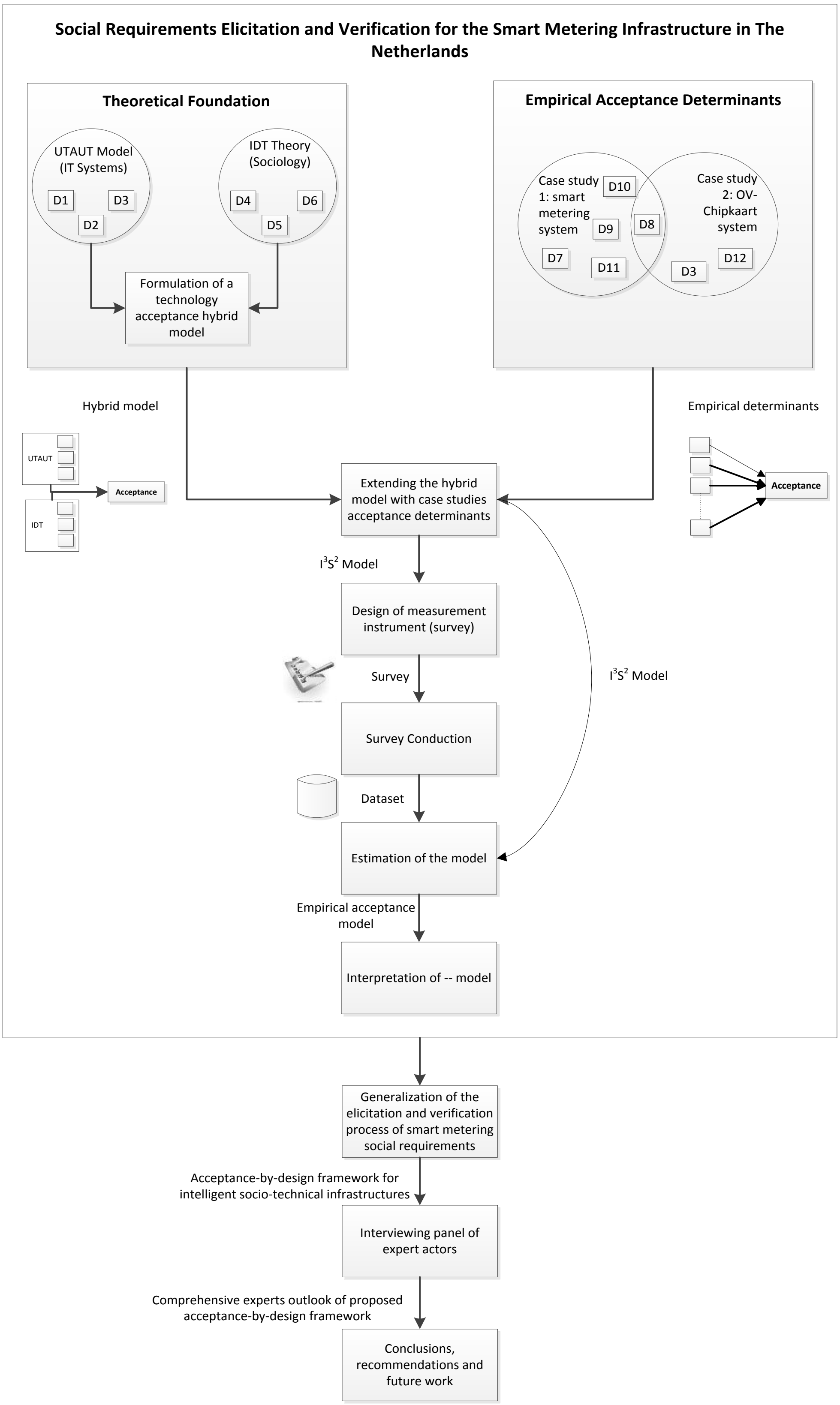

Figure 1.1: Research Plan

Chapter 2 : Technology Acceptance Theories and Models

2.1 Introduction

“ New technological innovations often fail because too much attention is still given to technical product-related features without taking into account the most important parameters of user acceptance” (Verdegem and De Marez 2011).

There exists a wide spectrum of theories and models across the technology acceptance literature. These theories originated from different fields of sciences such as psychology, sociology and information technology. Each theory was formulated based on certain concepts and hypotheses and applied within the context of different technologies. However in general, almost all these theories share a common scheme of investigating the influence of a set of technology acceptance determinants on a set of constructs that designate a variety of observed behaviors such as: the intention to accept a technology or the intention to use it.

In this chapter, a number of well-known technology acceptance and diffusion theories and models are presented. In addition to the sematic of these theories, their fields of application, possible extensions and limitations are discussed. Two of these theories were chosen as a theoretical foundation of this work, these are the Unified Theory of usage and Acceptance of Technology- UTAUT, and the Innovation Diffusion Theory- IDT. The two theories were used to form an initial hybrid technology acceptance, which is further extended with additional technology acceptance determinants later in chapter 5 of this thesis.

The remainder of this chapter is organized as follows: section 2.2 presents the UATUT model along with a set of theories encompassing its theoretical foundation. The IDT theory is discussed in section 2.3. In section 2.4 the integrated UTAUT and IDT model is presented. Finally in section 2.5 conclusions are given.

2.2 The Unified Theory of Usage and Acceptance of Technology- UTAUT

The Unified Theory of Acceptance and Use of Technology- UTAUT was constructed by Venkatesh et al. in 2003 in the IT field, to study individuals’ acceptance and usage of new information technologies introduced within organizations (Venkatesh, Morris et al. 2003). Over the decades technology acceptance research efforts have resulted in a wide spectrum of diverse theories and models, each of which offering a different view of individuals’ acceptance and usage of technology. This, according to Venkatesh et al. forces researchers to either “pick and choose” acceptance determinants across the different models, or choose a "favored model" and discard other models along with their variant contributions. The significance of the UTAUT is that it is a synthesis of a set of technology acceptance theories and models that offers researchers a unified view of user acceptance and usage of technology (Venkatesh, Morris et al. 2003). Figure 2.1 illustrates the UTAUT model.

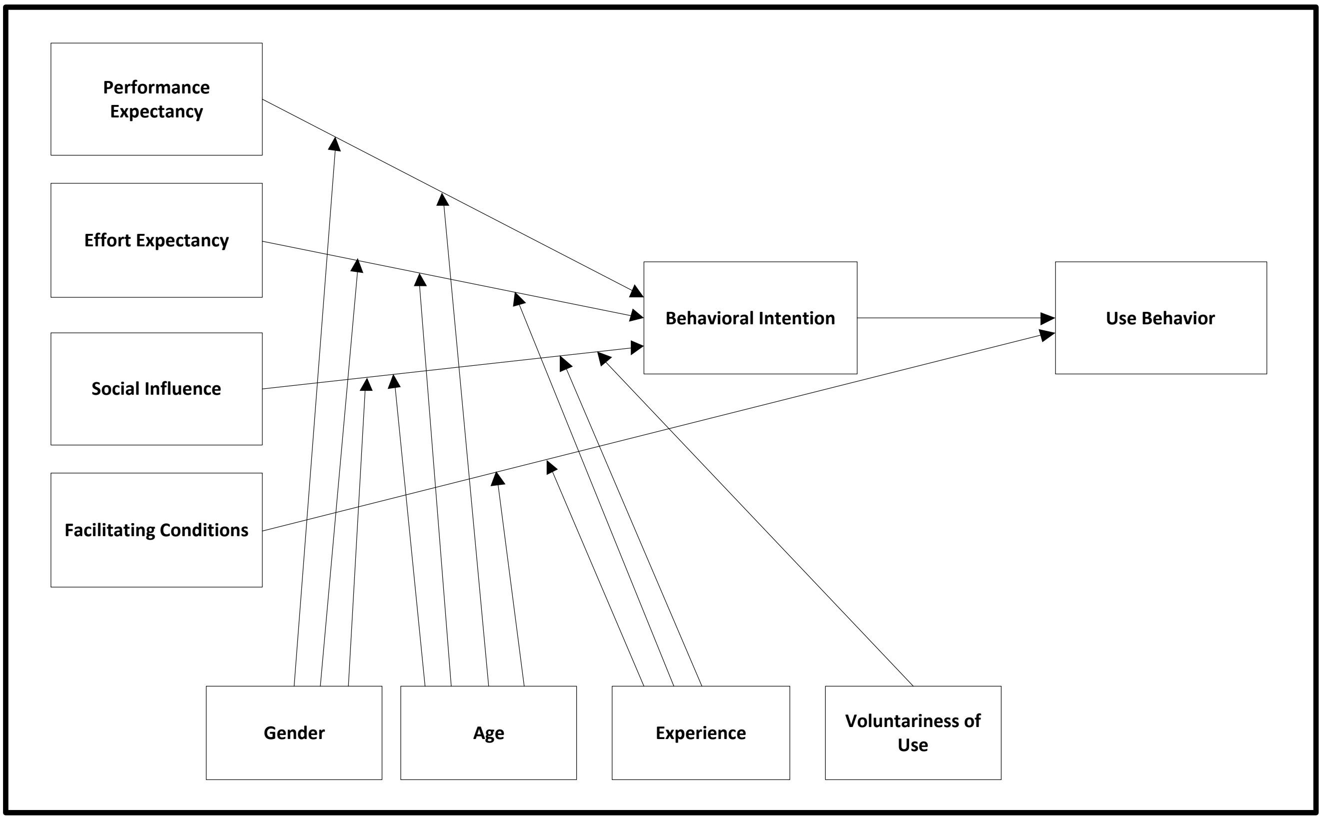

Figure 2.1: The Unified Theory of Acceptance and Use of Technology (Venkatesh, Morris et al. 2003)

The theory was formulated based on a compilation of eight prominent technology acceptance theories and models; each consists of a different set of technology acceptance determinants, and originates from different research area such as: information systems, sociology and psychology. These theories were reviewed and a number of their constructs were combined together to form the UTAUT model as a representation of a unified view of these theories. The theories comprising the UTAUT model are: Theory of Reasoned Action- TRA, Technology Acceptance Model- TAM, Motivational Model- MM, Theory of Planned Behavior- TPB, Combined TAM and TPB (C-TAM-TPB), Model of PC Utilization- MPCU, Diffusion of Innovation– DOI, and Social Cognitive Theory – SCT, each of which is described in further detail in subsequent sections of this chapter.

Another distinguishing feature of the UTAUT model is that its empirical data resulted from a longitudinal study, which was carried out over a protracted period of time at four different organizations. The questionnaire formulated to measure constructs from the eight models was administered within four organizations at multiple points in time: after users attended a training program intended to familiarize users with the newly introduced technology, one month after deployment of the new technology, three months after deployment of the new technology, and finally after a period of six months post training.

An overview of the theories and models encompassed in the UTAUT model is presented below.

2.2.1 Technology acceptance Model – TAM

One of the most used and broadly cited technology acceptance models is the Technology Acceptance Model- TAM, which was developed by Davis et al. in 1989. TAM's is an extension of the Theory of Reasoned Action- TRA, its development and initial application was in the area of information system to predict user acceptance of any technology by two factors: perceived usefulness and perceived ease of use. Both determinants were proven by TAM to have a significant impact on a user's attitude toward using the system. The model was later applied by researchers in different disciplines to understand what causes users to reject or accept a new information technology based on the systems' characteristics (Davis 1993).

The need for TAM originated from the rising trend of introducing new information technologies within organizations to improve job performance, a goal that very soon proved to be difficult to achieve due to rejection of new technologies by users within an organization. As a result, it became evident that users' acceptance of new information systems has become a crucial determinant of the success or failure of new technologies. Therefore, TAM has become one of many models and theories in the body of technology acceptance literature, which aims to explore the possible technology acceptance determinants, and develop an understanding of how these determinants or factors relate to users' acceptance and potential usage (Davis 1993).

The TAM model, shown in Figure 2.2 suggests that two beliefs in particular are significant in predicting users' acceptance of new information technologies, these are: Ease of Use, and Perceived Usefulness. These two beliefs comprise the only determinants in the model that demonstrate the impact of external variables in the form of the system's functionality and properties –on user-related properties, namely: attitude towards using a new system, and the intention to use a new system, and how that in turn affects the actual usage of the system within an organization. The results of Davis et al. work show that the TAM model is capable of explaining approximately 50% of the variance in acceptance levels of new information technology applications introduced within organizations. In addition, many other studies based on the TAM model showed results stating the perceived usefulness determinant proved to be more important than the ease of use determinant in explaining users' acceptance of new information technologies (Dillon 2001). The results given by Davis et al. showed that perceived usefulness was 50% more influential than ease in determining usage (Davis 1993). The constructs comprising TAM are defined as follows:

Perceived usefulness- U is the degree to which a person believes that using a particular system would enhance his or her job performance (Davis 1989).

Perceived ease of use- E is the degree to which a person believes that using a particular system would be free of effort (Davis 1989).

Attitude towards use- A is the degree of evaluative affect that an individual associates with using the target system in his or her job (Davis 1993).

Behavioral Intention- BI is a measure of the strength of one's intention to perform a specified behavior (Davis, Bagozzi et al. 1989).

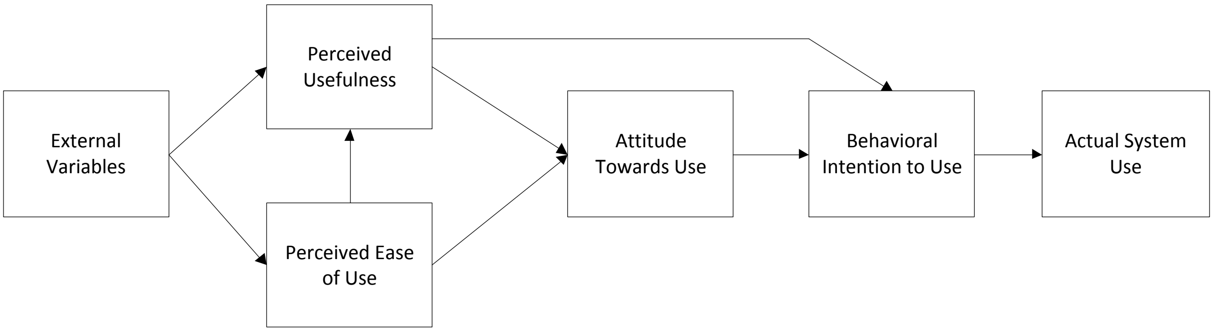

Figure 2.2: Technology Acceptance Model by Davis et al (Davis 1989)

The structure of the TAM model is defined by a set of relationships assumed by Davis et al. that associate the different constructs of the model. The existence of these relationships is supported by the empirical studies presented in the work of Davis et al. These relationships are explained further next.

The actual usage of a new information technology is determined by the behavioral intention to use a new technology, where behavioral intention to use is jointly determined by the perceived usefulness and the attitude towards use of technology as shown in formula 2.1:

$$BI = A + U \tag{2.1}$$

In a similar manner the model states that the attitude towards use is defined by both the main acceptance determinants of TAM, which are perceived usefulness and perceived ease of use as shown in formula 2.2:

$$A= U + E \tag{2.2}$$

In principal, both acceptance determinants perceived ease of use and perceived usefulness are determined by external variables, which are defined as a set of characteristics related to the new information technology system being introduced, to the potential users of the system, or to the organizational context in which the new system is introduced. An important distinction between the two acceptance determinants is demonstrated by TAM, the study carried out by Davis et al presented an empirical proof that the perceived usefulness is directly affected by perceived ease of use in addition to external variables, this relationship is shown in formula 2.3:

$$U = E + \text{External Variables} \qquad (2.3)$$

Applications and Extension of TAM

An important feature of the TAM model is its small size, as it consists of two acceptance determinants only. This made the model easy to administer especially in relation to developing the measurement instrument, which normally takes the form of a questionnaire (Dillon 2001). This feature made TAM an appealing model to apply, either alone or as a hybrid with other technology acceptance or innovations diffusion theories, by researchers from diverse disciples to try to measure the acceptance of various different new technologies by different user groups within the respective fields of the studies. According to Dillon, the application of TAM across different application types showed consistent results.

Each model extension was devised to supplement for a missing determinant that is deemed necessary in a specific field. One extension of the TAM model was applied in the mobile commerce arena. The suggested model incorporated the compatibility determinant from the Innovation diffusion Theory (explained in later section), in addition to perceived risk and cost determinants into the TAM model. The aim was to study the impact of these additional determinants in combination with the existing determinants of TAM –ease of use, and perceived usefulness- on user's usage of a new technology (Wu and Wang 2005). Another extension of the TAM model was applied in the electronic commerce field. The sole focus of the researcher in their proposed model was security and privacy aspects, each represented as an explicit determinant in the model that impacts an additional trust determinant (Pavlou 2001). A recent extension of the model is found in (Kranz, Gallenkamp et al. 2010) that was devised for the smart metering system, which is a relatively new technology. The authors proposed a slightly modified TAM model that aims to study the acceptance of smart metering technology among residential consumers. The novel contribution of this model is the inclusion of subjective control determinant, which captures the effect of consumers' concerns regarding their loss of control over the meter devices installed at their homes, and the negative feelings resulting from that on their willingness to use a smart meter.

Since its introduction in 1989 and during the past decades, the TAM model has become one of the most popular theories in the technology acceptance literature. The model has been extended and widely used across a wide spectrum of fields, such as: healthcare, e-government applications, hotel front office information systems, digital library information systems, business management software, e-learning systems, ERP implementation environment, e-commerce, mobile commerce, RFID technology, hedonic technologies, web-based systems, academic administrative information systems for universities, wireless technologies, and mobile banking. For a list of literature of application of the TAM model across different fields the reader is referred to Table A.1 in Appendix A.

Limitations of TAM

Despite the demonstrated ability of TAM to predict usage of information systems based on the perceived usefulness and perceived ease of use acceptance determinants, the model was reported to suffer from a few limitations throughout the literature. One main drawback of the model is the fact that it measures the perception of users whom are presented with a ready-made system at a single instant of time. Though this is useful for making tradeoffs among different competing technologies at the implementation stage, it makes the model less useful during early stages of system design, when it is important for designers to know and to understand factors that can render designs of systems that are highly acceptable by users, and thus increase the success rate of these systems (Dillon 2001).

A widely reported limitation of the TAM model throughout the literature is its reliance on self-reported usage. Lee et al. (Lee, Kozar et al. 2003) stated that 36 studies assumed that the self-reported usage reflects the actual usage and was used accordingly rather than measuring the actual usage. In reality this implies that what TAM actually measures is the variance in self-reported usage; a measure that is naturally imprecise and should be used as a relative indicator (Legris, Ingham et al. 2003).

Other shortcomings of TAM mentioned by Sun et al. in their analysis of limitations in existing technology acceptance research, are the explanatory power of the model, and the inconsistent relationships among constructs. Concerns related to the explanatory power of the model stem from differences between the results of laboratory and field studies, which implies that existence of other contextual factors affecting the acceptance of the technology that are not accounted for by the model. Furthermore, the inconsistent relationships among TAM constructs impose a difficulty in generalizing the model’s results across different contexts (Sun and Zhang 2006). Another problem that jeopardizes the generalizability of the model’s results is the use of empirical data that is obtained entirely from students. Though Legris et al. acknowledge that the use of students as study subjects minimizes cost, they believe that conducting the research in a business context would yield better results (Lee, Kozar et al. 2003, Legris, Ingham et al. 2003).

Further limitation of the TAM model is that beyond the feedback it offers regarding the perceived usefulness and perceived ease of use, it lacks insight of a number of factors that can potentially improve acceptability of new technologies, such as flexibility, intention, and completeness of information (Al-Qeisi 2009).

One of the broadly cited weaknesses of TAM studies is that they are mostly conducted in a narrow context. The experiments are usually conducted at a single point of time, among a group of homogenous respondents, and testing a single task of a particular information system. Again, this becomes particularly problematic when considering the generalization of the results across different contexts (Lee, Kozar et al. 2003).

Conducting experiments at a single point of time poses a dilemma considering that the development of beliefs and intentions occurs over a period of time, and change in them could change over time. Based on this limitation, Al-Qeisi argued that it is best to conduct technology acceptance research in a longitudinal approach due to the changing perceptions of technology users between the time of introducing a technology and actual time of using the technology (Al-Qeisi 2009, Ku 2009). The longitudinal approach, in which UTAUT model study was carried out, made the model a suitable choice for the work in this thesis.

2.2.2 Extended Technology Acceptance Model- TAM2

Considering the numerous limitations of the TAM model detected in the literature, the model was later extended into TAM2 by Venkatesh and Davis in 2000 to address some of these drawbacks (Venkatesh and Davis 2000). The novelty of TAM2, shown in Figure 2.3, is that it studies the impact of the perceived usefulness determinant, previously introduced in the original TAM model, in light of social influence and cognitive instrumental processes.

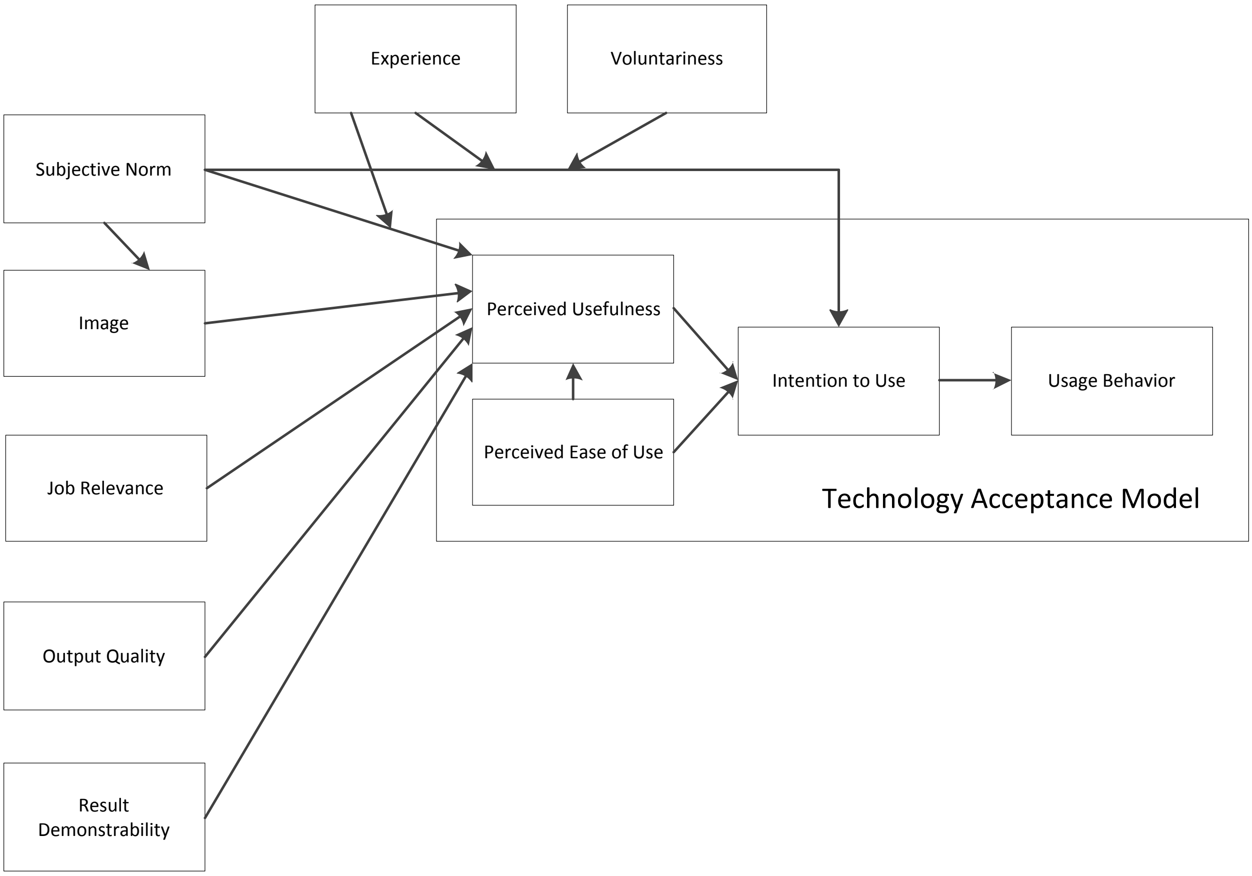

Figure 2.3: Extended Technology Acceptance Model - TAM 2 (Venkatesh and Davis 2000)

The model represents the impact of social influence on users' willingness to adopt new technology in the form of three relevant social influences: subjective norm, voluntariness and image (Venkatesh and Davis 2000). Whereas the effect of cognitive instrumental processes on a user's technology employment is demonstrated in the model by four determinants: job relevance, output quality, result demonstrability, and perceived ease of use. The first three are new determinants comprising a part of the model's extension, whereas ease of use is part of the original TAM model. The additional model constructs introduced to TAM 2 are defined next.

Subjective Norm: is a person's perception that most people who are important to him think he or she should or should not show the behavior in question. It implies that a technology user may be compelled to use a new technology even if he or she were not personally in favor of it or its consequences if other individuals -whom are perceived to be important by the user- believed that he or she should adopt the technology (Venkatesh and Davis 2000).

Voluntariness: is the extent to which potential adopters perceive the adoption decision to be non-mandatory (Venkatesh and Davis 2000).

Image: is the degree to which use of an innovation is perceived to enhance one's status in one's social system (Venkatesh and Davis 2000).

Job relevance: is an individual's perception regarding the degree to which the target system is applicable to his or her job (Venkatesh and Davis 2000).

Output quality: is how well the system performs tasks (Venkatesh and Davis 2000).

Result demonstrability the tangibility of the results of using the innovation (Moore and Benbasat 1991).

The work of TAM2 was carried out across four longitudinal field studies, regarding four information systems within four organizations, which addressed a number of the limitations associated with the original TAM model. A novelty of TAM2 lies in the introduction of the Voluntariness moderating construct. Two of studies were carried out in a mandatory context, while the other two involved voluntary usage of the system. Furthermore, the model constructs were measured at three points in time at each organization: before implementation, one month after implementation, and three months after implementation. The results of the four longitudinal studies demonstrated that TAM2 accounts for 40%-60% of the variance in usefulness perception and 34%-52% of the variance in usage intention. In addition, both social influence processes and cognitive instrumental processes showed a significant influence on technology acceptance (Venkatesh and Davis 2000).

Extensions and Applications of TAM2

The extended TAM model was adopted and extended in a number of studies in different fields. For example, TAM2 was applied in the field of healthcare by Chismar et al. (Chismar and Wiley-Patton 2002). In their study, the researchers attempted to examine the applicability of the extended Technology Acceptance TAM2 in the context of physicians' intention to adopt Internet-based health applications (Chismar and Wiley-Patton 2002). The study confirms the TAM2 model except for one construct: perceived ease of use. In their study the construct did not show any effect on intention while the perceived usefulness proved to be a strong determinant of intention (Al-Qeisi 2009).

Another application of the model was carried out by Ozag et al. (Ozag and Duguma 2004). Their work was based on the suggestion given by Venkatesh et a. (Venkatesh and Davis 2000) regarding the job relevance cognitive process, that statistically speaking has a significant relationship with perceived usefulness, and further proposed that it could correspond to the person-job-fit construct. In their work, Ozag et al. presented a literature review of organizational commitment processes, and further extended the model with three additional cognitive process: attribution/ obligation, rationalization, and investments (Ozag and Duguma 2004).

In the area of On-Line Analytical Processing- OLAP, which is involved with multi-dimensional analysis of enterprise data, another application of TAM2 was carried out. In this work, the authors applied TAM2 to investigate the role played by the perceived usefulness determinant in the acceptance of OLAP technologies in companies in South Africa. The results showed that the perceived usefulness acceptance determinant is positively affected by output quality, result demonstrability, job relevance and perceived ease of use. Furthermore, the results also demonstrated that experience and frequency of use both have a significant impact on the perceived usefulness (Porter 2004).

2.2.3 Theory of Reasoned Action- TRA

The Theory or Reasoned Action- TRA, shown in Figure 2.4, is a model that was formulated by Ajzen and Fishbein (Fishbein and Ajzen I 1975) in the context of social psychology to study consciously intended behaviors. It is one of the most influential and widely used theories of human behavior. It has been applied to predict behavior in a spectrum of areas (Venkatesh, Morris et al. 2003).

The theory was formulated on the ground that humans are rational, and will decide whether or not to perform an action based on reasoning related to the act. Though the TAM model is an extension of the TRA, the major difference however between the two models is the focal determinant of behavior, which is behavioral intention rather than attitude.

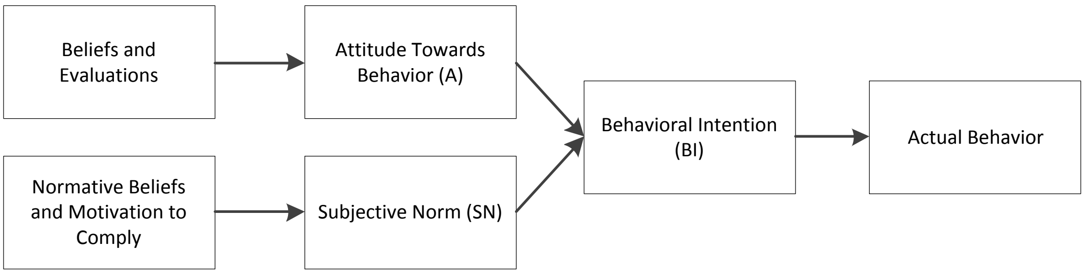

Figure 2.4: Theory of Reason Action- TRA (Fishbein and Ajzen I 1975)

The model consists of three main constructs: Behavioral intention (BI), attitude (A), and subjective norm (SN) that are defined as follows.

Behavioral Intention- BI is a measure that determines the strength of an individual's intention to show a specific behavior (Fishbein and Ajzen I 1975).

Attitude- A is the negative or positive impression of an individual with regards to showing a particular behavior (Fishbein and Ajzen I 1975, Davis, Bagozzi et al. 1989).

Subjective Norm-SN is an individual's perception that others who are important to him believe that he should or should not show a particular behavior (Fishbein and Ajzen I 1975).

The theory states that the actual performance of an individual's behavior is influenced by their behavioral intention (BI), which in turn is determined by their attitude (A) and subjective norm (SN) toward that particular behavior. This is shown in formula 2.4:

$$BI = A + SN \tag{2.4}$$

The theory further states an individual's salient believes (b_i) about the outcome of performing a behavior multiplied by the evaluation (e_i) of these outcomes, in summation determine one's attitude towards a behavior (Davis, Bagozzi et al. 1989). This relationship is shown in formula 2.5:

$$A = \sum b_i \, e_i \tag{2.5}$$

Believes (b_i) are the individual's subjective probability that performing the behavior in question will result in consequence *i*, whereas the evaluation term (e_i) refers to an implicit evaluation response to the consequence (Fishbein and Ajzen I 1975).

Limitations of TRA

Like other theories or models, the TRA model suffers from a few shortcomings. One limitation is that the model is based on the assumption that when an intention is formed by an individual to perform an action, then the action will be carried out without impediments. This contradicts reality when in practice people are sometimes faced with external factors preventing them from performing an action even though they have already formed the intention to do so. This limitation was addressed by the Theory of Planned Behavior-TPB (Ali 2006).

Sheppard et al. (Sheppard, Hartwick et al. 1988) mentioned three limitations of the TRA in their work. The researchers conducted two meta-analyses of the model to investigate the consequences of three limiting conditions, which are related to the use of attitude and subjective norms to predict intentions and the use of intention to predict the performance of behavior (Sheppard, Hartwick et al. 1988). These limitations are described below.

Goals Vs. Behaviors In their work, Fishbein and Ajzen declared that one limitation of their model is the distinction between a goal intention and a behavioral intention. The model was built to address behaviors and not to address the consequences that may result from such behaviors. Furthermore, the model focuses on behaviors that are within an individual's voluntary and free control, factors that are beyond one's control are not represented by the model even though that these factors can lead to one's inability to carry out the action despite formation of the intention. The difference between goal intention and behavioral intention is evident in instances when an individual's ability to perform an intention by carrying out a related action is not guaranteed (Sheppard, Hartwick et al. 1988).

The Choice Among Alternatives The TRA model considers only a single behavior, where in reality people need to make choices regarding different alternative behaviors. For example, individuals have to take decisions related to choice of a color, or a store and so on. This realistic scenario is not captured by the TRA model, which naturally poses a serious drawback (Sheppard, Hartwick et al. 1988).

Intentions Vs. Estimates Often it is the case that researchers apply the TRA model to predict individual's behaviors and intentions for future events, a period of which one lacks full knowledge or control. This implies that in reality researchers are actually measuring whether an individual will or will not carry out an action to achieve a desired goal. The use of actual intention and estimated intention as terms has become interchangeable despite the difference between the two (Sheppard, Hartwick et al. 1988).

2.2.4 Motivational Model

Throughout the literature there exist many variations of motivation theories and model that differ in specific aspects they tackle and the context in which they are applied. One well-known theory is Vallarnd's hierarchical model of intrinsic and extrinsic motivation (Vallerand 1997). In his model –shown in Figure 2.5 - Vallarnd adopted from previous efforts throughout the literature two classes of motivation; intrinsic and extrinsic. The intrinsic class of motivation denotes "behavior performed for itself, in order to experience pleasure and satisfaction inherent in the activity" (Vallerand 1997). The second class of motivation is referred to as extrinsic motivation, which "involves performing behavior in order to achieve some separable goal, such as receiving rewards or avoiding punishment" (Vallerand 1997). Furthermore, Vallarnd included a third class of motivation that is referred to as amotivation, which denotes "the relative absence of motivation, [either] intrinsic or extrinsic. A distinctive aspect of Vallarnd's model is that it represents the notion that the three classes of motivation (i.e. intrinsic, extrinsic, and amotivation) are present within an individual at three hierarchical levels of generality: global (or personality), contextual (or life domain), and situational (or state). These hierarchical levels allow individuals to consider motivation in a more precise and refined manner. Another distinctive aspect of Vallarnd's model is that it focuses on determinants of motivation, which are illustrated in the left-side of Figure 2.5. The model tackles a number of aspects related to motivational determinants; first, motivation results from social factors existing at each of the three levels of generality, such as situational factors can influence situational motivation, contextual factors influence contextual motivation, and global factors influence global motivation. Second, the influence of social factors on motivation is mediated at each of the generality levels by three elements, these are: competence (i.e. "interacting effectively with the environment" (Vallerand 1997)), autonomy ("feeling free to choose one's course of action" (Vallerand 1997)), and relatedness ("feeling connected to significant others" (Vallerand 1997)). A third feature of the model is the top-down effect from motivation at a higher level in the hierarchy on motivation at the next lower level, such that global motivation can have influence on contextual motivation, and the latter can have influence of situational motivation. However, in general there should not be a direct influence from global influence on situational motivation. A fourth aspect of the model is that illustrates the recursive relationship between motivation at the three various levels of generality, this is denoted by the double arrows in Figure 2.5 between the levels of the hierarchal. Finally, one of the hypotheses underlying Vallarnd's model is that motivation results in different types of outcomes for an individual, which can be cognitive, affective or behavioral.

Vallarnd's study proved that intrinsic and extrinsic motivation constitutes a significant amount of one's experience when involved in an activity. Furthermore, as previous research efforts focused on the global and situational levels of the hierarchy from a personality and social psychology perspectives respectively, Vallarnd's addition of the contextual level of generality in the hierarchy was justified with findings that suggest that the contextual level as an intermediary level proved to be significant as it contributes to deepening the understanding of intrinsic and extrinsic motivation phenomena. Moreover, a novelty of Vallarnd's model is its hierarchal nature. Evidence proved that motivation can indeed have a recursive influence from motivation at a lower level in the hierarchy on the next higher level in the hierarchy (Vallerand 1997).

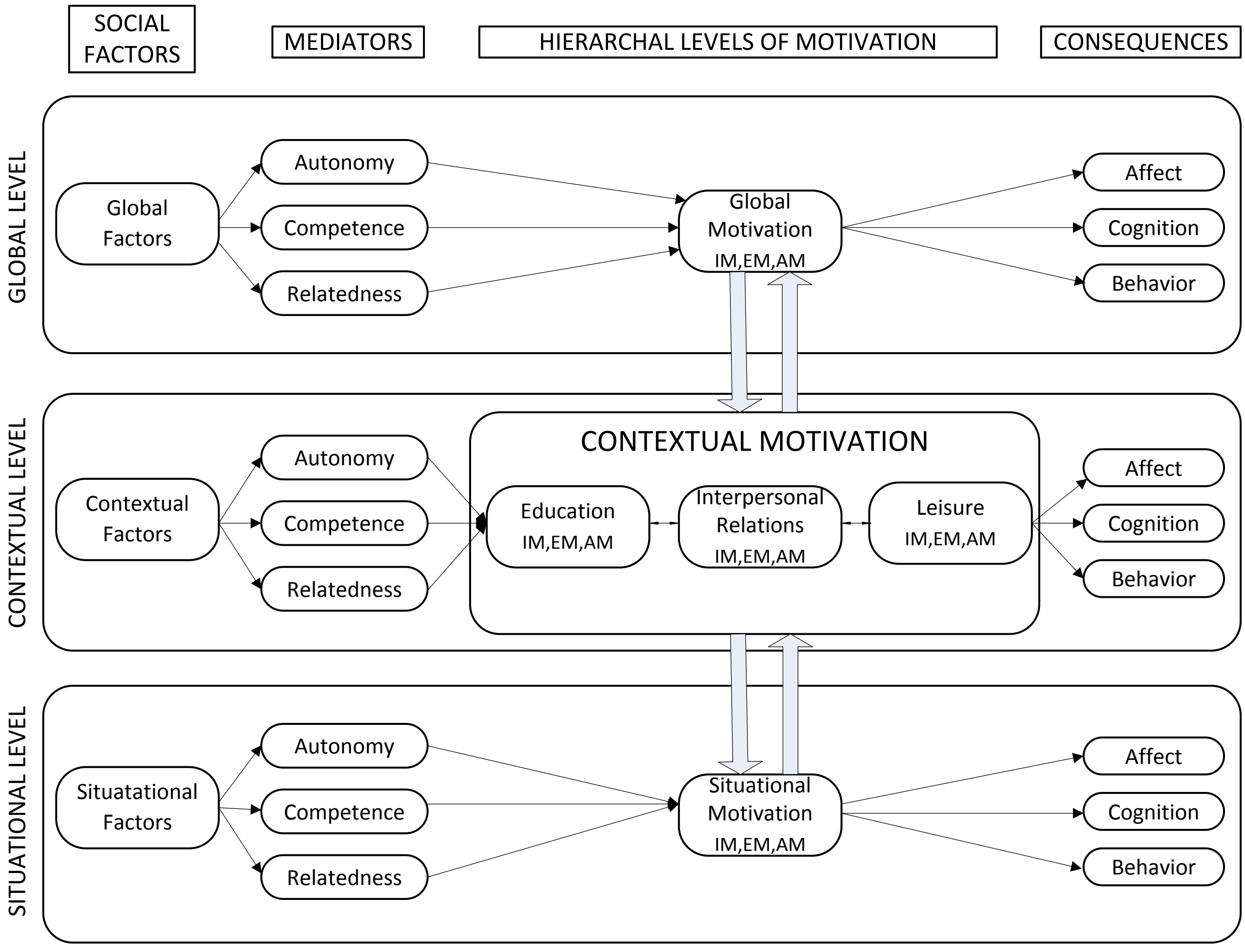

Figure 2.5: Vallarnd's hierarchal model of intrinsic, extrinsic and amotivation (Vallerand 1997)

Another research effort that explored the motivational theory was by Davis et al. (Davis, Bagozzi et al. 1992), who applied the theory in the context of information systems to gain an understanding regarding the adoption and usage of new technology, i.e. computers, in the workplace. In their work, the authors adopted a number of concepts throughout the technology acceptance literature such as usefulness and enjoyment, where the former was adopted as an example of extrinsic motivation and the latter was applied as an example of intrinsic motivation. The authors anticipated that usefulness will prove to be a major determinant of intention to use a computer in the workplace in consistency with results of previous research; however, they also expected enjoyment to have a significant influence on usage intention that exceeds the influence of usefulness alone. Furthermore, the authors anticipated that behavioral intention to mediate the influence of usefulness and enjoyment on the usage behavior. The influence of both concepts on individuals' intention to use a computer in the workplace was hypothesized as follows: first, both usefulness and enjoyment will have a significant effect on individuals' intention to use a computer in the workplace. Second, usage intention will mediate the effect of usefulness and enjoyment on usage behavior. The main results of the study of Davis et al. indicated that individuals' intention to use computers in the workplace are mainly influenced by their perceptions of the usefulness of computers for improving their job performance, then it was impacted by a less-significant influence of the degree of enjoyment experienced during the usage of a computer. Davis et al. concluded with the need for further research to examine the influence of additional acceptance determinants on usage intention of new technology in the workplace.

2.2.5 Theory of Planned Behavior

Theory of planned behavior was presented by Ajzen in 1985 (Ajzen 1985), as an extension to the theory of reasoned action. The theory encompasses a number of key concepts in the social and behavioral sciences. Further, these concepts are defined in a manner that allows prediction and fathoming certain behaviors in certain contexts.

The new theory introduced perceived behavioral control as an antecedent of behavior with the aim to improve the predictive ability of the theory of reasoned action. The extension was deemed necessary due to the limitation of the theory or reasoned action in tackling behaviors over which people have incomplete voluntary control. Figure 2.6 depicts the behavior antecedents included in the theory. As shown in Figure 2.6, an individual's intention to perform a certain behavior is a central factor in the theory. It is believed that intentions capture the motivational factors that influence a voluntary behavior. In general, the stronger the intention is to carry out a behavior, the more likely it will be performed.

The theory of planned behavior suggests three determinants of behavior. The determinants are defined as follows:

Attitude towards the behavior: this refers to the "degree to which a person has a favorable or unfavorable evaluation or appraisal of the behavior in question".

Subjective Norm: which is defined as "the perceived social pressure to perform or not to perform the behavior"?

Perceived Behavioral Control: this is defined as the "perceived ease or difficulty of performing the behavior and it is assumed to reflect past experience as well as anticipated impediments and obstacles".

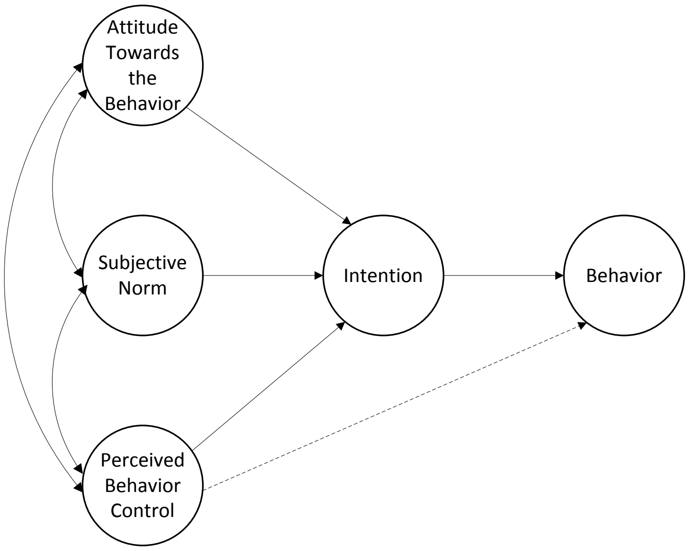

Figure 2.6: Theory of Planned Behavior (Ajzen 1991)

The more positive subjective norm and attitude towards the behavior, and the stronger the perceived behavioral control, the more likely an individual will carry out the behavior. The relative significance of the three antecedents of behavior varies depending on the behavior and situation. For example, in some applications attitude may prove to be the only significant precedent of intention, whereas in other cases attitude and perceived behavioral control may prove sufficient to predict intention. In general, applying the theory of planned behavior regardless of the context enables to build a knowledge base that is useful in understanding the behavior under question, and to plan required interventions that can effectively alter the behavior (Ajzen 1985).

As the case with most theories and models across the literature, the theory of planned behavior suffers from a few limitations. One of which is the theory's lack of consideration to emotional variables such as fear, mood, or feelings. Despite such limitation, the theory of planned behavior has been applied successfully in the context of different technologies to understand individuals' acceptance and usage of technology.

2.2.6 Combined TAM and TPB

In 1995 Taylor and Todd (Taylor and Todd 1995) devised a theory that is a hybrid of the Technology Acceptance Model and the theory of Planned Behavior. The model was an attempt for account for some shortcomings of previous theories and model in the technology acceptance literature. One shortcoming cited by the authors is that empirical tests of earlier theories focused on systems that are already in use by the targeted user group. Another limitation was that some models focused on technologies which users were familiar with such as: word processing packages. These weaknesses have created a sense of vagueness of whether the predictive power of previous models is limited to groups of experienced users, and whether the determinants of users' utilization of information technologies are the same for both experienced and inexperienced users. Thus, to investigate the role of prior experience in assessing using of information technologies, the authors formulated a combined Technology Acceptance Model and Theory of Planned Behavior model; C-TAM-TPB shown in Figure 2.7.

The reason for choosing the Technology Acceptance Model- TAM model as basis for the C-TAM-TPB theory is that fact that the TAM model was the most applied model for investigating usage of information technologies. However, despite the popularity of the model it still suffered from some shortcomings, one of which is that it does not account for social influence or the impact of control factors on individuals' behavior. These notions are acknowledge by the Theory of Planned Behavior -TPB as acceptance determinants. Therefore, Taylor and Todd augmented the two theories to combine their predictive power. In particular, the extended TAM model included both subjective norm and the perceived behavioral control as acceptance determinants due to their common usage in social psychology and their usage in predicting usage of information technologies.

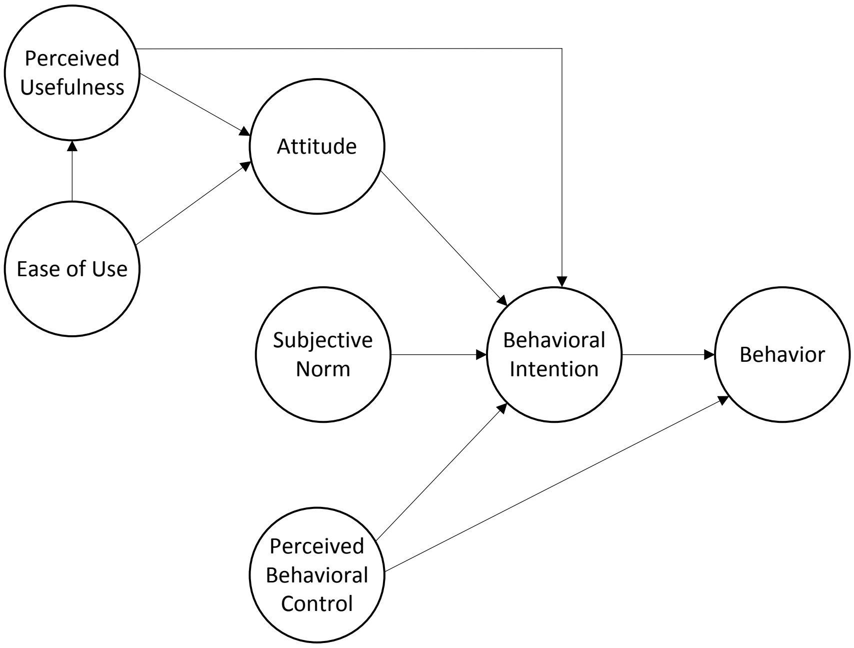

Figure 2.7: the combined TAM and TPB Model (Taylor and Todd 1995)

Taylor and Todd's interest in the influence of experience on adoption of information technologies results from previous research efforts that established that knowledge obtained from past behavior contributes to forming intention. This suggests that prior theories model individuals' usage of information technologies more effectively for experienced users. Therefore, the C-TAM-TPB model was assessed for two groups of users: experienced users and inexperienced ones, to capture differences in the influences of the acceptance determinants on the behavioral intention to use an information technology. Identifying these differences is important to better plan the development and the implementation of new IT systems.

The model was tested for two groups of users: experienced and inexperienced. The results proved that the C-TAM-TPB model offers a suitable model of usage of information technologies for both experienced and inexperienced users. Results of both groups indicate that attitude was the only determinant in the model that lacked any significant influence on intention. Therefore, the model can be applied to forecast usage behavior before users acquire any experience with the technology. Furthermore, the results revealed significant differences in the relative influences of the usage determinants depending on the experience of the user. This implies that informing inexperienced users can have a significant influence on intention, but intention will not translate completely to behavior. A further difference between the two groups is related to the perceived usefulness; which proved to be the strongest predictor of intention for inexperienced users, whereas this was not the case for experienced users. In addition, behavioral intention fully mediated the relationship between perceived behavioral control and intention for experienced users, whereas in the case of inexperienced users the perceived behavioral control had a weaker influence on behavioral influence, and a significant influence on behavior.

The C-TAM-TPB model suffers from a number of limitations. First, the study was conducted among a community of students; this implies that the subjective norm and perceived behavioral control determinants might perform differently in the context of a workplace. Second, the influence of factors such as gender that may correlate with experience was not taken into consideration. Third, the values of some model fit indices of the statistical models for both groups were slightly below the desired levels. Fourth, the model was tested for a single IT technology, which is a computer information resource center. Finally, estimation of experience as a dichotomous variable does not offer more than a gross distinction (Taylor and Todd 1995).

2.2.7 Model of PC Utilization

The Model of PC Utilization- MPCU –illustrated in Figure 2.8- was formulated by Thompson et al. in 1991 (Thompson, Higgins et al. 1991). The theory is based on Triandis' theory of human behavior. Thomson et al. applied their model in the context of information systems to predict usage behavior instead of technology users' intention in optional use environments. The theory was originally devised to predict individuals' utilization of PCs. In addition, the model is suitable to predict individuals' acceptance and usage of a wide spectrum of information technologies (Venkatesh, Morris et al. 2003). The MPCU model fundamentally differs in two ways than Triandis' original theory. First, concepts such as social factors, affect, perceived consequences, and facilitating conditions were included as acceptance determinants to investigate the direct effect on behavior. Second, the concept of habit that is part of the Triandis' theory was excluded from the MPCU model. The acceptance determinants encompassed in the MCPU model are described next in further detail.

Social Factors

Social factors are defined as the individuals' internalization of a reference groups' subjective culture, and specific interpersonal agreements that the individual has made with others in specific social situations" (Triandis, 1980) cited in (Thompson, Higgins et al. 1991). Subjective culture consists of three components:

Norms: which are "self-instructions to do what it is perceived to be correct and appropriate by members of a culture in certain situations" (Thompson, Higgins et al. 1991).

Roles: which are "concerned with behaviors that are considered correct but relate to persons holding a particular position in a group, society, or social systems" (Thompson, Higgins et al. 1991).

Values: which are "abstract categories with strong affective components".

Empirical support proved that social factors indeed are predictors of individuals' PC utilization, such that the former has a positive influence on the latter.

Affect

Attitude is a concept that is often incorporated in technology acceptance and usage models to predict a range of observed outcomes, such as behavior. Attitude consists of two components: affective and cognitive. The affective component is related to notions such as liking or disliking, whereas the cognitive component encompasses information that a person holds about an object, an issue or a person. Triandis recognizes that as attitude lacks precision, it is perhaps better applied where precision is not needed. Furthermore, whenever relationships between attitude and behavior are to be investigated, Triandis suggests that precision can be ensured by the separation of the affective and cognitive components of attitude. For this purpose affect is encompassed in the MPCU model, which refers to the "feelings of joy, elation, or pleasure, or depression, disgust, displeasure, or hate associated by an individual with a particular act" (Triandis, 1971) cited in (Thompson, Higgins et al. 1991). The separation between the affective and cognitive components of attitude contributes to the novelty of the MPCU model, as most information systems researchers did not make this distinction. The MPCU model originally hypothesized that affect has a positive impact on PC use and the utilization of PCs. However, this anticipated relationship was not empirically supported.

Perceived Consequences

In Triandis original theory, behavior is influenced by consequences that are expected to result from an exhibited behavior. This concept is included in the MPCU model as the perceived consequences. In reality, perceived consequences encompasses many different dimensions, three of which are; complexity, job fit, and long term consequences of use, which are included in the MPCU model.

Complexity

Complexity is a near-term consequence that relates to perceptions about the complexity of using a PC. It is defined as "the degree to which an innovation is perceived relatively difficult to understand and use". Based on prior research empirical results, it was expected that complexity and PC utilization would be negatively related. This relationship was empirically supported as complexity proved to be a significantly negative predictor of PC utilization.

Job Fit

Job fit is another near-term dimension of perceived consequences, which relates to how job performance of an individual can be enhanced by the capabilities of perceived consequences. Job fit is defined as a measure of “the extent to which an individual believes that using a PC can enhance the performance of his or her job. e.g. Obtaining better information for decision making or reducing the time required for completing importance job tasks” (Thompson, Higgins et al. 1991). The MPCU model empirically proved that the perceived job fit has a positive influence on the utilization of PCs.

Long-Term Consequences of Use

Long-Term Consequences of Use is the third dimension of perceived consequences that is included in the MPCU model. It differs from the other two dimensions of perceived consequences in the sense that it is evident on the long run, as opposed to the near-term nature of complexity and job fit. Long term consequences of use is defined as “the outcomes that have a pay-off in the future, such as increasing the opportunities for more meaningful work” (Thompson, Higgins et al. 1991). The rationale behind including this concept in the MPCU model is that in certain cases the adoption and usage of PCs is motivated by the will to prepare for the future rather than focusing on current circumstances. Long-term consequences of use were proved to have a positive relationship with the utilization of PCs.

Facilitating Conditions

Facilitating conditions is defined as “objective factors 'out there' in the environment that several judges or observers can agree make an act easy to do” (Triandis, 1980) cited in (Thompson, Higgins et al. 1991). The rationale behind facilitating conditions is that behavior cannot occur if “objective conditions in the environment prevent it”. The concept of facilitating conditions in the field of PC usage entails providing users with support, either by training them or providing them with assistance whenever difficulties are encountered. This in turn should decrease or diminish potential barriers of system usage. Facilitating conditions was initially hypothesized to have a positive relationship with behavior. However, empirically it was proven to have a negative and insignificant impact, thus negligible.

Four of the six hypothesized relationships depicted in Figure 2.8 demonstrated a significant influence on the utilization of PCs. Social factors proved to have a positive influence on utilization of PCs. Furthermore, the perceived complexity associated with usage of a PC negatively influences the utilization of PCs. In addition, job fit proved to be a predictor of utilization of PCs, whereas long-term consequences proved to have a significant and positive influence on utilization of PCs.

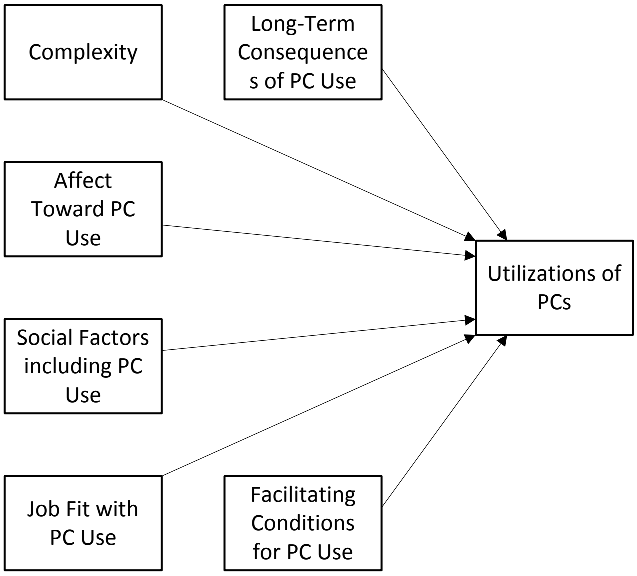

Figure 2.8: Model of PC Utilization

Limitations of MPCU Model

The MPCU model suffers from a number of limitations. First, the generalizability of the model as it was tested within a single organization. Another limitation is related to the method measuring PC utilization, as the researchers relied on self-reported utilization of PCs, whereas a more accurate measure would be via electronic usage monitor to confirm self-reported usage. A third limitation of the MPCU model is related to the statistical analysis process applied to identify the model. Finally, the affect construct appeared to be measured in an incomplete manner as not all its possible facets were represented with regards to PC use. Thus, the scale used to measure the affect construct needs to be improved.

2.2.8 Social Cognitive Theory

The social cognitive theory is one of the most powerful theories of human behavior, which was presented by Bandura in 1986. The theory was extended in 1995 by Compeau and Higgins (Compeau and Higgins 1995) to investigate the impact of computer self-efficacy on individual's usage of personal computers. The nature of Compeau and Higgins model – illustrated in Figure 2.9- and its underlying theory made it possible to generalize the model to investigate the acceptance and usage of information technologies. Thus, Ventakesh et al. included Compeau and Higgins model in their work to examine the model's predictive validity with respect to intention and usage in comparison with the seven other theories and models (Venkatesh, Morris et al. 2003).

Self-efficacy is defined as “the belief that one has the capability to perform a particular behavior” (Compeau and Higgins 1995). In social psychology, self-efficacy is considered a significant concept due to its influence decisions related to which behavior to carry out, the effort applied and level of perseverance in conducting those behaviors, emotional response of the individual conducting the behavior, and the actual conduction of the behavior.

In essence, the theory focused on exploring the influence of individuals' beliefs about their ability to use computers in a competent manner on their actual usage of computers. Understanding this influence is crucial for successful deployment of technologies within organizations. The Social Cognitive Theory suggests the existence of a reciprocal relationship among three elements: cognitive factors, environment and behavior. Compeau and Higgins theory encompasses components from all three elements listed above, in an effort to integrate findings or previous research efforts. The model included the key constructs that were presented in the context of social cognitive theory literature. The proposed model consists of 7 components that are hypothesized to influence usage as illustrated in Figure 2.9, these components are described briefly next.

Encouragement by others

Encouragement by the people from whom one seeks guidance on behavioral expectations, which takes the form of verbal persuasion. This component is assumed to have an influence on both self-efficacy, such that individuals are hypothesized to rely partially on others' opinion in the formation of judgment regarding their own abilities. Furthermore, encouragement by others is assumed to influence outcome expectations such that the more an individual is encouraged by others to use a computer, the higher the individual's out-come expectations.

Others' use

Others' actual use of a technology is another factor that influences self-efficacy such that the higher the use of a technology by other people, the higher the individual's computer self-efficacy. In addition, Others' usage of a technology influences outcome expectations such that the more a technology is used by others, the higher the individual's out-come expectations.

Support

The support of an organization to its users of a technology is another component that was hypothesized to positively influence both self-efficacy and outcome expectations.

Computer self-efficacy

The concept of computer self-efficacy was assumed to positively influence an individual's outcome expectations, such that the higher an individual's computer self-efficacy the higher their outcome expectations.

Outcome expectations

Outcome expectations is hypothesized to have a significant influence on how individuals react to a technology. In the model, individuals' response to a technology was captured by two concepts: affect and usage. Affect in essence can be conveyed by one's satisfaction that can be derived from the favorable consequences of the behavior. Outcome expectations is assumed to have positive influence on affect. Further, it was assumed that the higher an individual's outcome expectations, the higher their computer usage.

Affect

Affect refers to individuals' favoring of a certain behavior. This component is assumed to have a positive influence on computer usage such that the higher an individual's affect for computer usage, the higher their usage of computers.

Anxiety

The feeling of anxiety that can be associated with the usage of computers was assumed to impose a negative influence on an individual's use of a technology, such that the higher the individual's level of anxiety towards computer usage, the lower their usage of computers.

The estimation of the Compeau and Higgins' model revealed that among the hypothesized influences underlying the theory, self-efficacy has a significant influence on individuals' outcome expectations of technology usage, individuals' reaction to the technology, i.e. affect and anxiety, and the actual usage of a technology. Furthermore, the encouragement of others and others' usage of a technology both had a positive influence on self-efficacy and outcome expectations.

Limitations of the Social Cognitive Theory

Compeau and Higgins' model suffers from a number of limitations that should be taken into consideration when reflecting on the results. One limitation is that the model was estimated using structural equation modeling, though the method is suitable for simultaneous estimation of causal relationships in the model, yet alternative models depicting different causal relationships cannot be ruled out. Furthermore, the researchers deemed their presented model as incomplete since the Social Cognitive Theory is founded on the concept of underlying interactions among the factors encompassed in the model, and the collected data did not facilitate for modeling Feedback mechanisms.

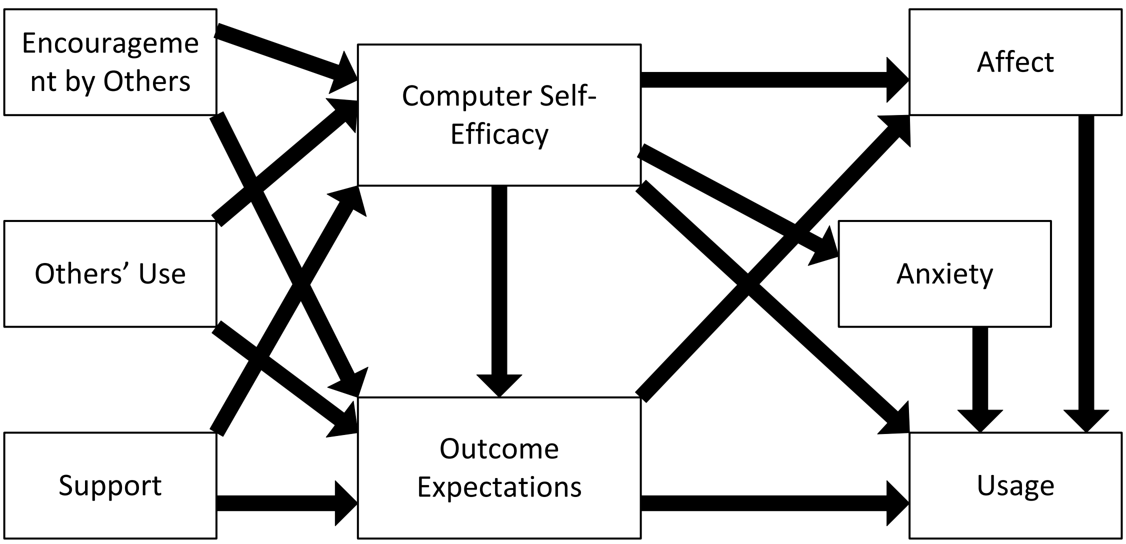

Figure 2.9: Social Cognitive Theory (Compeau and Higgins 1995)

UTAUT Model Description

The constructs encompassed in the UTAUT model to predict individuals' acceptance of technology fall under three classes: technology acceptance determinants, moderators, and the anticipated outcome, i.e. behavior and action being predicted. The predicted behavior and action are represented in the model by the Behavioral Intention and Use Behavior constructs respectively. The two constructs represent individuals' acceptance of new technology and their actual use of it. These two constructs are considered to be the dependent variables of the model.

The model consists of four technology acceptance determinants, which are attributes that are in general assumed to have an impact on both Behavioral Intention and Use Behavior. The acceptance determinants in the UTAUT model are: Performance Expectancy, Effort Expectancy, Social Influence, and Facilitating Conditions. The construction of the model was based on a number of hypotheses, each assumes a relationship between an acceptance determinant and the predicted behavior.

In the UTAUT model, the relationships between acceptance determinants constructs and the predicted behavior constructs is moderated by four moderating constructs: Age, Gender, Experience, and Voluntariness of Use. A moderator is a "variable that represents a construct proposed to magnify, attenuate, cancel or reverse the association between two other variables" (Hoyle and Robinson 2003). A moderator can be a qualitative or quantitative variable, which is intended to capture the dynamic influences on a relationship between a technology acceptance determinant and the technology acceptance and usage prediction constructs, and may influence the direction and/or the strength of the assumed relationship between the two constructs (Baron and Kenny 1986).

The acceptance determinants and the moderating constructs of the model are described next in further details.

Performance Expectancy

Performance Expectancy is "defined as the degree to which an individual believes that using the system will help him or her to attain gains in job performance" (Venkatesh, Morris et al. 2003). This determinant is analogous to five determinants, each of which is encompassed in one or more of the technology acceptance theories and models underpinning the UTAUT model. These determinants shown in Table 2.1 were deemed to be similar to each other by a number of researchers throughout the literature (Venkatesh, Morris et al. 2003).

Table 2.1: Determinants related to performance expectancy

Determinant	**Theory**	**Author**
Perceived usefulness	Technology Acceptance Model- TAM	Davis 1989, Davis et al. 1989
	Technology Acceptance Model 2- TAM2	Venkatesh and

		Davis
	Combined TAM and TPB C-TAM-TPB	Taylor and Todd
Extrinsic motivation	Motivation Model- MM	Davis et al. 1992
Job fit	Model of PC Utilization- MPCU	Thomson et al. 1991
Relative advantage	Diffusion of Innovation - DOI	Moore and Benbasat 1991
Outcome expectations	Social Cognitive Theory- SCT	Compeau and Higgins 1995

Regardless of the different labels these determinants take across the various models, they all proved to be the strongest predictor of intention within their respective models, at different points of measurement, and in different organizational settings: mandatory versus voluntary (Venkatesh, Morris et al. 2003).

The UTAUT model assumes that the relationship between Performance Expectancy and Behavioral Intention is influenced by both Gender and Age moderators, where Gender in this context is defined as "socially constructed roles of women and men rather than biologically determined differences" (Clancy and Roehr 2003). The effect is assumed to be stronger particularly for younger men. This assumption was based on findings from gender differences research, which revealed that men are more task-oriented than women (Minton and Schneider 1980) cited in (Venkatesh, Morris et al. 2003). Such a difference stems from "gender roles and socialization processes reinforced from birth" rather than it having a biological origin (Bem and Allen 1974, Bem 1981) cited in (Venkatesh, Morris et al. 2003).That, combined with the fact that performance expectancy is related to the concept of job fulfillment, leads to the conclusion that Performance Expectancy would be prominent in men as opposed in women (Venkatesh, Morris et al. 2003).

Another moderating construct that proved to have a significant impact on the relationship between Performance Expectancy is Age. In general, job-related attitude research shows that younger individuals tend to find extrinsic rewards more significant. However, in technology acceptance literature, Age impact is often studied closely with Gender impacts to capture a more realistic representation of reality. In this regard, Venkatesh et. al. (Venkatesh, Morris et al. 2003) mention that "Levy (1988) suggest that studies of gender differences can be misleading without reference to age", this is most evident when considering that job-related priorities may change drastically for women around childbearing age, in light of traditional gender roles within societies (Venkatesh, Morris et al. 2003).

Effort Expectancy

Effort Expectancy is a technology acceptance determinant that is "defined as the degree of ease associated with the use of the system" (Venkatesh, Morris et al. 2003). As in the Performance Expectancy determinant, Effort Expectancy is analogous to a number of the acceptance determinants that are part of the theories and models underlying the UTAUT model, which share similar definitions and measurement scales. The constructs comprising the Effort Expectancy acceptance determinant are shown in Table 2.2.

Table 2.2: Root constructs for the Effort Expectancy construct

Determinant	Theory	Author
Perceived ease of use	Technology Acceptance Model- TAM	Davis 1989, Davis et al. 1989
Complexity	Model of PC Utilization- MPCU	Thomson et al. 1991
Ease of Use	Diffusion of Innovation – DOI	Moore and Benbasant 1991

The results from Venkatesh et al. (Venkatesh, Morris et al. 2003) showed that the Effort Expectancy construct's significant varies over time. The construct proved to be significant only during the early stages of the introduction of a new system, and becomes rather insignificant later throughout a continuous system usage as users gain more experience. This moderating effect of Experience on Effort Expectancy is demonstrated in the model by the connecting line between the two constructs. Furthermore, the Age and Gender constructs also have a moderating impact on the Effort Expectancy construct, such that the Effort Expectancy construct proved to be more significant for women, and especially younger ones (Venkatesh, Morris et al. 2003).

Social Influence

Social influence is defined as the "degree to which an individual perceives that important others believe he or she should use the new system" (Venkatesh, Morris et al. 2003). As the case with other constructs of the UTAUT model, Social Influence is based on many similar acceptance constructs found in a number of the models comprising the UTAUT model: these constructs are sown in Table 2.3. Despite the difference in labels, all these constructs share a common conception that the way individuals behave is influenced by how they believe they are being perceived by other individuals in their social network, as a consequence of using the newly introduced technology (Venkatesh, Morris et al. 2003).

Table 2.3: Root constructs for the Social Influence construct

Determinant	Theory	Author
Subjective Norm	Combined TAM and TPB C-TAM-TPB	Taylor and Todd
	Theory of Planned Behavior- TPB	Mathieson 1991
	Theory of Reasoned Action- TRA	Fishbein and Ajzen 1975

	Extended Technology Acceptance Model-TAM2	Davis et al. 1989
	Theory of Planned Behavior – TPB	Ajzen 1991
Social Factors	Model of PC Utilization- MPCU	Thompson et al. 1991
Image	Diffusion of Innovation – DOI	Moore and Bebasat 1991

The moderating constructs play a complex role in the relationship between the Social Influence acceptance determinant and the predicted behavior, as all four moderating constructs demonstrated a significant impact on the relationship. The results showed that the Social Influence construct is significant only in a mandatory context, a result that is compliant with results for similar constructs in other models. Furthermore, based on literature, the model assumes that the effect of Social Influence is significant for women rather than men, and especially older women at an early stage of experience with the new technology (Venkatesh, Morris et al. 2003).

Facilitating Conditions

Facilitating conditions acceptance construct is defined "as the degree to which an individual believes that an organizational and technical infrastructure exists to support use of the system" (Venkatesh, Morris et al. 2003). The root constructs encompassing the eight technology acceptance models forming the underlying basis for the UTAUT model, and from which the Facilitating Conditions construct originates are shown in Table 2.4.

Table 2.4: Root constructs for the Facilitating Conditions construct

Determinant	Theory	Author
Perceived Behavioral Control	Theory of Planned Behavior – TPB	Ajzen 1991
	Combined TAM and TPB C-TAM-TPB	Taylor and Todd
Facilitating Conditions	Model of PC Utilization- MPCU	Thompson et al. 1991
Compatibility	Diffusion of Innovation – DOI	Moore and Benbasat 1991

A major difference between the Facilitating Conditions construct and the other three acceptance constructs in the model is that empirical results did not reveal any significant direct effect on the Behavioral Intention Constructs, but rather it had a direct impact on Use Behavior. The effect on Use Behavior is moderated by both Age and Experience moderating constructs, in a way that it is assumed that the effect of Facilitating Conditions on Use Behavior is most significant for older and more experienced individuals (Venkatesh, Morris et al. 2003).

Applications and Extensions of the UTAUT Model

Over the past years many researchers adopted the UTAUT model to investigate acceptance of technologies of diverse nature in many different fields. These studies either applied the UTAUT model in different contexts to verify its suitability in different contexts or further extended the model with additional technology acceptance determinants originating from their respective fields of study.

Cody-Allen and Kishore (Cody-Allen and Kishore 2006) have extended the UTAUT model into a comprehensive model that encompasses quality, satisfaction and trust notions. The aim of their model was to investigate factors leading e-business systems' users to formulate an intention to use and actually use a system. In their model, the researchers limited their use of the UTAUT model to two acceptance determinants: Performance Expectancy and Effort Expectancy. The two constructs were further integrated with a number of other acceptance determinants that fall under three categories: trust, quality and satisfaction. The model tests the overall impact of the acceptance determinants on the Intention to Use and Use constructs (Cody-Allen and Kishore 2006).

Or et al. (Or, Karash et al. 2010) extended the UTAUT model in the context of healthcare information systems. Their initial model aimed to explore and understand factors leading patients to accept and use patient-focused healthcare technologies. In particular, the study was applied to investigate home care patients acceptance of an interactive web-based self-management system. In their model, the researchers coupled UTAUT acceptance determinants with patient-centered factors: Perceived Upper Extremity Functional Status, Perceived Visual Functional Status, Health Information Seeking Preference, and Health Care Knowledge. The aim was to study the effect of both groups of determinants on Behavioral Intention and consequently on Perceived Effective Use. Empirical data analysis resulted in a reduced model where insignificant determinants were eliminated. The final model retained only three UTAUT constructs: Performance Expectancy, Effort Expectancy, and Social Influence in addition to one patient-centered factor: Healthcare Knowledge. Though the researchers maintained three determinants from the UTAUT model yet the underlying relationships among these constructs and the predicted behavior constructs do not conform to these in the original model. While Venkatesh et al. (Venkatesh, Morris et al. 2003) assumed a direct relationship from Effort Expectancy and Social Influence on Behavioral Intention, Or et al. assumed an indirect relation that is mediated by Performance Expectancy.

A different focus of applying the UTAUT model was to verify the validity of the model within different cultural contexts. These research efforts aim to investigate to what extent does culture impact the acceptance determinants of the UTAUT model, and whether or not culture should be taken into consideration by these determinants. Chen (Chen 2007) applied the UTAUT model in a Chinese setting to explore the validity of the model in the Chinese cultural context. The results of this work proved that the Chinese national culture and organizational culture indeed had a significant impact on the acceptance determinants of the UTAUT model. Further investigation of the cultural aspect was carried out by Thowfeek and Jafaar (Thowfeek and Jaafar 2010) and Ismail (Ismail 2010).

Thowfeek and Jafaar claim that the national culture of a society has a significant influence on the actual behavior of individuals adopting or rejecting a new information and communication technology, and that it can increase the explanatory power of the variation in behavior with respect to technology adoption (Thowfeek and Jaafar 2010). Ismail (Ismail 2010) applied the UTAUT model in the context of higher education. The researcher applied the model to predict international students' acceptance of social networking sites as a learning instrument, as these sites are known to be able to bridge the cultural gap and enhance the level of trust between students and faculty members (Ismail 2010).

Another area of research interest is the acceptance of e-government services among citizens. An example of which is the work of Chan et al. (Chan, Thong et al. 2010), in which the researchers attempted to model the mandatory adoption of e-government technologies by citizens. Other research efforts investigating the acceptance of e-government services can be found in (Wang, Hung et al. 2006) and (Abdulwahab and Dahalin 2010).

Furthermore, the UTAUT model has been applied in other fields such as: education -to either investigate acceptance of e-learning tools, or course management systems- financial transactions such as internet banking or mobile payment, auditing, and driving support systems. Table A.2 in Appendix A contains a list of literature applying and extending the UTAUT model in the fields mentioned above.

Limitations of the UTAUT Model

In their work, Venkatesh et al. (Venkatesh, Morris et al. 2003) reported a limitation of the UTAUT model that is related to the scales developed to measure the model constructs. To measure each construct, the researchers used the highest-loading item. Such approach is not an unusual practice in psychometric literature. However, it risks the loss of a number of aspects of the construct being measured, and consequently affecting its validity. Therefore, the researchers suggest that the measures used for the UTAUT be considered as preliminary, and that future research should focus on developing and validating more accurate scales and maintaining content validity of the constructs (Venkatesh, Morris et al. 2003).

2.3 Innovation Diffusion Theory- IDT

The innovation diffusion theory – IDT was developed by Rogers (Rogers 1995) in the area of sociology. It is one of the principle theories on diffusion of innovations that originally tackles acceptance of innovation within societies at a global level and not restricted to the acceptance of information technologies, though the theory was later both adopted and extended by research efforts from various disciplines (Dillon and Morris 1996).

Rogers defines diffusion as "the process by which an innovation is communicated through certain channels over time among the members of a social system" (Rogers 1995), where communication is described as being distinctive with regards to the message it carries, which is related to a new idea. Roger further described diffusion as some sort of a social change that is defined as the "process by which alteration occurs in the structure and function of a social system". Rogers stated that social change occurs as a result of the invention and diffusion on new ideas, and the subsequent adoption or rejection of these ideas (Rogers 1995).

In general, Rogers' IDT theory attempts to explain the process of dissemination of new innovations within societies via an innovation-decision process model, and via concepts such as innovation adoption rate, and a number of variables affecting the adoption rate. These concepts are explained next in further detail.

Innovation-Decision Process

The innovation-decision process "is the process through which an individual –or another decision making unit- passes from first knowledge of an innovation, to forming an attitude toward the innovation, to a decision to adopt or reject, to implementation of the new idea, and to confirmation of this decision" (Rogers 1995). The model illustrated in Figure 2.10 is based on the assumption that decisions related to adopting new innovations are not instantaneous, but rather they are the result of a series of actions and decisions that occur over time. The model depicts this series of actions in five stages over time, which involve exploring options and making decisions based on evaluating new ideas and choosing whether or not to adopt the new innovation (Rogers 1995). The five stages of the innovation-decision process are:

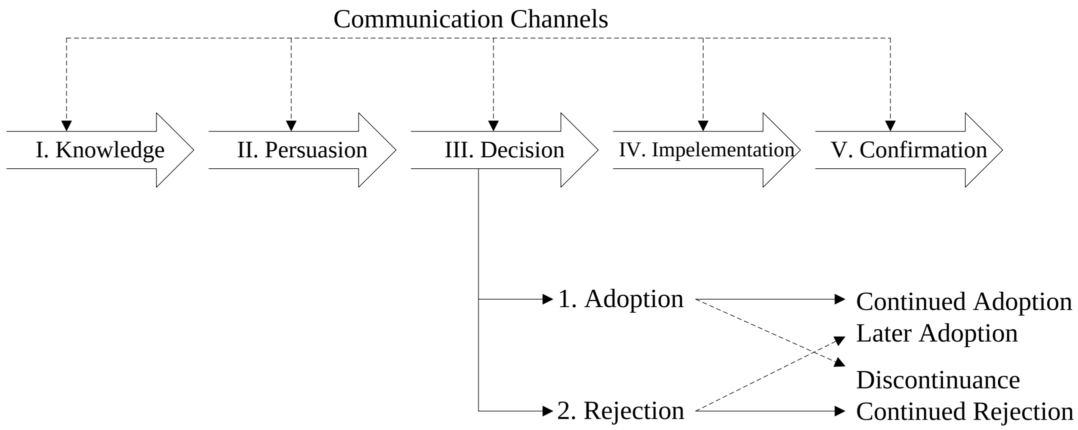

Figure 2.10: Steps of the innovation-decision process (Rogers 1995)

1. Knowledge

The knowledge stage takes place when an individual becomes aware of the existence of an innovation and becomes informed regarding its functionality. During this stage an individual becomes involved in a social process of communicating with other individuals, in an effort to seek knowledge about the new innovation to reduce its associated uncertainty. The process of knowledge seeking involves three types of knowledge; awareness-knowledge, which is the information related to the initial notion of the existence of an innovation. This type of knowledge leads an individual to seek yet another type of knowledge, which is how-to knowledge. The how-to knowledge is related to information needed to know how to use the innovation. The last type of knowledge is the principle-knowledge, which consists of the theories and principles that underlie the operation of the new innovation (Rogers 1995).

2. Persuasion

After an individual is exposed to the different types of knowledge related to an innovation, he or she forms an attitude towards the innovation that can be either positive or negative. This will lead to a subsequent change in behavior by either accepting an innovation or rejecting it. During this stage, an individual may attempt to mentally apply the innovation to predict future situations before making a decision whether or not to accept an innovation (Rogers 1995).

3. Decision

During this stage an individual becomes involved in a number of activities that can lead to either adoption of the innovation or rejecting it. Adoption is defined as "the decision to make full use of an innovation as the best course of action available" (Rogers 1995). Whereas Rejection is defined as" a decision not to adopt an innovation" (Rogers 1995).

4. Implementation

Stages prior to the implementation stage within the innovation-decision process are purely mental processes. In contrast, during the implementation stages the new idea is being put into practice, which results in a change in behavior (Rogers 1995).

5. Confirmation

Individuals' decisions to adopt or reject innovations are usually not final. During the implementation stage an individual continues to seek information related to the innovation, after he or she has already made a decision regarding whether or not to adopt the innovation. Based on the information acquired, an individual will either decide to continue or retreat with their decision to adopt or reject the innovation (Rogers 1995).

Innovation Adoption Rate

In addition to describing a model demonstrating the decision process of adopting new innovations, Rogers argues that the adoption rate of such innovations is determined by five variables: perceived innovation attributes, types of innovation-decision, communication channels, the nature of the social system, and the extent of change agents' promotion efforts. These variables are demonstrated in Figure 2.11.

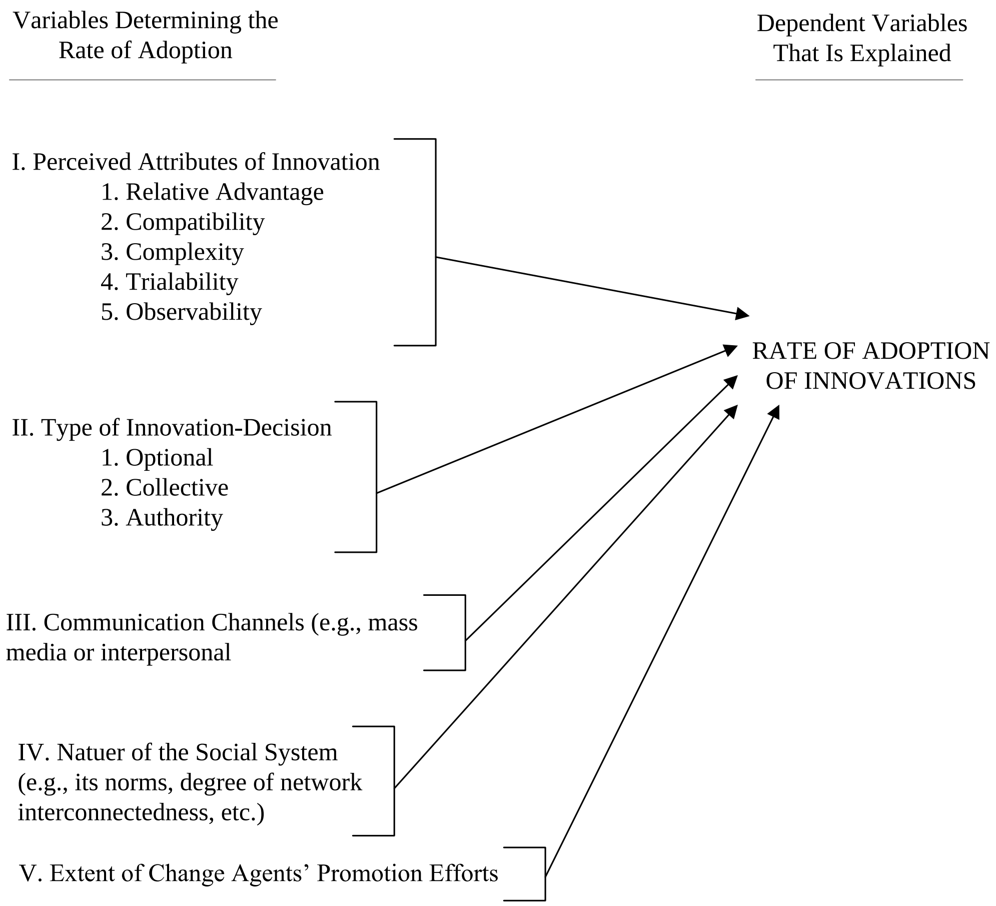

Figure 2.11: Variables Determining the Rate of Adoption of Innovations (Rogers 1995)

Among the variables depicted in Figure 2.11, the perceived attributes of innovation form an important element of explaining the adoption rate. According to Rogers, between 49% to 87% of the variance in the adoption rate is explained by these five attributes (Rogers 1995). Consequently, the innovation attributes received a great deal of attention throughout the literature, as they were adopted by researchers from different disciplines in various technology acceptance models, in combination with either other existing technology acceptance theories and models, or with acceptance determinants originating from their respective field of study. The definitions of the five innovation attributes are given in Table 2.5.

Table 2.5: Definitions of Rogers' Innovation Attributes

Attribute	**Definition**
Relative Advantage	The degree to which an innovation is perceived as being better than the idea it supersedes (Rogers 1995)
Complexity	The degree to which an innovation is perceived as relatively difficult to understand and use (Rogers 1995)
Observability	The degree to which the results of an innovation are visible to others (Rogers 1995)

Compatibility	The degree to which an innovation is perceived as consistent with the existing values, past experiences and needs of potential adopters (Rogers 1995)
Trialability	The degree to which an innovation may be experimented with on a limited basis (Rogers 1995)

The main principle underlying the innovation attributes is that the combination of all five can help predict the rate of adopting an innovation, such that if an innovation offers advantages to individuals, compatible with their values and beliefs, simple to use (low complexity), and offers trialability and observability to potential adopters, then the extent and rate of its adoption among individuals would be high (Dillon and Morris 1996).

Tornatzky et al. (Tornatzky and Klein 1982) conducted a meta-analysis study that included 75 articles on diffusion of innovations. Their results showed that Relative Advantage, Complexity and Compatibility, are the only innovation attributes constructs that demonstrated a consisted relationship to the adoption of an innovation throughout the literature (Tornatzky and Klein 1982).

Application and Extensions of IDT

Rogers' theory of Innovation Diffusion gained quite some popularity over the years. This is most evident in the amount of literature adopting the theory by researchers in different fields, to predict the diffusion of different types of innovations and their adoption rate by individuals within societies. The numerous research efforts varied in their adoption of the IDT theory, from adopting the theory in their respective field of study, to critiquing it and combining it with other theories from the literature to compensate for IDT's shortcomings. It is also quite often that researchers in addition to devising hybrid models of existing theories and models from the literature, extend these models with technology acceptance determinants derived from their respective contexts of studies. The Innovation Diffusion Theory has been applied to different areas relating to various technologies that are part of individual's lives. The use of IDT has been noted in fields such as: marketing strategies, information systems, healthcare, mobile services, mobile commerce, smart phones, digital music technologies, agriculture or even politics.

In particular, the IDT was widely applied within the area of education, where many studies attempted to predict the adoption rate of computer technologies, either by staff to improve the educational process, or by students in the case of e-learning technologies for example. The adoption of the theory was not limited to a certain level of education; studies were related to different levels of education ranging from early years of schools up to higher levels of education. Table A.3 in Appendix A presents a list of research efforts from different fields that utilized the IDT theory.

Diffusion of Innovation- DOI

From the many theories extending the IDT theory, one in particular stands out. The work of Moore and Benbasat (Moore and Benbasat 1991) is of special interest as their work, theory of Diffusion of Innovations- DOI is an extension and application of IDT in the area of information systems. DOI is one of the eight technology acceptance models and theories that were used as basis for the UTAUT model developed by Venkatesh et al. (Venkatesh, Morris et al. 2003)

Moore and Benbasat presented an overall instrument to measure various perceptions of adopting an information technology innovation. The researchers adopted Rogers' five innovation attributes and extended them with additional three constructs. The adopted innovation attributes are: Relative Advantage, Compatibility, Trialability, Complexity, and Observability. Where the last two attributes were adopted by Moor and Benbasat under alternative labels, these are: Ease of Use and Result Demonstrability respectively. The model was further extended with the following concepts as acceptance determinants: Voluntariness, Image, and Visibility (Moore and Benbasat 1991). The researchers argue that the acceptance determinants established in their measurement instrument have an effect as a whole on individuals' willingness to adopt an innovation (Swingler and Lee 2006).

The main contribution of their work is the development and validation of an extensive scale yielding a high level of confidence in relation to the validity of the associated acceptance construct. Their instrument consists of 34 items that meet acceptable levels of reliability, which was used to predict how individuals' perceptions can impact their adoption of a new technology (Moore and Benbasat 1991).

Moore and Benbasat's instrument has been later used and adapted in various manners by other researchers in different contexts (Furneaux 2005). An example of such adoption is the work by Brandford and Florin (Bradford and Florin 2003). The researchers applied the instrument to investigate factors that contribute to the success of ERP (Enterprise Resource Planning) systems. The results of their work revealed that Relative Advantage, Complexity, and Compatibility acceptance constructs have demonstrated a strong relationship with adopting innovations (Bradford and Florin 2003, Furneaux 2005).

Limitations of IDT

A number of shortcomings of Rogers' IDT were identified by researchers within the literature. Wright et al. (Wright and Charlett 1995) described Rogers' model as lacking predictive validity, and deemed its guidelines for marketing strategy as flawed. Rogers classified innovation adopters into different categories, and for each category he attempted to identify common traits, while Wright et al. argue that empirical evidence proved that there is no consistent link between personality characteristics and the personal trait of innovativeness. Furthermore, the researchers stated that innovation adopter groups are inconsistent in nature. That is, an individual can be an innovator in a particular field but not all. Though the researchers acknowledge that Rogers declared this in his work by stating that adopters' profiles are product specific, they nevertheless indicated that his theory does not account for this shortcoming as it does not offer a way to predict the change of the adopter's profile from one field to another (Wright and Charlett 1995).

Tornatzky et al. (Tornatzky and Klein 1982) criticize that Rogers' IDT was related to what they claim is the ambiguity of the definitions given for each of the innovation attributes, due to the fact that the criteria applied in defining the attributes were not offered. The researchers used Relative Advantage as an example, claiming that the manner in which an innovation is considered advantageous is not defined (Tornatzky and Klein 1982).

The IDT theory received more critique from Karahanna et al. (Karahanna, Straub et al. 1999) and Chen et al. (Chen, Gillenson et al. 2002) with regards to the formation of attitudes after an individual is exposed to the knowledge of the existence of an innovation. Both articles cite that the theory does not shed light on the formation of attitude, as it does not elaborate on how an attitude can transform into either acceptance or rejection of an innovation (Karahanna, Straub et al. 1999, Chen, Gillenson et al. 2002). Furthermore, Al-Qeisi (Al-Qeisi 2009) stated that though the IDT as a theory mentions the formation of attitudes and states that a decision regarding acceptance or rejection of an innovation can occur at any of the stages of the innovation-decision process model, yet the theory does not offer a clear insight with regards to how innovation attributes contribute in the formation of attitudes (Al-Qeisi 2009).

2.4 Integrating the UTAUT model and IDT Theory: The H-Model

Integrating different technology acceptance models in the IT arena to investigate users' acceptance of certain information technologies is not uncommon. The aim of these attempts usually is to combine the different points of strength of each model to devise a hybrid technology acceptance model that is high in its predictive power. One possible combination is that of the UTAUT model and the IDT theory, a blend of these two renowned theories is inspired by the success and outspread use of both theories throughout the literature. The usage of the UTAUT model appears to be a sensible choice as a very strong and competitive technology acceptance model in the IT acceptance literature (Chen 2007). The UTAUT model not only combines the competence of the underlying eight models, but it also outperforms the predictive power of all eight models by accounting for 70% of the variance in use (Adell 2009). Furthermore, the results of Shin's (Shin 2010) work showed that users' intention to use a technology and their actual use of it are influenced by innovation attributes from Rogers IDT theory. His results proved the existence of a link between the UTAUT model acceptance determinants and IDT innovation attributes, such that the UTAUT determinants are further enhanced and moderated by IDT attributes.

In this work the UTAUT model and the IDT theory are combined into a hybrid model, i.e. H-Model, to investigate the deployment and diffusion of ICT-based, privacy-sensitive infrastructure systems from a consumers' perspective, to explore factors that can stimulate consumers to adopt and use such technologies. Considering the different context of study and the associated different nature of the social component, only the relevant acceptance determinants from the UTAUT model were adopted, i.e. all determinants except Facilitating Conditions. This was necessary as the UTAUT model was originally developed and applied in the context of IT systems acceptance by users within organizations, which is quite different from the setting of the current study, where acceptance is being measured for infrastructure systems by consumers in a domestic environment. This contributes to the novelty of this work, as among other models the UTAUT was basically being applied and extended within an organizational environment.

The adapted UTAUT determinants were integrated with innovation attributes from Rogers' IDT theory to explore the possible enhancement in the predictive power of the model. Some innovation attributes of the IDT theory had to be eliminated from the H-Model. The Relative Advantage and Complexity IDT innovation attributes were discarded as they overlap with two already adapted UTAUT acceptance determinants, these are Performance Expectancy and Effort Expectancy respectively. Figure 2.12 illustrates the H-Model devised by integrating the technology acceptance determinants from the UTAUT model with IDT theory.

Finally, the H-Model will be further extended with additional acceptance determinants that were derived from two case studies of ICT-intensive infrastructure systems, i.e. the smart metering system in the energy sector, and the OV-Chipkaart system in the public transportation sector. This process is illustrated in Figure 2.13 where the final proposed research model consists of acceptance determinants falling under two categories: acceptance determinants adopted from exiting literature, and those originating from the above mentioned case studies. The extended hybrid model is described in further detail in Chapter 5.

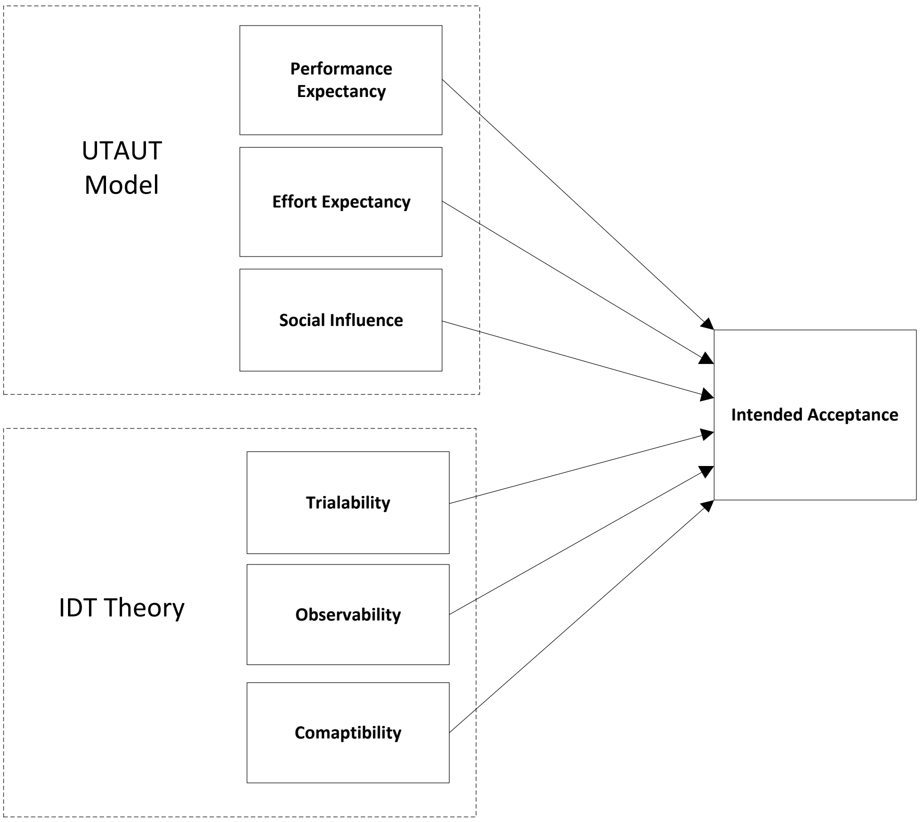

Figure 2.12: UTAUT and IDT hybrid model

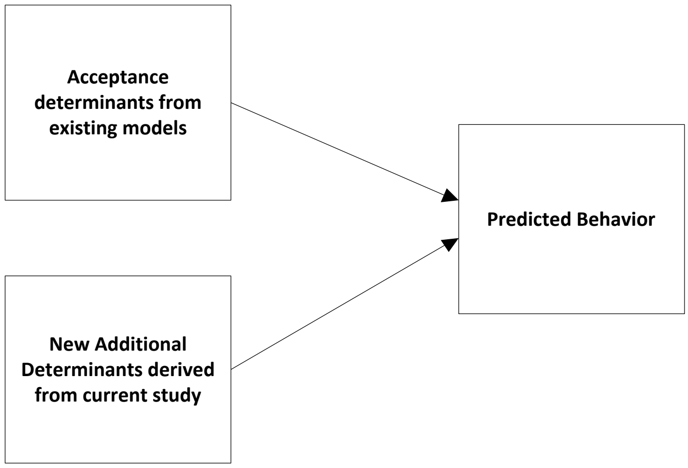

Figure 2.13: Abstract conceptualization of the proposed research model

2.5 Conclusion

In this chapter a number of well-known theories and models from the technology acceptance body of literature were presented. The theories originate from different areas such as psychology, sociology, information systems and information technology. The different perspectives offered by each theory or model were discussed in light of a various set of determinants that are hypothesized to have an influence on some observed behavior. Among these theories and models, two of which were chosen as a theoretical foundation for this work, these theories are: the Unified Theory of Usage and Acceptance of Technology- UTAUT, and the Innovation Diffusion Theory- IDT.

The two theories were chosen for their predictive ability of technology diffusion, adoption and usage. An initial-stage hybrid model, i.e. H-Model, was devised from the two theories to explore their predictive power in the area of ICT-based, privacy-sensitive infrastructure systems. In subsequent Chapters 3 and 4, two systems will be discussed as examples of ICT-based, privacy-sensitive infrastructure systems, i.e. the smart metering system in the energy sector, and the OV-Chipkaart system in the transportation sector respectively. The H-model will be tallied against both systems to explore how the acceptance determinants in the H-Model relate to these systems and to discover other limitations of both systems that are not capture by the H-Model.

In light of the additional shortcomings of both the smart metering and the OV-Chipkaart systems, the H-Model will be revisited in the Chapter 5 to be augmented with additional factors to account for the limitations of both systems. Each identified limitation will be mapped into an acceptance determinant to be included in the H-model, which will yield an extended H-Model. This process is discussed in further details in Chapter 5.

Chapter 3 : Case Study 1 – Smart metering

3.1 Introduction

A smart metering system is an interdependence between both the energy and ICT infrastructures. It consists of a number of distributed components -belonging to either of the two infrastructures. The collaboration of such components brings the intended services to the consumers. In essence, the system is intended to govern energy infrastructures by means of ICT in order to offer energy consumers capabilities beyond the tracking of their energy consumption. For example, a smart meter can operate with a two-way commination medium that makes it possible to inform consumers about energy prices in real-time manner. Furthermore, the 2-way communication infrastructure of the smart metering system allows energy companies to communicate with consumers by displaying short message on the meter display. By putting the smart metering system in use a number of goals are expected to be achieved that brings gains to both consumers and energy companies. For example, it is expected that consumers will reduce their electricity usage as they become aware of their actual consumption. This in turn is expected to reduce the need to build more power plants and to expand the existing networks. Furthermore, the system can provide more accurate information to grid operators regarding how to allocate electricity use (Smart Grid News 2007). In addition, the system will facilitate energy-related developments such as decentralized electricity generation and the increasing electrification, e.g. electric cars.

The smart metering system in The Netherlands is an example of a new generation of intelligent critical infrastructures that are ICT-intensive. The system is also a good example of a socio-technical system, where consumers' interaction with the system is considered of great importance to ensure reaching the desired goals. The reliance of the smart metering system on an ICT infrastructure has resulted in the emergence of some short comings that are inherent to the "digital" nature of the system. In one way, smart meters have become a privacy-sensitive technology that can jeopardize the privacy of consumers' personal information. An example of another short coming is the potential of adverse health effect that may be caused by the electromagnetic radio waves emitted from the smart meter. These limitations among others have led to a social acceptance dilemma that in fact put a halt on a mandatory rollout of the system in The Netherlands.

In this chapter, the smart metering system is presented as a case study of an ICT-intensive privacy-sensitive infrastructure system, against which the H-Model introduced in chapter 2 will be tallied in order to identify further short comings that are not captured by the H-Model. The remainder of the chapter is organized as follows: in section 3.2 the incentives behind the smart metering system is presented. Section 3.3 discusses the rollouts and pilot projects of the system, whereas the main components of the system -both social and technical- are presented in the section 3.4. The H-Model is tallied against the smart metering system in section 3.5, and in section 3.6 some additional inherent limitations of smart meters are presented. Finally, section 3.7 presents the conclusions of this chapter.

3.2 Incentives and Motivation

The motivation behind the adoption of smart metering differs from one country to another. However, in general there are some common drivers that encourage the different governments to adopt the smart metering system within their respective countries. In Italy for instance the main drivers for the implementation of their smart metering system were: improved operations, service quality and customer choice. In France however it was energy efficiency and improved market competition (Koenis 2007). In the Netherlands the motivation behind the launch of the smart metering project is based on a number of key drivers; one of which is improving liberalized markets (Togeby 2008). Another main driver is protecting the environment since the use of smart metering can contribute to the reduction of global warming and CO_2 emissions. Furthermore, the significance of smart metering rises also from other chief goals, which the government aims to achieve; that is to eliminate the need for more electricity generation, which in turn eliminates the need for electricity grid expansion to overcome the electricity congestion problem. This is made possible by means of distributed generation and demand response. Smart metering is a prerequisite for the former, while the latter takes effect as users become aware of their exact energy consumption patterns by means of real-time energy pricing that is available via smart meters (Strbac 2008). As a direct result, energy consumption levels are substantially reduced, and peak load generation is lessened as loads are being shifted from peak to off-peak (European Regulators' Group for Electricity and Gas 2007).

From an economic point of view, smart metering contributes in the cutting back of a number of costs that are related to the operation of the system and electricity consumption. For example, consumers will witness reduction in their energy consumption bills as a direct result of their modified energy consumption patterns- given that they are provided with proper and useful feedback, and the reduction of energy prices due to competition among the different energy suppliers. Smart metering will also allow for the use of prepaid electricity, an option which is useful for customers with bad debt. In addition, costs associated with customers' services and transactions will be reduced as customer self-service is put into effect, whereas costs related to manual meter reading will be abolished.

In addition, as opposed to the currently estimated energy bills, smart metering offer consumers the chance to receive accurate energy bills based on time-of-use tariffs (Steg 2008). From an operational perspective the use of smart metering allows for an improved management and control over the electricity grid. For example, system administrators would be able to detect theft, as well as being notified of and able to locate power cuts and interruptions more rapidly, which results in faster restoration. Moreover, the on-demand grid condition information that is made available by using smart metering facilitates for future grid planning.

From a higher abstraction level the following institutional reasoning can be followed in the context of smart metering. The European Union energy policy sets the regulatory framework on energy markets throughout member states of the Union, with a focus on a number of goals including the following, for the aim of integrating EU energy markets in the future:

- Competitive, transparent and liberalized European electricity market
- Energy efficiency and saving
- Sustainability
- Security of supply

This is essence boils down to the realization of a technically- sufficient infrastructure, i.e. a smart grid that is able to support an improved market operation in addition to a new set of services offered to consumers

The fulfillment of the aforementioned goals is supported either directly or indirectly by the operation of smart metering system. In addition, the smart metering system has been mentioned explicitly or implicitly in a number of European Union Directives as an instrument that enables consumers in taking a more active role in energy efficiency and saving, which in turn can lead to achieving a number of the intended goals of the system.

Directive 2005/89/EC: Directive of the European Parliament and of the Council of 18 January 2006, concerning measures to safeguard security of electricity supply and infrastructure investment. Under article 5- maintaining balance between supply and demand- smart metering is mentioned as a tool for real-time demand management, as one of the measures member states are encouraged to take to "to maintain a balance between the demand for electricity and the availability of generation capacity" (The European Council 2005).

Directive 2006/32/EC: Directive of the European Parliament and of the Council of 5 April 2006, on energy end-use efficiency and energy services and repealing Council Directive 93/76/EEC. Article 13 –metering and informative billing of energy consumption- states that member states should ensure that consumers are equipped with "meters that accurately reflect the final customer's actual energy consumption and that provide information on actual time of use" (The European Council 2006). Accurate billing is intended as an effective instrument that leads to energy efficiency and savings which a high priority goal of the EU regulatory framework.

Directive 2009/72/EC: Directive of the European Parliament and of the Council of 13 July 2009, concerning common rules for the internal market in electricity and repealing Directive 2003/54/EC. The directive states that member states of the union are to ensure the implementation of smart metering systems to enable consumers to resume an active role in the electricity supply market. Furthermore, each state is responsible for plan a roll-out of the system over a time frame of 10 years, where at least 80% of consumers should be equipped with a smart meter by the year 2020. Each state must take proper measures and apply appropriate standards to ensure the interoperability of their respective smart metering systems (The European Council 2009).

20-20-20 Targets: An integrated approach regarding climate and energy policy was adopted by European leaders in March 2007. The aim was to lead Europe towards a highly energy-efficient and low carbon economy, by tackling climate change, increasing EU energy security, and reinforcing competitiveness of energy markets. These aims were to be realized by the 20-20-20 targets listed below:

- At least a 20% reduction in EU greenhouse gas emissions, below 1990 levels
- A 20% reduction of energy usage by promoting energy efficiency
- 20% of energy consumed must come from renewable resources

In December 2008 the European Parliament and Council approved the climate and energy package, and by June 2009 it has become a law (European Commission Climate Action 2010).

These goals however rely to a large extent on demand response, i.e. consumers' active participation in reducing or shifting their electricity consumption behavior, and their willingness to allow electricity suppliers and grid operators to remotely read their meter registers on daily basis. Such readings are crucial for utilities for forecasting and planning purposes in relation to electricity grid expansion and forecasting electricity generation.

Therefore, in compliance with the European Union directives and laws above, it is clear that the implementation and roll-out of smart metering systems within member states of the EU is inevitable, and that governments should tackle any problems jeopardizing a successful roll-out and operation of the system, such as consumers' rejection of smart meters due to a number of different reasons. The causes for smart meters rejection among electricity consumers within different countries are discussed further next.

3.3 System Roll-Outs and Pilot Deployments

The roll-out timeframe of the smart metering system in the Netherlands has changed several times over the past few years since the project was first initiated. In early 2007 a start of a massive roll-out of the system was not considered possible before 2008 (Jones 2007). The Netherlands' Ministry of Economic Affairs was aiming for a 100% system roll-out plan, that beings in mid-2008, and to be completed over a six-year period; that is by 2014, a time at which all 13 million users within the Netherlands should have operational smart meters (European Regulators' Group for Electricity and Gas 2007, Jones 2007, Togeby 2008). Due to a number of obstacles, which were either of a technical or political nature, the smart metering system deployment had to be delayed, and in 2008 a new roll-out timeframe in the Netherlands was drawn. This timeframe is illustrated in Figure 3.1.

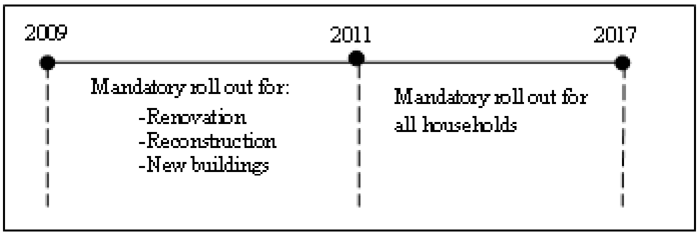

Figure 3.1: An initial smart metering system roll-out timeframe

Within this timeframe, it was decided that by the year 2009 a 2-year experimental period will begin. During this period, as of the 1st of January 2009 smart meters must be placed in renovated or newly constructed buildings, in addition to priority consumers. And as of April 2009 release I of the system will be launched, where port P1 will be inactive, and port P4 will be active and over which six unidirectional (read-only) messages will be operational. The different ports of a smart meter are described in further detail in subsequent sections of this chapter.

During this 2-year period, a mechanical meter can still be replaced by another mechanical meter. However, as of January 2011, a seven-year mandatory full roll-out of the system for all domestic users will being, during which all mechanical meters must be replaced by smart ones.

By early 2007, the largest system roll-out was by Oxxio, an energy supplier and certified metering company in the Netherlands, where they deployed up to 80,000 smart meters, and aim to install another 200,000 meters within a 4-year plan (Ruderman 2008). During the same year, Continuon, a Dutch grid operator (which now goes by the name Alliander) was planning on deploying up to 50,000 meters (Jones 2007), of which 38,000 meters were installed up until late 2008.

Again, the roll-out timeline shown in Figure 3.1 was not put into effect due to objections voiced against a mandatory rollout of the system, which in turn had an impact on both the legislation and the rollout time frame of the system.

Deployment Delays

The launch of the smart metering system in the Netherlands has been delayed due to several difficulties faced. The main obstacles facing the deployment of the system include: lack of required and essential knowledge among some individuals who are involved in the project, the lack of meters in the early stages of the system, utilities and IT systems were not yet implemented until recently, system requirements were not ready, debates in 2nd Chamber of Parliament over the sufficiency of the system due to claims that the system was not smart enough, the need for a new legislation by the parliament, and the cost of smart metering system technologies, which only started to witness a significant reduction in recent years (Jones 2007).

Pilot Projects

A number of grid operators in the Netherlands, such as Delta, Continuon and Oxxio, have already started with launching smart metering pilot projects for selected consumers within their respective regions. For example, by early 2008 the size of Delta's pilot roll-out was 350 households in Zeeland province. Their pilot roll-out consists of a number of phases beginning from the first quarter of 2008, followed by a period of decision making regarding which meters and IT systems to adopt. This was to be followed by a second testing phase that includes a thorough testing of the requirements stated in NTA 8130, which is a technical agreement that specifies a minimum set of functions of smart meters(Metering 2007).

The size of Continuon's pilot roll-out by later 2008 was 38,000 meters for domestic households in Arnhem and Alphin aan De Rein. Oxxio, has started offering smart meters to its customers in 2006 (Ruderman 2008), by late 2007 they have already installed 100,000 meters (Oxxio 2007). In total, there is around 150,000 smart meters installed as part of pilot projects by the different grid operators in the Netherlands.

The purpose of these trial roll outs is "to build experience with all operational aspects of smart meters" (Ruderman 2008). Under these pilot projects grid operators get to explore and experiment with the different available technologies and implementation choices for the different parts of the system. This gives grid operators a better insight and the ability to make well-informed decisions regarding which of these technologies to adopt.

System Implementation

Choosing the most suitable technology remains a challenge facing grid operators implementing the system in their respective regions. Grid operators in the Netherlands use smart meter installations manufactured by different companies such as Echelon and Iskraemeco. The NTA 8130 standard states possible implementation choices for several components of the system such as the communication ports.

Port P1, a read-only port, should be implemented with an RJ11 connector and NEN-EN 62055-21 mode read only protocol. Whereas port P2, can be implemented using either a wired M-bus using screw terminal blocks in accordance with NEN-EN 13757-2; or wireless M-bus in accordance with NEN-EN 13757-4 (Nederlands Normalisatie-instituut 2007). Furthermore, the standard states that port P3 can be implemented using: PLC, GPRS or Ethernet. Oxxio is an example of a grid operator that uses GSM/GPRS technology for communication with smart meters (Ruderman 2008). The choice of using any of these technologies is based on a number of factors such as reachability; if a smart meter is in a location that is not reachable by GPRS then PLC is used instead. Another factor is cost; GPRS is considered more expensive compared to other technologies. Finally, the NTA 8130 standard states that port P4 is implemented using the XML protocol as the port is accessible via the Internet.

To recap, the timeline of the evolution of the smart metering system in The Netherlands can be summarized as shown in Table 3.1 (Renner, Albu et al. 2011).

Table 3.1: Smart metering system evolution timeline in The Netherlands

Year	Event
2004	Dutch Government started considering the smart metering system after the liberalization of the energy markets
2005	• Electricity Act and Gas Act included mandatory rollout of the smart metering system • Cost-benefit analysis conducted by KEMA and commissioned by SenterNovem (Angentschap NL) expected a positive business case of approximately 1.3 billion Euro
April 2007	• The smart metering technical standard NTA 8130 is released by the Netherlands Standardization Institute. The standard defines minimum set of basic smart meter functions
2008	• A mandatory rollout was considered critical as it was expected that a voluntary adoption of smart meters would not exceed more than 30% in light of the liberalized market and without further regulation • A legislative proposal is released that states a mandatory rollout of the smart metering system
July 2008	• Despite privacy implications, the mandatory rollout was approved by the House of Representatives of the Dutch parliament • The legislation was opposed by consumer organizations due to privacy concerns, and energy saving claims
April 2009	• The Dutch upper house of Parliament did not approve a mandatory rollout of the smart metering system due to a report released by the University of Tilburg and commissioned by consumer organization and privacy activists. The report stated that the 15 min reading is a violation of the right to privacy as guaranteed by Article 8 of the European Convention of Human rights • The Dutch upper house of Parliament requested a change to the proposal to allow for voluntary adoption of the meter

September 2010	• The Ministry of Economic Affairs commissioned KEMA for another cost-benefit analysis to calculate financial implications on a national-level to gain insight into the consequences of the changed circumstances with respect to the business case for the rollout of the smart metering system
	• The revised analysis was urged by:
	  o Under the new legislation a smart meter will only be read once every two months. Furthermore, consumers have the right to reject the installation of a smart meter
	  o The need for the Dutch government to gain an understanding of measures that could influence social costs and benefits into the direction desired by the government
	• The KEMA cost-benefit analysis report stated that a 100% acceptance would result in a positive business case of approx. 770 million Euros. Savings

	mainly coming from: o Energy savings o Savings on call center costs o Savings in meter reading costs • The analysis concluded that at least 80% acceptance is needed to achieve a positive business case • A recommendation was given that the government must focus on societal acceptance when it comes to policy targets
November 2010	• The Dutch upper house of Parliament approved a new legislation that grants consumers the right of voluntary adoption of the meter
2011-2012	• 2 year pilot-phase rollout of smart meters • Based on findings from this period, decisions will be made for the final rollout in 2020

Smart Metering in the European Union

The progress of the smart metering system's implementation within member states of the European Union varies in terms of a number of aspects such as; the level of government's involvement, nature of services to be fulfilled by the system, and degree of consumers' involvement. However, despite the differences there exist a number of serious issues that are common within these countries, which still needs to be addressed in order for the system to achieve its desired goals. Examples of these issues include: lack of regulation, lack of standardization, the absence of means to provide consumers with proper and useful feedback, and the need for a more innovative approach of the system's development to ensure a maximum utilization of the system's capabilities. A few examples in a number of European countries are presented in Table 3.2 of the current status of the system.

Table 3.2: Examples of smart metering systems roll-outs in the EU

European Union State	Description
Austria	In Austria, a number of actors have been actively involved in the deployment of the system. For example, Energie AG was planned to launch a pilot project with the size of 10,000 smart meters in autumn 2008, the company also aims to have deployed smart meters for 85% of their consumers by the year 2015. Linz AG, a grid operator in the city of Linz, have started a pilot project in an ecological energy park within the company. Whereas in the city of Feldkirch, the public municipal services plans to install 17,000 smart meters over the next 12 years, 2000 of which are already installed (Santer 2009).
Norway	Smart metering had a rather slow and late start in Norway due to a number of obstacles, such as high costs and lack of regulation. The system development timeframe began in 2004 with a cost benefit analysis, and is expected to end in 2014 with a full system deployment. New regulation was expected to be released in summer 2009 (Moen 2009). Since 2007 two hearing rounds have been held regarding the new regulation. The first

	proposed timeline aimed for a full scale deployment of Automated Meter Reading - AMR by 2012. However, due to several delays a second proposal was made that suggested a full scale system deployment by 1st of January 2018, given that the new regulation would be ready during the 1st half of 2011(Renner, Albu et al. 2011). On the 24th of June 2011 new rules regulating a large-scale deployment of smart metering that amended the Regulation of 11.03.1999 nr. 301, was adopted by the national energy regulator. The regulation stated that by 1st of January 2017 all energy consumers in Norway must be equipped with smart meters (Simonsenlaw.no 2012)(Simonsenlaw.no 2012)(Simonsenlaw.no 2012)(Simonsenlaw.no 2012)(Simonsenlaw.no 2012)(Simonsenlaw.no 2012)(Simonsenlaw.no 2012).
Denmark	A number of grid operators in Denmark have installed in total 300,000 smart meters for large scale users- mostly industrial consumers. However, except for these large scale users, the Danish government did not mandate the roll out of smart meters – which is yet to be debated in the parliament for domestic households, but rather considered guidelines to manage the system. As in some other countries, a leading problem in Denmark with regards to smart metering is the lack of standardization; where systems from different grid operators run on diverse technical platforms, and lack common rules for managing energy data (Jensen 2009).
Italy	Within in Europe, Italy is considered a leader in terms of a massive roll out of the smart metering system and its regulation. There are 33 million smart meters that are already installed, and they aim to reach a total of almost 36 million meters by 2011 (Pavan 2009). Until early 2012, it was reported that Italy had smart meters penetration rate of 94% within households (Savvas 2012). The roll out of the system in Italy was mainly motivated by costs saving, and overlooked vital issues like demand response or energy efficiency.
Finland	In Finland regulation regarding smart metering took effect starting from the first of March 2009. The roll out of the system complies with a legal requirement to deploy 80% of the smart meters by 2014 (Koponen 2009).
Slovenia	a number of smart meters were installed as part of pilot projects within five grid operators, with a reported rate of ~ 2% of unsuccessful installations (Fatur 2009).
United Kingdom	a mandatory time frame exists for the roll out of the system, which must be completed by the year 2020.

As can be seen from the examples in Table 3.2, there is still a pressing need for research for methods to promote innovative development of the system, to ensure a maximum utilization of its resources, and to provide consumers with effective and meaningful feedback to increase their level of involvement.

3.4 Smart Metering System Architecture

3.4.1 Social System Components

The main stakeholders involved in the smart metering system in the Netherlands are mentioned in the NTA 8130-Nederlandse Technische Afspraak (Nederlands Normalisatie-instituut 2007), a document that contains the functional requirements for market facilitation. These stakeholders are; consumers, suppliers, grid operators, metering data companies, independent providers of services and systems equipment (Nederlands Normalisatie-instituut 2007), in addition to the Ministry of Economic Affairs.

Each one of these stakeholders plays a different role with regards to the operation of the smart metering system, and in return the system has diverse effects on the ways these stakeholders interact with the system; whether it is how market players contribute to the entire process of electricity generation, transmission, supply and billing, or how consumers react to the system by adjusting their consumption behavior. The role played by the main actors regarding the system, and the effects the system has on these actors are explained further below.

Grid operators

The introduction of a smart metering system has a great impact on grid operators and the way they manage and operate the electricity grid. From an administrative perspective "smart meters give grid operators the information they need to efficiently fulfill their roles in the market" (European Regulators' Group for Electricity and Gas 2007); using the information generated by the system, grid operators can have a clear insight on customers' consumption patterns, which can assists in making decisions regarding for example the size of future electricity generation and whether or not there is a need to expand the electricity distribution grid. From a technical perspective, electricity grid operators are responsible for the system implementation and smart metering units' installation at remote households, they are also responsible for deciding on the different implementation choices, such as those for the communication medium to ensure correct and secure transfer of the metering data across the communication mediums between the metering installations and the central access servers. In addition, among the different market players, grid operators play a key role in the overall operation and management of the system. For example, "the metering installation is only accessible for the grid operator via port P3. In case there is a separate grid operator for electricity and for gas, only the electricity grid operator has direct access to the metering installation via P3" (Nederlands Normalisatie-instituut 2007).

Furthermore, grid operators are accountable for enforcing the implementation of security measures across the entire system. This is most crucial considering the severe consequences should a security breach occur compromising the operation of the system and the confidentiality of the different categories of information that is generated and maintained by the system. Such information includes metering data, consumers' profiles but most importantly information that is related to controlling the operation of the system. Therefore, grid operators must ensure the implementation of strong data encryption schemes regardless of their implementation choices, and enforce proper identification, authentication and authorization of both the metering installations, and different stakeholders of the system in a way that restrict their access only to parts of the system to which they are entitled (Nederlands Normalisatie-instituut 2007).

Energy suppliers

The launch of the smart metering system reshapes the services offered by energy suppliers to their consumers, and allows for the introduction of new services. After a full system deployment, suppliers will be able to promote awareness among consumers on efficient energy consumption and savings. Furthermore, the use of the system offers energy suppliers the following benefits: the ability to offer pre-paid electricity to their consumers, endorsing competition among different electricity suppliers, enabling energy and/or water suppliers to work with differentiated tariffs, and the ability to obtain meter readings instantly whenever deemed necessary by suppliers (Nederlands Normalisatie-instituut 2007).

Energy suppliers are responsible for managing consumer-related processes, e.g. metering data management. Unlike grid operators whom have direct access to the smart meter installation at remote households, energy suppliers have access to metering data and control commands only through the central access servers –CAS, via port P4 (Nederlands Normalisatie-instituut 2007, Hoffmann 2008).

Ministry of Economic Affairs, Agriculture and Innovation

The Ministry of Economic Affair plays a critical role in smart metering in the Netherlands from the early stages of the system. Not only does the ministry hold a position as the legislator of the system, but it also instigated the launch of the project by commissioning the Dutch Normalization Institute- NEN to "formulate and describe a standardized minimum package of basic functions for remote readable metering for electricity, gas, thermal energy (heat and cold) and water for domestic consumers" (European Regulators' Group for Electricity and Gas 2007). However, the scope of mandatory functions of the system was reduced mainly reduced to electricity and gas at the early stages of the system's deployment. This description in addition to a set of requirements, which the system must satisfy, came out in 2007, in the form of the NTA 8130 Document (Nederlands Normalisatie-instituut 2007). Regulators within the different member states of the European Union assume various responsibilities regarding smart metering systems. However, in the Netherlands, a country where the system lies within the regulated domain under which grid operators function in a monopolistic manner, the system is under the jurisdiction of the ministry as a regulator, whom is in charge of regulating metering prices and market organization. In addition, the ministry is also responsible for devising ideal metering infrastructure framework, considering the key role metering plays in numerous aspects of the market. In their smart metering legislation, the Ministry of Economic Affairs considered achieved a number of goals such as: guaranteeing consumers' freedom of choice, promoting energy savings, and create market opportunities for third parties to offer data management services (European Regulators' Group for Electricity and Gas 2007). In essence, smart metering can be an instrument through which regulators can function more effectively in separating market roles and implementing the market (Hoffmann 2008).

Consumer

Though consumers do not play a direct administrative or a regulatory role in the operation of smart metering, they are still expected to make a substantial contribution after a full roll out of the system, as they are given new and more proactive roles that enables them to assume new responsibilities relating to adjusting their energy consumption behavior (Defeuilley 2009). This is expected to be in the form of demand response; where consumers become aware of their precise consumption rates and react to that by adjusting their electricity consumption behavior to reduce the total energy demand (Hinnells 2008). This will have the great advantage for energy suppliers and grid operators to eliminate the need to generate more energy and expand the distribution networks. In return, smart metering offers energy consumers the possibility to make use of more services, in a far more flexible manner. For example, meter data reading is carried out automatically without intervention from the users. Another example would be for consumers with bad debts, who can take advantage of pre-paid electricity. Furthermore, the use of smart metering facilitates switching between energy suppliers, as consumers have the freedom to make the switch at any time. Consumers preserve the right to decide, which of the market players –except grid operators and electricity suppliers- can access their metering data for commercial purposes (European Regulators' Group for Electricity and Gas 2007).

3.4.2 Technical System Components

The main components of the smart metering infrastructure system –illustrated in Figure 3.2- are described below.

A Smart Meter

A smart metering installation refers to the device installed at remote households, which among other tasks keeps track of electricity, gas and water consumption in an advanced manner. A smart meter differs from a conventional one in the wide range of highly developed services that it offers, such as remote activation/deactivation of connections, and the two-way communication between the meter installation and service providers. Where the latter is of an extreme importance due to the rising awareness of the importance of public engagement and interaction among the involved parties, as opposed to top-down communication, where the public are treated as passive recipients rather than having a more active role (Owens and Driffill 2008). As stated in the NTA 8130, the instruments used for the Dutch smart metering system are compliant with the requirements of Metrology Act, the Electricity Metering Code, and the Gas Metering Conditions (Nederlands Normalisatie-instituut 2007).

Data Concentrators:

A data concentrator is a device that is usually located at substations to manage its data, which is gathered from the different smart meters at remote households. Mainly, these data concentrators act as a link between meters and the rest of the components of the advanced metering infrastructure by assuming a store-and forward role; as they collect data related to energy consumption from meters at remote households, transmit the data to control stations, and supply the data to the billing system (Siemens 2008). In addition to that, data concentrators are capable of detecting and configuring newly installed smart meter and creating repeating chains if necessary (Unicom Microsystems 2008).

In general, data concentrators automatically manage a portion of the infrastructure's functionality, such as monitoring the operation of the power grid and smart meters in an on-going basis, reporting disruptions and failures (Siemens 2008), and detecting and reporting of theft and tampering attempts (Unicom Microsystems 2008). Data concentrators are not capable for accepting incoming calls; however, if a connection is dropped the concentrators are capable of initiating and establishing contact.

Central Access Servers:

A central access server is defined in the NTA 8130 as "central application that takes care of the data collection, control and parameterization commands, and the centralized authorization for access to the metering installation" (Nederlands Normalisatie-instituut 2007). Each grid operator maintains a cluster of servers as part of the smart metering system operation.

The servers can be roughly divided into three categories based on the applications they host. In addition to databases that store the system's data, these servers also host the different software and applications that are necessary for the operation of the system. Furthermore, these servers also act as web portals, through which clients can access their profiles and can monitor their consumption rates for example.

Communication Ports:

To facilitate communication among the system components and market players, the smart metering system has a number of ports through which information can flow. In principal, the NTA 8130 standard lists four ports; P1, P2, P3, and P4 as illustrated in Figure 3.2, however throughout the literature a fifth port P0, which is located on the meter installation is sometimes mentioned, which is used for configuration purposes.

Table 3.3 presents a brief description of each of the four main ports of the system as mentioned in the NTA 8130 standard (Nederlands Normalisatie-instituut 2007).

Functionality

In principle, smart metering systems can offer a wide range of services, which can vary in diversity from one provider to another. However, aside from value added services, a minimum set of basic functionality –strictly related to electricity and gas at the early stages of the system- that must be satisfied by the system was defined in the NTA 8130 standard

(Nederlands Normalisatie-instituut 2007). The main functions are listed in Table 3.4. These functions belong to grid operators, consumers, or sometimes to both.

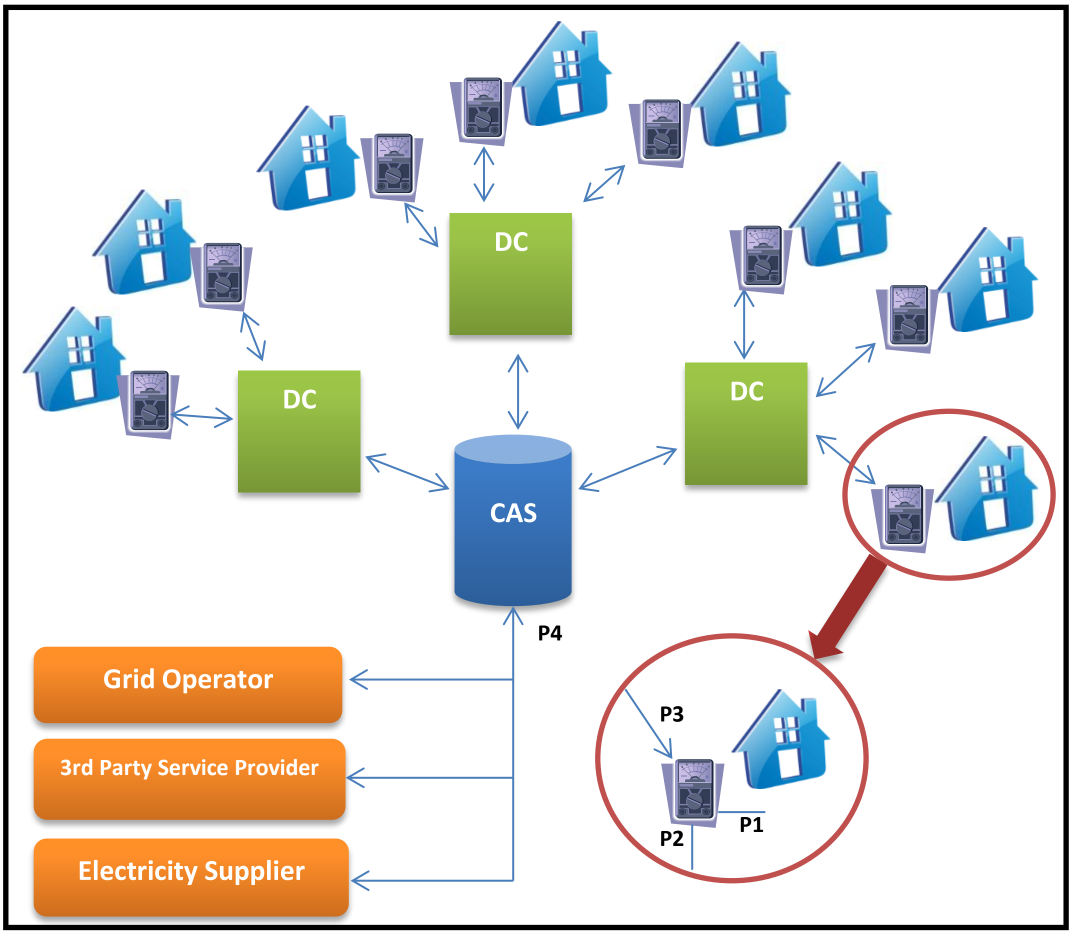

Figure 3.2: Components of the smart metering infrastructure

Table 3.3: Description of the four main ports of the smart metering system

Port	Description
Port P1	this is a read-only port that is mainly used to link the metering installation to an external device
Port P2	through this port the smart metering installation is linked to grid operator’s equipment or up to four metering devices
Port P3	this two-way communication port is used to connect the metering installation to the central access servers through a series of intermediate nodes
Port P4	This port differs than the others in the sense that it is not located on the metering installation but rather on the CAS, to which authorized market players are given access via this port

Table 3.4: Main functions delivered by the smart metering system

Function	Actor(s) Involved
Generate remotely readable real-time meter readings either on a periodic basis, or on demand. The readings indicate the amount of energy consumed or supplied to the system in case of decentralized generation. This helps in improving administrative processes.	Consumer
Facilitate for promoting energy saving awareness among consumers.	Consumer
Enable safe and remote activation/ deactivation of electricity and gas connections, either collectively or individually.	Grid Operator
Allow energy suppliers to work with differentiated tariffs.	Grid Operator, Consumer
Facilitate prepaid electricity.	Consumer
Monitor of distribution networks, and generate alerts of service disruptions or fraud detection.	Grid Operator
Measure and detect power quality remotely	Grid Operator
Online interaction between suppliers and consumers.	Grid Operator, Consumer
Enable remote electricity threshold changing	Grid Operator

From a technical perspective, the system needs to provide a number of functionalities; most importantly is a two- way communication network to support the above mentioned functionality (Unicom Microsystems 2008). To carry out these functions among others, the system facilitates for the exchange of messages between grid operators, suppliers, and independent service providers, and the consumers. These messages are mainly related to the status of the metering installation and controlling its settings. For example, authorized parties can request via ports P3 or P4 the current status of the metering installation, such as the actual tariff indicator, actual breaker position and actual threshold (Nederlands Normalisatie-instituut 2007).

Grid operators and energy suppliers display via port P3 (also available via port P1) status information in the form of standard messages on the display of the meter installation. These messages mainly cope with: reasons for deactivation, limitation of the threshold and its level, and impending shortage of prepaid credit (Nederlands Normalisatie-instituut 2007). Another form of communication that can occur between grid operators and the metering installations at remote households is the update of firmware installed on the meters.

3.5 The Smart Metering System in Light of the H-Model

The launch of smart metering systems in The Netherlands is hindered by a number of obstacles that prevented a mandatory or a 100% roll-out within the country. One of the major obstacles encountered the smart metering deployment in The Netherlands is consumers' rejection of the technology. In this section, the acceptance determinants encompassing the H-model –presented in Chapter 2- are revisited to investigate how they associate with the smart metering system.

Performance Expectancy

Performance Expectancy is defined as the "degree to which an individual believes that using the system will help him or her to attain gains in job performance" (Venkatesh, Morris et al. 2003). In the context of the smart metering system, this denotes a set of functions or goals that the smart meter is expected to provide for consumers or help to reach in addition to its basic function of logging energy usage. As a minimum, consumers could expect a smart meter to aid them in managing their energy consumption. This can be achieved by an around-the-hour access to meter data reading, e.g. a web interface provided by the energy company. Providing consumers with such information would empower them to manage their energy consumption by either shifting their time-of-use or reducing the amount of energy consumed. This in turn can help consumers in achieving goals such as decreasing the amount of their energy bill or even reaching further goals such as contributing to saving the environment.

The ability of a smart meter to offer consumers the afore mentioned capabilities may contribute in generating a more positive perception among consumers of smart meters. Furthermore, it could lead to a conviction that not only does a smart meter is not only a device that delivers expected services but it can also provide means of improving consumers' lives.

Effort Expectancy

Effort Expectancy is defined as "the degree of ease associated with the use of the system" (Venkatesh, Morris et al. 2003). The concept of Effort Expectancy in the context of the smart metering system relates to the degree of ease of learning how to use the smart meter, and the extent of simplicity associated with the steps required to use a smart meter. In theory, the more difficult it is to use a smart meter, the less likely it would be for consumers to be willing to obtain a smart meter. In reality however, applying the concept of Effort Expectancy to predict acceptance of smart meters is somewhat controversial. This is true due to the design of the meter, which encompasses a rather small and basic display that is intended to display energy consumption levels, energy prices, and messages from energy companies. Thus, though consumers can now get slightly more information from their meter, yet the interaction is very limited. Consumers whom wish to obtain more "useful" information regarding their energy consumption levels can do so by using an external meter display, which can be connected to the smart meter through P1 port.

Therefore, since smart meters are supplied to consumers as stand-alone devices without an external display, then it is expected that Effort Expectancy would be an insignificant smart meter acceptance predictor. Consequently, it is argued that Effort Expectancy is better to be investigated in relation to the external display devices instead of the smart meter itself, this however is outside the scope of this study.

Social Influence

Social influence is defined as the "degree to which an individual perceives that important others believe he or she should use the new system" (Venkatesh, Morris et al. 2003). The concept of Social Influence was applied in previous studies to other types of technologies such as the deployment of IT systems within organizations. The roll-out of the smart metering system however is quite different from the deployment of IT systems due to inherent characteristics of the system and the nature of the intended technology recipients. Social influence within the smart metering context can take several forms. For example: a consumer can feel encouraged to adopt and use a smart meter if members within the consumer's social network whom are perceived important for the consumers either: think that the consumers should adopt and use a smart meter, or use a smart meter themselves. Another form of social influence can be the perceived status of those owning and using a smart meter. If a consumer perceives those using a smart meter as individuals of high prestige and status then a consumer may be motivated to adopt a smart meter.

Trialability

Trialability is "the degree to which an innovation may be experimented with on a limited basis" (Rogers 1995). Normally, it entails allowing a potential technology-user an opportunity to experiment with said technology, in order to explore how to operate it and what functions it has to offer. In the arena of the smart metering system, this would involve offering a consumer the chance to try out a smart meter so they would get a feel of how it operates. Moreover, it helps consumers to have a clear understanding of what services a smart meter can offer, and what advantages that may bring. An obvious advantage that consumers can gain from trying out a smart meter before acquiring it is having the certainty that it is beneficial before investing financially in one. Energy companies on the other hand would benefit from the increased chance of consumers' acceptance of a smart meter. This is especially true when considering that people normally dread or avoid what they do not know.

In theory, there are possible approaches by which consumers can experiment with a smart meter to see what it can do. For example, energy companies can set informatory points that roam residential neighborhoods or public spaces like commercial centers of cities and towns. These points can be equipped with mock smart meters that demonstrate the operation of the system and simulate the information the meter can generate. In addition, consumers can experiment with online access to data maintained by energy companies to explore the manner in which feedback about energy consumption can be offered. Another approach of granting consumers the chance to try out a smart meter is via pilot roll-out commenced by energy companies within designated regions of the country. Though pilot roll-out is driven by other incentives for an energy company, yet it is still a chance for consumers to experiment with the meter. To the knowledge of the author of this thesis, pilot roll-outs are the only possible way for consumers to experiment with a smart meter.

Observability

Observability is defined in the original IDT theory as “the degree to which the results of an innovation are visible to others” (Rogers 1995). In the context of the smart metering system, Observability refers to the extent to which the results of using a smart meter are visible to consumers. Such results include: the decrease in consumers’ electricity bills due to their utilization of a meter, the ease with which consumers can switch between different energy suppliers and consumers’ active contribution in saving the environment by monitoring and controlling their energy consumption. As the afore mentioned results are all of an intangible nature, the role Observability plays in influencing consumers’ perception of smart meters becomes somewhat difficult to predict.

Compatibility

The degree to which an innovation is perceived as consistent with the existing values, past experiences and needs of potential adopters (Rogers 1995). In the arena of the smart metering system, Compatibility relates to the extent to which the manner in which the system operates is harmonious to what consumers are accustomed to. For example, the smart meter should be able to serve a minimum set of functionality that is already guaranteed by the conventional meter such as logging consumers’ energy consumption. Furthermore, changes to other aspects, e.g. billing, that are trigged by alterations in the system’s policy and operation need to be compatible with what consumers are used to. One facet of the system where consumers can sense a difference is billing. Under the conventional metering system, consumers were charged monthly based on approximate estimations that are balanced out at the end of the year. Whereas by using a smart meter, bills can be issued based on time-of-use, every two months. The influence of these alterations on consumers’ perception of the system is unknown. Thus, caution must be practiced to ensure that consumers are comfortable with the new methods in which the system operates.

3.6 Smart Metering System Limitations

An in-depth analysis of the smart metering system revealed that it suffers from a number of shortcomings that are negatively perceived by energy consumers, and that can potentially hinder a large-scale deployment. In this section, a number of drawbacks of the smart metering system that can pose as factors hindering consumers’ adoption and utilization of the system, and were not accounted for the H-Model introduced in Chapter 2 are introduced.

3.6.1 Information Security and Privacy

The launch of smart metering systems within a number of member states of the European Union is faced by numerous issues, which are adding to the limitations of the system and jeopardizing its success as it can prevent the system from satisfying few of its intended goals. A serious problem associated with smart metering system is ensuring the security of the information that is being generated and maintained by the system. According to a survey conducted by Secure Computing; 33% of participants voted the energy sector to be the biggest target to attacks, 30% voted it to be the most vulnerable and 42% voted it to be the most detrimental if attacked (Dallaway 2009).

Considering the interconnected nature of the supporting IT infrastructure of smart metering; the system faces the risk of information security breaches, against which counter security measures must be devised.

Smart Metering Security Threats and Information Assets

Threats or breaches are the potential for abuse of a system's assets by intruders (Haley, Laney et al. 2004). The degree of a threat depends on the attacker's skills, knowledge, resources, authority, motives and intentions. A security threat to the information assets of the smart metering system can have serious consequences. The severity of these consequences depends mainly on the sensitivity and the worth of the information. The protection of this information is rather crucial to ensure a normal and uninterrupted operation of its services and to preserve the consumers' right to privacy. Table 3.5 illustrates the main categories of the information assets of the smart metering system, and some possible threats targeting this information.

Table 3.5 The main categories of information in the smart metering system and possible threats

Type of information	Description	Possible threat
Consumer profile	The consumers' personal data such as their name and address	Risk to the safety of consumers and violation of their right to privacy upon unauthorized possession of this information
Meter readings	Daily and monthly meter readings	Theft by penetrating the communication medium, mimicking a device and finally altering genuine meter readings
System maps	Information that is related to the architecture of the system, the layout of its components and their interconnectedness	Tapping and penetration of communication mediums and data repository points and possible vulnerabilities within the system
Prepaid credit	A method of payment for energy consumption that is mostly used by consumers with poor finances	Information related to this method of payment is stored on the system's servers; access to credit information may result in credit theft
Confidential	Information that is related to the	Interruption of service, loss of system

system information	operation of the system, *e.g.*, encryption keys	control or system shutdown

In addition to raw data and information, the system also contains a number of critical functions that allow the monitoring and controlling of the system among other things. The unauthorized access to these functions can result in more severe consequences than those resulting from violating the confidentiality of information assets. Examples of security breaches to the smart metering system functionality include the following:

- fraud by altering meter reading to reduce it below the actual consumption levels
- gaining control over certain devices which could result in disconnecting their energy supply, e.g., shutting down certain appliances within a household such as a washing machine or a refrigerator
- maliciously monitoring users' electricity consumption rates (low rates indicate that the user is away from home, possibly for extended periods of time, which could result in theft)
- gaining control over the entire system should attackers gain access to critical information related to the operation of the system, this can be regarded as the most disastrous scenario.
- shutting down the entire grid (this would result in electricity supply down-time throughout the entire system).
- injecting Programmable Logic Controllers (PLC) signals on the communication medium causing communication disturbance
- initiating a denial of service attack on port P4

These breaches have many grave consequences that can be of a financial, legal, technical or operational nature, which can impact the different stakeholders or social actors of the system. However, one consequence of information security breaches that impacts consumers in particular is the violation of their right for privacy of their personal lives. This is discussed in subsequent sections in further detail.

Information Privacy

There exists a wide spectrum of definitions for privacy, each of which addresses various aspects. A frequently cited definition is: the right to be left alone (Cooley 1880), while another definition describes privacy as the wish to remain unnoticed or unidentified in the public realm. But perhaps a working definition in the context of consumers' privacy in relation to smart metering can be: the right of energy consumers to be guaranteed adequate measures of protection of their personal data maintained by the system, to prevent disclosure of this data to unauthorized parties, and prevent unlawful deduction of further information from the data that can reveal private aspects of consumers' behavior and habits. Some claim that smart metering systems provide more privacy since meter readers no longer visit consumers and invade the privacy of their homes. However true this may be; the use of smart metering introduces new means of privacy violations and exposure of consumers’ personal information.

Information Privacy and Data Acquisition Devices

The problem of consumers’ privacy violation -arising from security breaches of the information rich smart metering system- is neither new, nor is it exclusive for smart metering. Similar scenarios occurred with previous experiences, such as electronic voting and patients’ electronic medical records systems (McDaniel and McLaughlin 2009). Lisovich et. al. (Lisovich and Wicker 2008) describe several technologies throughout history that suffered from the same shortcoming; most of which made cases in American courts of law. This dates back to 1890, when the use of instantaneous photography was considered a breach of individuals’ privacy. Another example is thermal imaging; despite the fact that the technology is operated outside of someone’s home; its use constituted as search that violates privacy and can only be carried out by authorized parties with a warrant. Other examples include wiretapping and recording of dialed phone numbers.

In general, the aforementioned examples are all forms of data acquisition technologies, the use of which can pose a serious threat to preserving individuals’ privacy and their right to be left alone. In a similar sense, smart metering systems pose the same threat as data acquisition devices installed at consumers’ homes, which can reveal more information than consumers are willing to share. This introduces another point of controversy.

Despite their social and technical benefits, the use of smart meters requires consumers to share more information related to their energy consumption with utilities; which of course raises a number of security and privacy concerns (McDaniel and McLaughlin 2009). Unlike loyalty cards in stores, where consumers give away their personal information willingly in return of gains mostly in the form of freebies or discounts; the deployment of smart meters does not give consumers the choice of whether or not to give their information away. Instead, consumers have very limited control over the use of their personal information by the utilities (Marquis, Robinson et al. 2004).

The exposure of meter readings does not only reveal information about households’ electricity consumption magnitude and patterns; but also this information can be mined and combined together or with information from other sources to create a clear picture about the lives of the consumers’ households, including their daily activities and living cycles. Mining of such information can be accomplished via usage loggers or non-Intrusive Load Monitoring –NILM algorithms. NILM samples data several hundred times per second, and it is mainly used for appliances’ loads tracking. Some NILM algorithms are so powerful that they can reveal information regarding appliances’ brands and whether or not they are defective. In principal, they are useful for load research but can also be harmful considering its ability to infer consumers’ living patterns from the monitored data. (Lisovich, Mulligan et al. 2010).

In the following sections, an overview is given regarding parties that are interested in exploiting consumers' private data and their incentives, the different levels of information that can be inferred from a smart meter, and the adverse effects of such violations on consumers' lives.

Intruders and Incentives

Exploitation of meter readings and other consumer private data, which is maintained by or exchanged through different smart metering system components, can be carried out by different parties due to various motivations that can be of a commercial, political, or even criminal nature (Quinn 2009). These intruding parties can either be governmental -such as police enforcement, or non-governmental such as commercial establishment or criminals (van den Hoven and Weckert 2008).

In general, intruders have ulterior motives for using power-consumption data for purposes other than load research and demand response (Lisovich, Mulligan et al. 2010). "History has shown that where financial or political incentives align, the techniques for mining behavioral data will evolve quickly to match the desires of those who would exploit that information" (McDaniel and McLaughlin 2009). Examples of intruders include:

Law enforcement

Law enforcements may observe consumers' electricity consumption to monitor home-based activities in real-time basis, due to suspected criminal activities such as producing drugs. Police may use public utility records to seek out drug producers. An example is Austin police department in the U.S, which has an agreement that lets it access Austin Energy power-usage records without a search warrant (Lisovich, Mulligan et al. 2010).

Utilities & 3rd party service companies

Utility companies that maintain -or may have access to- consumers' private data could use it for other reasons than those originally declared to the consumers (Lisovich and Wicker 2008). A number of third party companies launched services that offer a customized interface to consumers, which displays their electricity usage by receiving real-time usage statistics from the users' installed smart meters. Under the lack of proper consumers' privacy regulation, these companies can use this information for commercial purposes (McDaniel and McLaughlin 2009).

Criminals

Individuals with malicious intent could tap smart meter devices installed at consumers' homes to monitor their electricity consumption. This helps to establish the living-cycles and patterns of consumers' households, which facilitates for conducting theft if low consumption rates are observed for an extended period of time (Lisovich and Wicker 2008).

Profit organizations

Some commercial companies or other relevant profit organizations, can take advantage of data mined from NILM algorithms to improve their marketing strategies. Some NILM algorithms are strong enough to deduce information regarding what appliances are present within a household, its brand, and whether it's malfunctioning. Such information can aid in customizing marketing strategies targeting the consumer base (Lisovich, Mulligan et al. 2010).

Levels of Exposure

The information exposed by monitoring consumers' consumption rate can be of varying levels of detail. In the simplest sense, consumption patterns can be observed. Though some argue that this information is rather insignificant, yet its exposure can pose a serious issue as more detailed information can be inferred from it, such as the number of individuals within a household, frequency of using a microwave oven as opposed to cooking dinner, use of home appliances in general and detecting their brands, number of hours spent watching TV by household members, times for eating, showering, sleeping, and presence/ absence from home. All these examples are little pieces of information, which if revealed and put together can help establish a clear picture of consumers' life cycles, their activities or even their beliefs. (Lisovich and Wicker 2008, Quinn 2009).

But perhaps a more specific example of privacy breaches is one given by Quinn (Quinn 2009); where in 2007 the Tennessee Center for Policy Research stated that electricity consumption of Al Gore's home was significantly more than the national average. This was only one day after he received an Oscar for Best Documentary for his production "An Inconvenient Truth", in which the story of Al Gore's campaign to raise people's awareness about global warming is told. Furthermore, nearly a year later the center stated that despite the installation of energy-efficient renovations in Gore's house; his energy use had increased by 10% within that year. Needless to say, this drew negative comments to Gore's lack of dedication to his beliefs (Quinn 2009), furthermore, it raises concern about the possibility of violating the privacy of individuals' homes.

Consequences of Information Privacy Breaches

Privacy violation of consumers' information can have many different negative effects on consumers' lives. In the simplest sense; there is the risk of the loss of secrecy of personal habits, behaviors, preferences, living patterns or even religious beliefs of consumers' lives (McDaniel and McLaughlin 2009). In addition to that, further risks and privacy violations can occur by exploiting the detailed perception that can be formulated by combining these small pieces of information about a consumer's life. For example, consumers can live unknowingly under real-time surveillance (Quinn 2009). This can in turn pose serious threat to physical security of consumers, as intruders can establish the presence or lack of security system within a home, which may result in invasion of these premises. Other possible risks include manipulating energy cost, fabricating meter readings (McDaniel and McLaughlin 2009), and financial losses.

3.6.2 Insufficient Feedback

A smart meter in itself is a basic device that allows for an extremely limited interaction with a user. This is most evident in the basic digital display mounted on the meter that does not offer more than limited information. One of the main goals to be achieved by the smart metering system is energy efficiency and savings, a goal that can be achieved via demand response, where consumers have turned into active agents as opposed to being passive agent under the conventional metering system. Demand response can be achieved by providing consumers with a meaningful form of feedback regarding their energy consumption. However, the energy consumption feedback that can be obtained from the smart meter is considered to be quite basic, both in content and form.

One way for consumers to monitor their energy consumption by using a smart meter is by observing and recording their consumption rates via the basic display mounted on the meter. However there is no actual obligation to do so. In addition, the mounted display has a limited capability in terms of the amount of information that it can display. For example, a consumer can check the total number of units consumed, but she or he cannot refer to the display for information such as the time at which energy was used, the a mount of energy usage during a certain period, or the price of electricity at that time. Moreover, the display does not have the capability to present meter readings in a graphical form, such graphical representation can aid consumers to a great extent in utilizing their meter readings for energy saving. In general, the content and form of information displayed by the meter is more suited for consumers who possess technical awareness, and therefore the feedback obtained directly from the meter does not give consumers any incentive worth mentioning to adapt their energy consumption behavior (Ahmed and Yousaf 2011). Furthermore, most of the time the meter is installed in places that are low in visibility such as in cupboards or underneath a staircase for example, both of which are positions that are out of sight (Darby 2006). This makes the smart meter display alone insufficient for achieving an effective demand response, which can ensure energy efficiency and savings.

One possible way to provide consumers with effective forms of feedback about their energy consumption is by means of external meter displays, which can be connected to the smart meter via port P1. There exist many different types of the external meter display that vary in their capabilities and the functions they encompass. In general, almost all displays can show energy consumption in real time manner. In addition to that, second generation displays are capable of giving an overview of the history of energy usage, whereas third generation displays can offer information regarding current and past energy consumption in high accuracy (Darby 2010). The use of an external display can contribute to influencing consumers' energy consumption behavior to achieve energy efficiency and saving, however the fact that consumers have to pay for external display separately can make it an unappealing option for some consumers. In The Netherlands, consumers are obligated to pay 60 Euros – excluding value added tax- to obtain a smart meter. This cost is further increased if a consumer decides to obtain an external display. The cost of the display differs from one type of display to another.

Another form of an effective feedback is via web applications, which is considered to be somewhat a more appealing option as it is relatively inexpensive compared to other means of feedback such as the external display. Consumers can use web applications to either access their meter readings or to configure the application to send feedback to various devices such as personal computers and mobile phones. An advantage of using web applications as a form of feedback is that it can give consumers a fine level of detail regarding their energy consumption readings, such as by comparing the usage of one consumer to that other consumers (Darby 2010).

In order for the system to help achieve goals of demand response and energy efficiency and savings, consumers must be given access to and provided with effective feedback regarding their electricity consumption. Feedback must be provided via attractive and affordable interfaces that are available in different forms such as real time and online portal access for a detailed analysis of their electricity consumption.

3.6.3 Potential Adverse Health Effects

A property that distinguishes a smart meter from a conventional mechanical one is that fact that it is a digital device, which logs meter readings and communicates it to energy companies electronically. This property allows for more efficiency in the metering infrastructure performance, but it also raises some concerns for consumers that are inherent to the electronic nature of the meter. From a technical perspective, a smart meter has the capability to transmit meter readings to energy companies either via a wired communication medium -i.e. Power Line Communication- PLC, or a wireless medium such as General Packet Radio Service-GPRS. The latter form of communication method promoted a sense of concern among a group of consumers regarding the adverse impact on health caused by the electromagnetic waves emitted by the meter.

Though many consumers adopt willingly technologies that emit electromagnetic waves, such as cellphones and Wi-Fi communication, yet some still object to wireless smart meter. One reason is the fear of potential damage to consumers' health caused by the prolonged exposure to the radiofrequency emitted by the meter around the hour. Furthermore though a smart meter can emit fewer waves than a cellphone or Wi-Fi, yet unlike these two technologies a smart meter emits these waives at an irregular pattern that has sharp spikes of radio frequency. In addition to that, some consumers groups are opposing the presence of a wired smart meter in their homes. The reason for their concern is the same for the wireless meters but in relation to the circuit boards and internal digital components of the meter that allows it to carry out its functions. Activists' blogs campaigning against the adverse health effects of smart meters listed a number of symptoms that have been reported by consumers in different countries such as the United States and Australia. For example, some consumers have supposedly developed an auditory sensation and tinnitus, blurred vision, dizziness, headaches or even migraines, fainting spells, chest pain, or heart palpitations. Further illnesses that have been reported by consumers due to exposure to smart meters include: sleep disturbance or insomnia, anxiety attacks, inability to concentrate, memory loss, nausea, fatigue, negative impact on the immune system, nosebleeds and infertility. Some physicians voiced warnings against the adoption of smart meters at home, due to the increased risk of cancer, and damage to the nervous system among other vital organ systems of the human body (Carpenter 2011, EMF Safety Network 2012, Stop Smart Meters 2012).

This increased awareness have resulted in numerous activists-led campaigns that demand that consumers be given the right to retain their mechanical meters, or the right to choose for a wired smart meter instead of a wireless one.

3.6.4 Loss of Control

The new smart metering infrastructure offers energy companies the possibility to remotely control consumers' electricity connections. This feature is intended to facilitate for the disconnection of consumers' energy supply when consumers do not pay their energy bills. Another application of the remote control feature is peak demand management, where energy companies can alternately switch off certain appliances within households to reduce energy demand in peak hours (Simalis 2011).

This ability to ration and regulate households' consumption of energy has its gains for both utilities and consumers. On one hand it helps energy companies in reducing the operational costs in addition to the ability to achieve peak shaving. On the other hand, it can help consumers in achieving financial savings by controlling the amount of the electricity consumed. However, this ability to remotely control or even disconnect households' energy supply is causing the sense of loss of control among a group of consumers, which could alienate them and discourages them from adopting a smart meter (Darby 2010).

3.7 Conclusion

In this chapter, the smart metering system was presented as a case study of an ICT-intensive, infrastructure system. The system was described in terms of its main social and technical components, the motivation behind its launch, and its deployment timeline. The H-model presented in chapter 2 was tallied against the smart metering system, to explore how the acceptance determinants included in the H-model relate to the smart metering system, and to identify further limitations or possible enabling factors that could impact consumers' acceptance of such technology.

A number of limitations were identified in the smart metering system that could lead to social rejection of the system and impede its deployment, such as information security and privacy risks, insufficient feedback over energy consumption, potential adverse health effects, and loss of control over the household's electricity connection. The elicited factors are to be mapped into technology acceptance determinants that are to be used to extend the H-model, to investigate their influence on social acceptance of smart meters in The Netherlands. This process is described in further detail in chapter 5.

Chapter 4 : Case Study 2- OV-Chipkaart System

4.1 Introduction

The OV-Chipkaart System is a new method for travelers to pay for public transport services in The Netherlands, with a total implementation cost of two billion Euros (Rieback 2008). The different types of cards employed by the system and used by travelers are referred to as the OV-Chipkaart, which are smart cards that are the size of a bank card, and are intended to replace all other forms of public transport paper-tickets, for all forms of public transport such as trains, trams, buses, and metros. The main idea behind the introduction of this card is to allow travelers to pay for their trips within The Netherlands by deducting an amount of money based on the distance travelled from a pre-loaded credit in Euros on the card (OV-Chipkaart 2010).

The OV-Chipkaart system is a good example of an ICT-intensive infrastructure system. The system's reliance on an ICT backbone infrastructure allowed for the introduction of an electronic-based travel-fare collection system, which brings gains to public transport operators and possibility to travelers. As beneficial as it may be, this reliance on ICT does not come without a cost. The new digital technical components of the infrastructure have caused the emergence of new inherent properties of the system that could have contributed to a negative perception of the system by public transport commuters. For example, instead of buying paper-tickets, under the OV-Chipkaart system travelers have to purchase, charge and swipe in and out, a plastic card before embarking or disembarking public transport vehicles. This process entails more complexity when compared to the obsolete paper-based system, which was further worsened by some technical flaws that the system suffered from early stages of the system deployment. Furthermore, the system allows for collecting travel information such as identity of the traveler in the case of some types of the OV-Chipkaart, time of travel, starting point and destination. The collection and retention of such information has led to travelers’ apprehension regarding the usage of this information and the violation of their privacy.

In this chapter, the OV-Chipkaart system is presented as an exploratory case study of an ICT-intensive infrastructure system. The system was thoroughly investigated as a technology that has already been deployed on a grand scale, hence the consequences of its limitations on travelers’ willingness to adopt it can be observed. Furthermore, the OV-Chipkaart system differs than the smart metering system -another case study of this work- in the sense the system requires more interaction with individuals than a smart meter; such that an energy consumer can choose not to utilize a smart meter, but a traveler cannot opt for using other method of payment for some public transport carriers.

The remainder of this chapter is organized as follows: section 4.2 presents the incentives behind the launch of the OV-Chipkaart system. Section 4.3 outlines the deployment timeframe of the system. The architecture of the OV-Chipkaart system is presented in section

4.4. In section 4.5 the H-model presented in chapter 2 is tallied against the OV-Chipkaart system, to investigate how the acceptance determinants of the H-Model relate to the OV-Chipkaart system. In section 4.6 further limitations of the OV-Chipkaart that were not accounted for by the H-model are identified. Finally, conclusions are discussed in section 4.7.

4.2 Incentives and Motivation

There are diverse motivations behind the launch of the OV-Chipkaart system in The Netherlands. From a financial perspective: the deployment and operation of the system offer public transport companies the chance for a fair division of revenues and subsidies, and reducing costs associated with printing paper tickets and tickets-inspection conductors. The system also helps preventing fraud, and improves public safety and system security by enforcing restricted access via electronic gates. Furthermore, in addition to the intention to offer travelers a simple and convenient manner of travel, public transport companies are able to deduce travel patterns by analyzing the detailed travel logs maintained by the system, to anticipate potential improvements in the services offered by the system and target travelers with customized marketing strategies based on their travel behavior and patterns (Jacobs 2010).

4.3 System Roll-Outs and Pilot Deployments

The deployment of the OV-Chipkaart system has witnessed some delays that resulted in the announcement of different system roll-out time frames. Originally, the deployment of the OV-Chipkaart system was intended to be completed by the end of 2007. As this deadline was not met, another time frame was announced that aimed to have a complete roll-out by the summer of 2009. Again, this deadline was not met, which resulted in the deployment to continue throughout the year 2010. A timeline of the OV-Chipkaart system deployment for trams, metros and buses is listed below (Nu.nl 2008, Dutch News 2009, compleetste 2010, Connexxion Holding 2010, RET 2010).

1. In April 2005, the OV-Chipkaart system was first introduced in Rotterdam metro transport network.
2. In 2006, the OV-Chipkaart system was deployed in all Amsterdam metro lines and rapid-tram lines.
3. In June 2007, trams and buses in Rotterdam accepted the OV-Chipkaart.
4. In November 2008, all trams and buses in Amsterdam accepted the OV-Chipkaart.
5. On the 29th of January 2009, the strippenkaart was longer acceptable as method of payment for metros in Rotterdam, which made it mandatory for travelers to use the OV-Chipkaart as the sole method of payment. This made the Rotterdam metro the first public transport network in The Netherlands that ceased the strippenkaart
6. In 2009 the deployment of the system continued throughout the following regions:
    - Zaanstreek on the 25th of April
    - Haaglanden and the Province of South Holland on the 14th of May
    - The Province of North Holland On the 16th of June

- City region of Arnhem Nijmengen on the 1st of July
- Province of Utrecht and city service Utrecht on the 1st of August
- Almere on the 24th of August
- On the 27th of August, the Amsterdam metro network mandated the use of OV-Chipkaart as method of payment and ceased the use of the strippenkaart
- North and South Friesland on the 15th of September
- Flevoland, Gelderland and Overijssel on the 1st of November
- City region of Endhoven on the 1st of December
- Express tram lines in Utrecht on the 15th of December

7. On the 11th of February 2010, the urban Rotterdam area ceased the usage of the strippenkaart and mandated the use of the OV-Chipkaart
8. On the 3rd of June 2010, the Urban Amsterdam area mandated the use of the OV-Chipkaart system
9. By the 23rd of August 2010, the use of the OV-Chipkaart system was possible everywhere in The Netherlands except in Groningen Province, and parts of the Drenthe Province. In addition, the use of the OV-Chipkaart by then was still not in effect for the following regional public transport operators: Arriva, Syntus, Veolia and Connexxion.

As for the Dutch Railway (NS) the use of the OV-Chipkaart has been in effect since October 2009 for a discounted fare.

From the above timeline it is evident that after several postponements and despite the acknowledged problems related to the OV-Chipkaart system, its deployment finally took place gradually within some parts of The Netherlands. However, after a period of denial on the stakeholders part with regards to the existence and severity of the technical and security and privacy-related problems associated with the system, it was decided that the system needs to be revised and a replacement to the current OV-Chipkaart will be developed (Jacobs 2010). The task of developing the new and improved card was commissioned to the Digital Security Group of the Radboud University of Nijmegen, The Netherlands. The focal point of improvement will be addressing security and privacy issues stemming from the usage of the current card. The aim is to incorporate security measures within the card as built-in solutions rather than retrofitting security in the form of patches (Ovchip 2008).

4.4 OV-Chipkaart System Architecture

4.4.1 Social System Components

Trans Link Systems

Trans Link Systems- TLS is a private company that is responsible for the implementation of the OV-Chipkaart system. The company was established in 2002 as a partnership formed by five major Dutch public transport companies. In addition to this partnership TLS also cooperates with all other Dutch public transport service providers (Trans Link Systems 2010).

The five transport companies are listed in Table 4.1. These companies' services collectively covers 80-90% of public transport market in The Netherlands (Trans Link Systems 2003, Ovchip 2008).

Table 4.1: Public transport companies forming TLS

Company	Description	Share owned in TLS
NS Groep N.V.	Nederlandse Spoorwegen is the Dutch national railway company that is owned 100% by the federal government	55%
Connexxion Holding N.V	is a regional bus service company that is owned 100% by the federal government	20%
GVB	Gemeente Vervoer Bedrijf is a public transport company owned by the municipality of Amsterdam, it offers its services to travelers via busses, trams and metros in Amsterdam	10%
RET N.V	Rotterdamse Elektrische Tram of the municipality of Rotterdam, and commercial actions B.V. in The Hague	10%
HTM	Haagsche Tramweg-Maatschappij is a public transportation company that is 100% owed by the municipality of The Hague, it offers its services to travelers via buses and trams	5%

East-West Consortium

East-West consortium is an international group that won a tender by TLS for the implementation of an automated fare collection system, i.e. the OV-Chipkaart infrastructure, which employed the Mifare Ultralight and Mifare classic chips that are produced by NXP. The East-West Consortium is a body that consists of the three participating companies shown in Table 4.2 (Ovchip 2008, Siekerman and van der Schee 2008).

Table 4.2: The East-West Consortium participating companies

Company	Description
Thales	A company that is specialized in building information technology systems in the area of aerospace, defense and security.
Vialis	A subsidiary of VokerWessels. It is a construction company that operates in the area of public transport.
Accenture	A management consultancy company.

NXP Semiconductors

NXP is a global semiconductor company that operates in more than 25 countries. The company was founded by Philips and has its headquarters in Eindhoven, The Netherlands. NXP offers a range of innovations that are used in applications such as identification and wireless infrastructures. An example of the many innovations produced by NXP is RFID chips, two variations of which are used for the OV-Chipkaart system, these are the Mifare Ultralight and Mifare Classic. The company also produces other types of RFID chips such as the SmartMX, which is a smart card used in Dutch passports (Ovchip 2008, NXP 2012).

Ministry of Infrastructure and Environment

The Ministry of Infrastructure and Environment assumes a supervisory role of the OV-Chipkaart system. An agreement was made between The Ministry, the twelve provinces within The Netherlands, and the seven act regions regarding the deployment of the OV-Chipkaart system in their respective areas. A role that the Ministry plays is the regulation of the OV-Chipkaart systems is ensuring a smooth transition from the multi-trips paper-based ticket system to the usage of an OV-Chipkaart instead. Furthermore, the ministry states that its mission with regards to the OV-Chipkaart system is to ensure a quick, comfortable and safe commute for travelers in return for a reasonable price (Rijksoverheid 2012).

Travelers

The role travelers play as social actors of the OV-Chipkaart system is different than the role assume for example by energy consumers in the context of the smart metering system. The OV-Chipkaart system has been already deployed in The Netherlands, which gives travelers commuting by public transport (except trains) no choice but to use it. This is the contrary to the smart metering system, where consumers' right to reject a smart meter and refrain from using it is protected by the legislation. Though travelers do not participate directly in the decision making process with the other stakeholders, yet they are involved indirectly via the consultative consumers group (Rijksoverheid 2012).

4.4.2 Technical System Components

The OV-Chipkaart system consists of a number of physical front-end or back-end components that are interconnected via an ICT infrastructure. The system’s architecture is depicted in Figure 4.1 (Trans Link Systems 2003).

Level 0: OV-Chipkaart

The OV-Chipkaart is a card equipped with Radio Frequency Identification -RFID chip. The card serves as an identifier or a pass that allows travelers to commute using means of public transportation.

There are three main types of an OV-Chipkaart that are explained below in further details. Each card meets the needs of certain travel patterns and therefore there is a slight difference in the type of traveler-related information maintained by these cards.

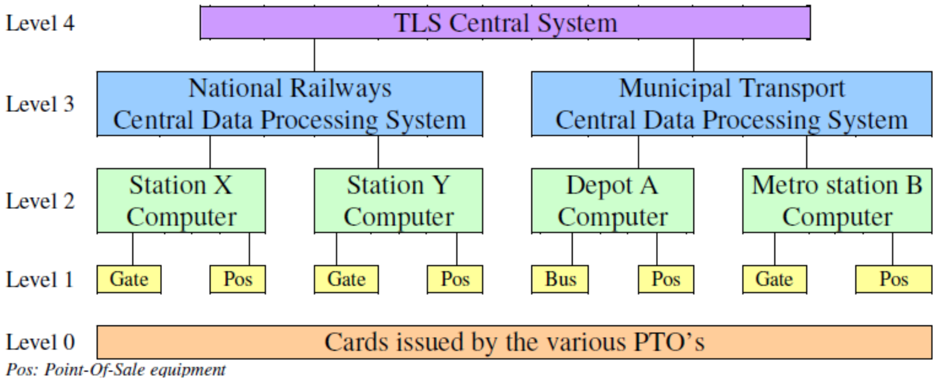

Figure 4.1: OV-Chipkaart system architecture (Trans Link Systems 2003)

Disposable Cards

The disposable OV-Chipkaart is made of paper and can be purchased from vending machines at train stations or on trams and buses. The card cannot be recharged after usage as it does not contain electronic money, and therefore it is disposed of. This card meets the needs of people whom rarely travel or for tourists.

Personal Cards

The personal OV-Chipkaart is a bank card-size plastic card that is used by travelers whom are eligible for any form of discount on their travel fare, such as travelers in possession of discount cards, students, senior citizens and children between 4 and 11. This form of cards supports electronic money and therefore it can be recharged manually or set to be automatically recharged when the balance is below 5 Euros.

Unlike the disposable and anonymous cards, the personal card displays the picture of the card holder and therefore its used is restricted to that traveler only. However, the personal card has a number of advantages over the other two types of cards in the sense that it is the only type of OV-Chipkaart that enables travelers to hold monthly or annual tickets, and if the card is reported lost or stolen it can be blocked.

Anonymous Cards

The anonymous OV-Chipkaart is a bank card-size plastic reusable card, which supports electronic money. As the card is anonymous and not bound to a certain traveler, it cannot serve as a discount card, nor as monthly or annual tickets, and it can only be manually recharged and not automatically. On the other hand, this makes it possible for the card to be used by multiple travelers, one person at a time.

Based on the variations in use between the three types of OV-Chipkaart, the information stored on these cards differs. In general, all cards contain a Unique Identifier –UID, and a log of the last 10 transactions bound to the card. The UID is a 32-bit identification number that is recognized by card readers at the anti-collision phase at the beginning of the communication process between a card and a reader in order to distinguish different cards (Jacobs 2010). In addition, the personal OV-Chipkaart has the name and photo of the card holder printed on the front of the card, and stores the card holder's birthday on the card.

Level 1: Front-end Components

Front-end system components are devices that travelers interact with to perform different tasks required to complete or ensure proper payment for their travel. These devices include:

- **Sales equipment:** such as on-board and hand-held paper ticket printers, vending machines or ticket office terminals. Information readers.
- **Information readers:** these devices are used by travelers to read information on their cards, such as the last ten transactions and the remaining balance.
- **Charging terminals:** these terminals are used by travelers to recharge anonymous cards or personal cards that are not set to recharge automatically.
- **Validators:** this includes gates and free standing card validators against which travelers swipe their cards for checking in and out of public transport vehicles, in addition to hand-held inspection readers used by conductors (Trans Link Systems 2003).

Level 2: On-Site System Components

This level consists of central systems located in stations and terminals. These systems are mainly responsible for managing front-end components, and storing transaction data generated and transferred these components for at least a week (Trans Link Systems 2003).

Level 3: Public Transport Operators Central System

Each public transport operator maintains a central system that communicates with TLS central system by sending registration and transaction data, and receiving processed information. The main functionality performed by these systems is cash handling from sales transactions, data collection and storage for at least a month, data processing and reporting (Trans Link Systems 2003).

Level 4: TLS Central System

The central systems managed by TLS interact only with public transport operators' systems and other systems managed by financial institutions that take part of the overall operation of the OV-Chipkaart system. The system at TLS level is responsible for carrying out several functions, such as card management, blacklisting, and auto-reload management to name a few (Trans Link Systems 2003).

Technology Employed

The technology employed by the OV-Chipkaart for card identification is the RFID- Radio Frequency Identification. Each card contains a small integrated circuit with an RFID tag, which exchanges data with card reading equipment via electromagnetic fields at standard radio frequencies (Mitrokotsa, Rieback et al. 2008). The RFID chips used for the OV-Chipkaart are the MIFARE Classic 4k for the personal and anonymous cards and MIFARE Ultralight for disposable cards. Both of which are manufactured and owned by NXP Semiconductors, a former division of Philips (Semiconductors 2010).

4.5 The OV-Chipkaart System in Light of the H-Model

The acceptance determinants encompassed in the H-Model that was presented in Chapter 2 are revisited in the context of the OV-Chipkaart system. The aim is to investigate how these concepts relate to the system, and to which extent would they be suitable as factors that could impact the society's adoption of this technology.

Performance Expectancy

Performance Expectancy is "defined as the degree to which an individual believes that using the system will help him or her to attain gains in job performance" (Venkatesh, Morris et al. 2003). An adapted definition of Performance Expectancy in the context of the OV-Chipkaart system is: the degree to which a traveler believes that using the OV-Chipkaart system will help him or her to fulfill payment for boarding public transport vehicles in order to commute across The Netherlands by means of public transport networks. In principle, travelers mainly expect the OV-Chipkaart to enable them to board public transport vehicles with an efficient manner and without ado. However, an in-depth study of the system exposed weaknesses in the system that hinder a smooth travel experience. These weaknesses are a result of different factors such as technical flaws, which can cause service disruptions and consequently impose travel delays and inconveniences for public transport commuters. A few examples of technical flaws of the system are listed below:

- Hardware and software failures: the hardware and software components of the OV-Chipkaart system showed poor performance and failed quite often. These frequent system down-times naturally result in service disruption (Iwuagwu 2009).

- Travel fares and clock synchronization: in so many cases hardware and software malfunctions led to travelers being charged the wrong fare for their trips. Furthermore, clock synchronization errors of electronic gates lead to problems with boarding charges. Travelers were charged for switching between travel mode, which contradicts with a rule stating that transferring between vehicles within a time period of 35 minutes should be free of a second boarding (Iwuagwu 2009, OV-Chipkaart 2010).

- Automatic credit reload: holders of the personal OV-Chipkaart are offered the option of automatically recharging their cards with credit once the balance on the card drops below a certain amount. Despite the convenience this feature is intended to offer what happens in reality is quite different, there are a number of incidents where travelers reported that despite activating the option and receiving confirmation the feature was not operational until after activating it one or sometimes two more times (van Kuijk 2010).

Effort Expectancy

Effort Expectancy is defined as "the degree of ease associated with the use of the system" (Venkatesh, Morris et al. 2003). In the context of the OV-Chipkaart system this definition would translate into the ease with which travelers can learn how to use this new method of payment for public transport. In addition, it refers to the level of easiness with which travelers can carry out the different steps required for their travel, such as acquiring an OV card, charging it, and checking in and out of public transport vehicles. An in depth analysis of the OV-Chipkaart system revealed a set of limitations that all have a common denominator, that is a decreased level of ease of system usage. These limitations are listed below:

- The OV-Chipkaart is a single system that serves several public transport companies with independent systems. Technically speaking this should not be a problem, except that the system is designed in a way that makes travelers aware of this separation and forces them to accommodate for this separation in their travel behavior. For example, a traveler cannot check in once to take a bus then a train or a metro, instead he must check in and out of every vehicle. This becomes extremely inconvenient and time consuming in stations like Bijlmer, where travelers check out of trains and metros when they exit the station hall, but due to the separate systems travelers are directed to leave the station hall via one exit or another based on which system (train or metro) they are checking out from. This naturally causes confusion and inconvenience as a traveler must exit the station hall to check out of the system before being able to switch to another vehicle (van Kuijk 2010).

- Checking in or out on trams and buses, and in some train stations is done using the same device. This proves to be problematic when a traveler forgets to check out, when he or she attempts to check in later for another trip the system will check him out of the previous trip, this results in delays as the traveler must wait for a certain period of time before being able to check in again to start another trip (van Kuijk 2010)

- Managing the personal and anonymous OV-Chipkaart is neither a user-friendly nor a straight forward process, and it can be a somewhat complicated. This is true whether it is for activating the card –which is referred to as buying a product- or recharging it with credit (van Kuijk 2010).

- The official website of the OV-Chipkaart explicitly states that “these cards allow the holder to travel immediately” (OV-chipkaart 2010), this however contradicts with reality. Before holders of personal and anonymous OV-Chipkaart are allowed to board public transport vehicles they must have sufficient balance in the e-purse on their cards. This imposes the need to check/ recharge balance and then check in before starting their journey. In comparison to paper tickets this requires more time and hassle especially that balance checking/ reloading terminals are not wide spread within all stations.

- Travelers do not know at all times the exact balance on the e-purse on their OV-Chipkaart. To do so they can either use the internet (for personal cards only) or a credit recharge terminal. The problem with the former is that the information available via the internet is 48 hours old, and the latter is not outspread available everywhere.

- Some travelers reported that using the obsolete strippenkaart payment system was easier than the OV-Chipkaart (Grootenboers 2010) .

Social Influence

Social influence is defined as the “degree to which an individual perceives that important others believe he or she should use the new system” (Venkatesh, Morris et al. 2003). The social influence on travelers' willingness to commute by public transport using an OV-Chipkaart is analogous to that within the context of other technologies. Travelers report their experiences -whether negative or positive- to individuals in their social circles, such as: friends, family members, neighbors, or colleagues. Previous studies have reported that the Social Influence is an important factor that leads to the travelers' resistance to adopt the OV-Chipkaart system, such that when travelers cast a negative opinion of the system, this opinion will be adopted by fellow travelers and most likely by passed on to other travelers (Grootenboers 2010).

Trialability

Trialability is “the degree to which an innovation may be experimented with on a limited basis” (Rogers 1995). The concept of Trialability is well suited as a factor that could explain travelers’ acceptance of the OV-Chipkaart system considering the gradual rollout of the system. The OV-Chipkaart system was introduced gradually across the different regions of The Netherlands. Furthermore, the roll out took place for some means of public transport before others instead of introducing its use within all means of transport at once. In addition to that, the introduction of the OV-Chipkaart for certain means of public transport such as trains or busses did not mandate its use for travelers but made it an available option for those who wish to try it out. All of the above mentioned facets of the gradual deployment of the system contributed to an effective experimental environment for travelers to get a feel for the system, how it works and how it affects their commute.

Observability

Observability is defined in the original IDT theory as "the degree to which the results of an innovation are visible to others" (Rogers 1995). The concept of Observability with relation to the OV-Chipkaart system entails travelers' ability to observe the result of using their OV cards, i.e. paying their travel fair. Under the conventional ticket-based system, travels were always had a visible proof of their payment, whether it was a train ticket, or a strippenkaart, i.e. a form of a paper-ticket. However, this is not the case under the OV-Chipkaart system. One limitation is the fact that a traveler cannot tell if he/she is checked in as opposed to the obsolete paper ticket-based system. This can cause inconvenience if a traveler cannot remember if he or she has checked in or out. Furthermore, a traveler commuting by a tram, bus or metro using the past strippenkaart system was able to see their balance at all times. This option is no longer available when using an OV-Chipkaart as travelers can check their balance wither when checking in or out of the system, or at a user terminal of the system that are not widely available (Grootenboers 2010).

Compatibility

Compatibility is "the degree to which an innovation is perceived as consistent with the existing values, past experiences and needs of potential adopters" (Rogers 1995). The Compatibility of the manner in which the OV-Chipkaart system operates with travelers' experience with the previous system is a significant factor in predicting individuals' acceptance of this technology. This is true considering that the OV-Chipkaart system is an example of a technology with which individuals' have a more active interaction than a technology like the smart meter, where interaction is quite limited. An analysis of the OV-Chipkaart system revealed a number of functions that travelers need to carry out differently under the OV-Chipkaart system. The change is mostly negative, such that not only are thing done differently, but it is mostly in a more complicated manner, or with increased complexity. A number of examples are listed below:

- The use of an OV-Chipkaart for trains is bound to a certain class, therefore one cannot switch between classes from one trip to another, a freedom that was allowed under the conventional paper-based ticket system (van Kuijk 2010).

- Boarding rate: before travelers can embark on their journeys they must ensure that the e-purse on their OV-Chipkaart contains at least the boarding rate regardless of their destination. Boarding rate varies depending on the type of the card and the mean of public transport, for example it is 4 Euros for buses, trams and metros, 20 Euros for trains when using personal or anonymous OV-Chipkaart and 10 Euros when using personal card with discount, more details on boarding rates can be found in (SP Verkeer en Waterstaat 2010).

- The obsolete strippenkaart system allowed more than one traveler to use the same card; this is no longer possible with an OV-Chipkaart. (Grootenboers 2010).

- In the case of personal OV-Chipkaart with discount, the card holder must purchase separate paper tickets for other accompanying travelers (van Kuijk 2010).

4.6 OV-Chipkaart System Limitation

The operation of the current OV-Chipkaart system proved the system to be suffering from a number of shortcomings of varying nature. The shortcomings result mostly from poor design and implementation of the system. These weaknesses are described in detail in subsequent sections.

4.6.1 Financial Costs

After the deployment of the OV-Chipkaart system travelers started experiencing a change in travel fares, either an increase or a decrease. The change in fares is mainly due to the fact that under the OV-Chipkaart system travelers are charged per the number of kilometers traveled instead of the number of zones as was the case in the previous payment system. In addition, the OV-Chipkaart system introduced a number of changes that contributed to further financial burdens that are shouldered by travelers, such as:

- Card costs: in addition to paying the trip fare, travelers are required to pay a one-time extra amount of 7,50 Euros for purchasing the personal and anonymous OV-Chipkaart. A cost which was not required under the previous methods of payment.

- Increased travel fare: public transport operators ensured at the early stages of the project that public transport fare will not increase after the deployment of the OV-Chipkaart system. However, this proved not to be the case. An average increase of 5 to 10% in fares was noticed in a number of cities (van Kuijk 2010), and in the province of South Holland in particular an increase of 28.7% was cited (SP Verkeer en Waterstaat 2010).

- Fines: the way in which the system currently works makes travelers more prone to receiving fines for improper travel behavior, i.e. forgetting to check in or out of vehicles. A main reason for this is the lack of electronic gates ensuring passengers' checking in or out of vehicles. In the case of forgetting to check out, the fine is 20 Euros for travelers taking a train, and 4 euros for those taking a bus (van Kuijk 2010). It has been reported that a significant amount of money in the magnitude of thousands of Euros is being received by public transport operators due to travelers forgetting to check out towards the end of their trip (Dutch News 2010).

- The price of a single ticket is very expensive if a traveler is not in possession of an anonymous or personal OV-Chipkaart (Grootenboers 2010).

4.6.2 Information Security and Privacy

The information security measures applied to some types of the OV-Chipkaart were of a questionable effectiveness. In the case of the disposable OV-Chipkaart no security measures were applied, whereas the anonymous and personal cards were equipped with the Crypto 1 security protocol, which has been broken multiple times as part of scientific research experiments (Rieback 2008).
The Mifare Classic chip that was chosen for the OV-Chipkaart is the most widely used RFID chip around the world, of which 200 million copies are still used around the world. The chip is mostly used for access control of buildings, and for public transport in about 150 cities around the world. Some of the reasons behind choosing the Mifare card is that is it cheap and was “field-proven” technology. A security measure applied to the chip is a 48-bit long-key state cipher, which proved quickly to be vulnerable. In early 2008 experimental trials proved the card to be susceptible to intrusion (Nohl and Plötz 2007; Nohl et al. 2008; de Koning Gans et al. 2008; Garcia et al. 2008) cited in (Jacobs 2010), and that its contents -such as the balance- can be access and altered by unauthorized parties, thus the card does not properly protect its contents and consequently jeopardize both the security and the privacy of travelers' information (Jacobs 2010).

This technical security-related vulnerability can lead to a number of security and privacy breaches, which can potentially hinder travelers' willingness to adopt the OV-Chipkaart system. A number of potential security and privacy breaches are listed below:

- Tracking and tracing: each OV-Chipkaart has a unique identification number- UID. This number makes it possible to track people and trace their traveling patterns.

- Free travel: the hacking attempts so far targeting the OV-Chipkaart system managed to achieve free travel.

- Data access: the information retained on the OV-Chipkaart is limited to the UID, date of birth (in case of a personal card), and the last 10 transactions committed on the card. However, it is still unclear how much information about travelers is being maintained by the back office system, and why it needs to be kept for seven years. The official OV-Chipkaart website explicitly states that “All participating public transport companies and card issuer TLS will limit the processing of personal data to a minimum. They will not process more personal data than required to attain the objectives for which the data is processed ” (OV-Chipkaart 2009). This however, does not specifically state that the system prevents personnel of public transport organizations from accessing more information than they should.

- Deduced information: analyzing the travel logs accumulated by the back office system allows to build a second tier of information and deduce individual travel patterns (Jacobs 2010).

- Detailed databases can be exploited by the police. This scenario has already occurred in London with the Oyster card (Jacobs 2010).

- The illusion of anonymity: the anonymous OV-Chipkaart seizes to be anonymous the moment the card holder recharges it using their bank cards, either via the internet or the designated terminals (Jacobs 2010).

4.7 Conclusions

In this chapter, the OV-Chipkaart system was presented as an example of an ICT- intensive system. From the two case studies presented in this work, the OV-Chipkaart system was carried out as an exploratory case study of a system that has gone through a large-scale deployment. The system's architecture was presented in terms of its technical and social components, along with the incentives behind the deployment of the system and the timeline of its rollout.

The hybrid technology acceptance model, i.e. H-Model, which was presented in Chapter 2, was tallied against the OV-Chipkaart system. The aim of revisiting the H-Model in light of the OV-Chipkaart system is to investigate how the OV-Chipkaart system performs in light of the acceptance determinants encompassed in the H-Model. An analysis of the system revealed that the system suffered from a number of technical or design-related flaws that negatively impacted almost all the acceptance determinants in the H-Model except for Trialability. Such weaknesses of the system -that could be related for example to the hardware or software of the system, clock synchronization, automatic credit reload, or the e-purse mounted on the card- had a negative influence on the Performance Expectancy, Effort Expectancy, Observability, and Compatibility, by reducing these acceptance determinants to low levels. These low levels, or in other words the lack of fulfillment of these acceptance determinants is hypothesized to have an influence on consumers' acceptance of smart meters.

Furthermore, by applying the H-Model in the context of the OV-Chipkaart additional factors were identified such as: financial costs and security and privacy breaches, which were not accounted for by the H-Model, and are hypothesized to have a negative influence on travelers' willingness to commute by utilizing the system. These factors along with others that are identified in Chapter 3 from the context of the smart metering system will be addressed again in Chapter 5. The factors will be mapped into technology acceptance determinants that will be used to extend the H-Model, to help reach a more comprehensive view of acceptance determinants that can potentially have an influence in shaping individuals opinion and behavior towards ICT-intensive infrastructure systems.

Chapter 5 : A comprehensive Technology Acceptance Perspective: The I^3S^2 Model

5.1 Introduction

“If the aim is to make the customer central to a smart metering rollout…
a determined effort has to be made to identify affordances for customer engagement – physical and relational characteristics of a system – and include them in the specifications”
(Darby 2010).

In Chapter 2 of this thesis two well-known technology acceptance theories, i.e. UTAUT and IDT, were used as a theoretical foundation for a generic technology acceptance model, namely the H-Model that is illustrated in Figure 2.12. The semantic of the H-Model was later discussed in Chapters 3 and 4 in light of the OV-Chipkaart system in the transportation sector, and the smart metering system in the energy sector respectively. The OV-Chipkaart is an example of an ICT-based infrastructure system that is well under operation, and its use is even mandated for certain means of public transportation such as: buses, trams and metros. Furthermore, the system is somewhat at a more advanced stage of deployment than the smart metering system in the energy sector, which is still being deployed at a limited-scale. This made the OV-Chipkaart system an ideal choice for an exploratory case study to gain an insight into the pitfalls of the system, which have become hinderers of OV-Chipkaart adoption by travelers from an after-the-fact perspective. On the other hand, the smart metering system was chosen as an evaluative case study in order to explore consumers’ acceptance of ICT-based infrastructure systems from a before-the-fact perspective. The system was subjected to an in-depth analysis to elicit factors that may have a negative influence on consumers’ acceptance of smart meters. Furthermore, the smart metering system was chosen as an application field for the ICT-Intensive Infrastructure Service Systems model (I^3S^2), which is presented in section 5.4 of this chapter.

In order to formulate the I^3S^2 Model, the H-Model was tallied against both the OV-Chipkaart and smart metering systems to shed light on how the acceptance determinants of the H-Model relate to the context of both systems. Next, an in-depth analysis of both systems was conducted to investigate their shortcomings. The process resulted with a number of limitations in a varying degree of austerity that is assumed to most likely have an impact on consumers’ acceptance and willingness to adopt these technologies. Many of these limitations were not accounted for by the H-Model, yet it is of great importance to establish their impact on consumers’ acceptance. The set of identified limitations of both the OV-Chipkaart and smart metering systems were translated into acceptance determinants. These determinants were used to extend the H-Model into the I^3S^2 model, in order to achieve a comprehensive view of the social acceptance of ICT-intensive infrastructure systems,

The significance of conducting these case studies commences from the need to gain a deep understanding of these ICT-intensive systems and what might have gone “wrong” within to cause a negative public perception. As a result, a knowledge base of both systems was formed by looking into the history of each system, its evolution, how it operates, its legislation, its interaction with social agents in its surrounding context, and how these agents perceive these ICT-intensive systems.

In this chapter the I^3S^2 Model is applied in the context of the smart metering system in The Netherlands as an ICT-intensive infrastructure system. Such application of the model will aid in discovering whether determinants derived from original theories are suited to explain technology acceptance in the context of infrastructure-related systems by “consumers”, rather than the original contexts for these theories, in which the theories were applied to investigate “users” acceptance of newly introduced IT technologies (UTAUT) within organizations. Furthermore, application of the I^3S^2 Model in the context of smart metering system will facilitate for the investigation of the public opinion and behavior regarding the case study-based acceptance determinants, and explore the impact of such determinants on their willingness to adopt such a new technology.

The goal of applying the I^3S^2 Model is not only to establish the level of significance of all the acceptance determinants encompassing the I^3S^2 model, but further subsequently translate these determinants that represent important public values into social requirements that should be addressed at early stages of a system’s life cycle –i.e. at the requirements gathering stage- of new systems. Whereas in the case of existing systems, the findings of the model will aid in deciding which factors must the system owners or governors invest in by devising solutions to overcome their adverse impact on acceptance.

The remainder of the chapter is organized as follows: section 5.2 revisits the H-Model. Section 5.3 presents the smart metering acceptance determinants that are included in the I^3S^2 model. Whereas the I^3S^2 model is presented in section 5.4, and conclusions are given in section 5.5.

5.2 The H-Model Revisited

In this section the initial-stage hybrid model, i.e. H-Model, presented in Chapter 2 -illustrated in Figure 2.12- is revisited in the context of the smart metering system as a case study. In addition to the original definitions stated in Chapter 2 for each of the model’s acceptance determinants, an adaptation of these original definitions is presented here to account for the smart metering system as a field of application. The definition of each determinant is presented next along with the hypothesis underlying the relationship between each one of these acceptance determinants and the observed behavior in the model.

5.2.1 Determinants from the UTAUT Model

Performance Expectancy

Definition

Performance Expectancy is the degree to which a consumer believes that using a smart meter will help him or her attain gains in their lives.

Justification

As discussed in Chapter 3, a smart meter is capable of offering consumers more services than just logging their energy consumption. For example, by using a smart meter it would be possible for consumers to gain access to their meter reading data around the hour. This would empower consumers to either shift or reduce their total amount of energy consumption, which in turn can aid consumers in achieving goals such as decreasing the amount of their energy bills, or even enable them to participate in saving the environment. Providing all these possibilities to consumers via a smart meter creates incentives for consumers to acquire such a meter. It could also lead to a sense of satisfaction within consumers upon reaching the afore mentioned goals that consumers may aspire to achieve. Thus, Performance Expectancy is anticipated to positively influences consumers' acceptance of smart meters, such that the higher sense of a smart meter Performance Expectancy among consumers, the more likely they'll be willing to accept the installation of a smart meter.

The inclusion of Performance Expectancy in the I^3S^2 Model is necessary to test whether the gains stated above form strong enough incentives for consumers to accept a smart meter. Furthermore, if Performance Expectancy proved indeed to be a significant predictor of consumers' acceptance of smart meters -in compliance with the original UTAUT theory, then it is of interest to examine how it compares to the other acceptance determinants in the I^3S^2 Model.

Hypothesis

H_0: Performance Expectancy has a positive impact on consumers' acceptance of smart meters.

Effort Expectancy

Definition

Effort Expectancy is the degree of ease associated with the use of the smart meter.

Justification

The application of the concept of Effort Expectancy as an acceptance determinant in the field of IT systems proved it to be a significant predictor of users' acceptance of such technologies. Such that the more effort required to use an IT innovation, the less likely users would be willing to adopt it. However, this negative influence would not necessarily be in effect in the setting of the smart metering system. Conventional mechanical energy meters required almost no interaction with household members, except perhaps for the occasional reading of the meter to forward the information to utility companies. This manner of interacting with the energy meter still holds for the new smart meter, even though the frequency of meter-reading data acquisition could be increased.

Basically, consumers are provided with a stand-alone smart metering device without an external display, with which consumers could interact more. Consequently, this brings up the issue of how applicable is Effort Expectancy as an acceptance determinant in the context of the smart metering system. Further, if this determinant proved significant as a predictor of smart meters acceptance, would the influence necessarily be in the same direction. To obtain answers for the afore mentioned inquisitions, Effort Expectancy is included in the I^3S^2 model to investigate the significance and direction of its influence on consumers' acceptance of smart meters. The hypothesis relating Effort Expectancy to the intended acceptance of smart meters is adopted from the original UTAUT model, and retains the same direction.

Hypothesis

H_0: Effort Expectancy has a negative impact on consumers' acceptance of smart meters.

Social Influence

Definition

Social Influence is the degree to which an individual perceives that important others believe he or she should use the smart meter.

Justification

The concept of Social Influence proved to be a significant predictor of technology acceptance in the field of IT systems. In the original study of the UTAUT model, the Social Influence was captured via the beliefs of technology users within organizations, that social agents within an organization believe that an IT technology should be used, or even support its usage. These social agents who fall under the social network within an organizational setting range between people whom influence the behavior of a technology-user, people whom are important to the user, senior management, or the organization in general. Furthermore, under the UTAUT model the impact of Social Influence on IT system acceptance was measured by assessing users' belief that organizational social agents "believed" that a user should utilize a system, or simply the supported its use. The results of Venkatesh et al. (Venkatesh, Morris et al. 2003) proved that Social Influence is a significant technology acceptance predictor in the context of mandatory IT systems adoption only.

The particularities of the smart metering system context differ than those mentioned above in relation of IT systems. A "user" of a smart meter is translated into a consumer, whose social network is relatively wider and different in nature than an organizational social network. Important people to a user in an organizational are mainly co-workers within the organization, whereas for a consumer, those whom are considered to be important could be family members, friends, or neighbors..etc. In a similar manner, senior management as figures of higher status within an organization are mapped to a consumer's idols such as celebrities of all sorts, e.g. athlete and politicians. Furthermore, Social Influence was proved to be a significant predictor of only mandatory IT systems' adoption, a setting which contradicts with the current smart metering system legislation, which guarantees the right of free smart meter adoption to consumers.

Another distinctive feature of the smart metering system is the fact that it is an ICT-based infrastructure system, which contrasts with IT technologies deployed within organizations. Moreover, the impact of Social Influence in the current study is captured by assessing a consumer's belief that he or she will use a smart meter if those who are considered important in his or her social network, either use a smart meter, or believe that a consumer should use it. This differs than how Social Influence was captured within the context of IT systems, which assessed users' belief that those who are important to them or influence their behavior "think" that users should adopt a new IT system.

In light of the afore mentioned contrasts between the respective contexts of IT systems and the smart metering system, Social Influence is included in the I^3S^2 Model as an acceptance determinant of smart meters. This will aid in investigating whether Social Influence would still be a significant predictor of consumers' acceptance of smart meters despite all the differences between the two fields of study.

Hypothesis

H_0: Social influence has a positive effect on consumers' acceptance of smart meters.

5.2.2 Determinants from the IDT Theory

Trialability

Definition

Trialability is the degree to which a consumer has a chance to experiment with a smart meter before adoption.

Justification

As mentioned in chapter 3, offering consumers a chance to experiment with a smart meter prior to acquiring it, gives them a chance to ensure its usefulness before investing in it financially. In addition, energy companies could also benefit from allowing consumers to try out smart meters, mostly by the increased chance of consumers' willingness to adopt a smart meter at their homes. In one way, using a smart meter on trial basis has the potential to clear some misconceptions and confirm to consumers the added value utilizing a meter would bring them. Furthermore, a trial usage would "educate" consumers whom are entirely unfamiliar with smart meters. This proves significant when considering that people are inclined to reject what is unknown to them. Therefore, allowing consumers to use smart meters on trial basis can act as an enabler for consumers' acceptance of smart meter, and consequently it would be beneficial for energy companies to invest in possible venues and facilitate for consumers' experimentation with smart meters.

In order to establish the impact of Trialability on consumers' acceptance of smart meters, the concept has been included in the I^3S^2 model as an acceptance construct, which aims to capture the extent of a consumers' past trial experience with a smart meter. This will aid in establishing the significance of Trialability as an acceptance predictor, the direction of its influence, and how it compares against the other acceptance determinants in the model.

Hypothesis

H_0: Trialability has a positive impact on consumers' acceptance of smart meters.

Observability

Definition

Observability is the degree to which the results of using a smart meter are observable to consumers.

Justification

The concept of Observability has been applied differently in the various innovation diffusion studies. The difference stems from either the adopted definition of Observability by a study, or the nature of the innovation under study. Within the smart metering system results of consumers' usage of a smart meter include: a possible decrease in their electricity bill and their active contribution in saving the environment, both of which can been achieved by consumers' utilization of a smart meter to monitor and control their energy consumption. Furthermore, an observable result of using a smart meter can be the increased level of ease with which consumers can switch between different energy suppliers. Though Observability was proved to be a significant predictor of innovation diffusion and adoption by consumers, yet it is difficult to predict its influence on consumers' perception of a smart meter and consequently their willingness to adopt a smart meter, mainly due to the intangible nature of the above mentioned results of a smart meter usage.

In order to establish the significance of Observability on consumers' acceptance of smart meters, the concept has been included in the I^3S^2 Model as an acceptance predictor, to capture consumers' perception of the extent to which results are noticeable or observable rather than the extent a meter is physically visible to consumers. This will help in establishing whether Observability has an influence on consumers' acceptance of smart meters, the level of significance and direction of this influence, and how it compares among the other acceptance determinants in the I^3S^2 Model.

Hypothesis

H_0: Observability has a positive impact on consumers' acceptance of smart meters.

Compatibility

Definition

Compatibility is the degree to which a smart meter is perceived as being consistent with the existing values, needs and past experiences of consumers.

Justification

As technologies evolve it is sometimes inevitable for it to alter the ways in which it functions or offer its services to users, and the smart metering system is no exception. One associated problem however is the compatibility of the way a new system operates with conventions of an older system, which consumers are accustomed to. One of the most noticeable faces of change introduced by the smart metering system to consumers is billing. Where consumers can be charged bimonthly based on their time-of-use, instead of the current monthly approximate bills. Though change can be positive and can both retain satisfied users and attract new ones, yet it must be carried out with extreme caution as it can also have a repulsive impact. Consumers can be discouraged from using a smart meter if they perceive the new manner in which the system operates difficult to utilize. Further, even if the new metering system will retain the ease and convenience in which it offers its services to consumers, for a group of people change is simply hard to accept and would be a hinderer for them to adopt a new technology.

The impact of Compatibility on consumers' perception of the smart metering system, and their willingness to adopt a meter is unclear. In order to establish the significance and direction of Compatibility influence on consumers' acceptance of smart meters, the notion has been included as an acceptance predictor in the I^3S^2 Model. This will help in determining how the smart metering system compares to IT system to which Compatibility was proven to be a significant predictor of users' acceptance. Furthermore, including Compatibility in the I^3S^2 Model will establish how this concept ranks in importance among other acceptance predictors in the I^3S^2 Model.

Hypothesis

H_0: Compatibility has a positive impact on consumers' acceptance of smart meters.

5.3 Smart Metering Acceptance Determinants

The limitations previously identified of both the smart metering and OV-Chipkaart systems, in chapters 3 and 4 respectively, are presented here again as smart metering acceptance determinants. They are included in the I^3S^2 Model as an extension to the H-Model in order to reach a comprehensive perspective of factors that could either hinder the adoption of a smart meter or stimulate it.

5.3.1 Smart Metering Rejection Antecedents

Perceived Information Security and Privacy Risk

Definition

Perceived Information Security and Privacy Risk are worries on consumers' part that their personal information that is managed by the smart metering system is not sufficiently protected, which can result in the unlawful disclosure of information to unauthorized parties or intruders.

Justification

With the rapid developments in information and communication technologies the inclusion of the Perceived Information Security and Privacy Risk determinant in technology acceptance models becomes inevitable. Many of the systems and services that people interact with and depend on in their daily lives have become distributed and interconnected in nature. This made these systems heavily reliant on an ICT backbone by utilizing state-of-the-art digital networks technologies, which involve digital exchange and storage of massive amounts of information. In many cases, the information exchanged mainly belongs to consumers or users of the technology, which naturally leads to a state of apprehension among those user groups towards the adoption and use of such ICT-intensive technologies. Consumers' information security and privacy concerns mainly revolve around focal concepts such as: whether the system applies adequate information security measures, and whether organizations governing the system are actually putting the necessary effort to safeguard the privacy of consumers' information. Unsurprisingly, these concerns and worries on consumers' side may lead to their hesitation to use new ICT-intensive technologies or even rejecting it all together, due to the potential loss of information privacy and security.

Among the many smart meters system roll-out initiatives, The Netherlands, and the United States, especially the state of California, are the two regions that suffer the most from consumers' rejection due to information security and privacy concerns. In the state of California, a strong resistance towards the smart metering system led activists to demonstrate against the Big Brother effect in campaigns such as StopSmartMetersNow (StopsmartmetersNow.com 2010) which calls for stopping the deployment of the system due to the violation of consumers' right for privacy, and concerns related to how the utilities would use information about individuals' home appliance usage (Barringer 2011). In a similar manner, The Netherlands witnessed a similar movement that raised slogans against the allegedly ill-intentions of using consumers'' private information. As mentioned in previous chapters, the original plan of the Ministry of Economic Affairs in The Netherlands to mandate the roll out of smart metering system across all the provinces within The Netherlands failed in April 2009 when the Dutch Senate –upper house of parliament- rejected the proposal due to a report conducted by the University of Tilburg and commissioned by the consumer organization in The Netherlands (Cuijpers and Koops 2008). The report stated that from a legal standpoint the smart meters pose a legal dilemma since the frequent readings of the meter are considered a breach of article 8 –right to respect for private and family life- from the Convention for the Protection of Human Rights and Fundamental Freedoms (Council of Europe 2003, Garcia and Jacobs 2010). In September 2010, a revised smart metering legislation was introduced again to the Senate. The new legislation guarantees the right to refuse installation of a smart meter or turn it to administrative off mode, an option that allows consumers to disable remote meter reading and remote disconnection, while it enables consumers to access detailed meter reading locally via port P1. This situation inevitably had a negative impact on the business case, which in turn makes it crucial for regulators and policy makers to focus their attention on societal acceptance and explore possible means to understand consumers' opinion and behavior, a goal that is aimed to be achieved via the I^3S^2 model that is presented later in this chapter. A survey conducted in 2009 as part of a previous work revealed that 50.3 % of respondents agreed with the government's decision in 2009 to prohibit a mandatory rollout of the smart metering system in The Netherlands. Furthermore, the results showed that if respondents agreed with the government's decision then they are highly likely to reject receiving a free smart meter (AlAbdulkarim and Lukszo 2011).

Determinant in the Literature

Despite the serious nature of consumers' concerns regarding preservation of security and privacy of their information, the investigation on the influence of the security and privacy risks on consumers' acceptance of a variety of technologies has been rare but slowly increasing during the past few years as a result of technology advancements, and most notably in relation to technologies employed by financial transactions systems. Pavlou (Pavlou 2001) presented a variant of the technology acceptance model- TAM by Davis, to study factors effecting consumers' intention to conduct electronic commerce transactions. Pavlou extended the TAM model by including: Perceived Risk, Trust, Privacy Perception and Security Perception constructs. The inclusion of privacy and security perception was due to the possible privacy and monetary losses associated with online transactions. The author assumes that consumers' can develop trust towards online transactions when they believe that their personal information is well-protected by web retailers during transmission and storage. The hypothesis underlying part of the model states a positive relationship between security Perception, Privacy Perceptions and Trust towards online transactions with web retailers. The results of Pavlou's work support the hypotheses underlying the extended model presented in his work. In particular, the analysis revealed that Security Perception and Privacy Perception are non-significant predictors of risk as their impact was mediated by the Trust construct. Furthermore, while Security Perception proved to be a significant indicator of Trust, Perceived Privacy showed a non-significant support for its underlying hypothesis.

In 2005 Wu and Wang (Wu and Wang 2005) presented a theoretical model that investigates consumers' acceptance of mobile commerce (M-commerce) technologies. The model featured a hybrid model that was devised by integrating Davis's TAM and Roger's Innovation Diffusion Theory- IDT, and further extended with additional acceptance determinants, such as Perceived Risk among others. The motivation for including this acceptance determinant can be found in the inherit inhibitors, such as information security and privacy concerns, that are associated with M-commerce technologies due to its cyber nature. Despite the wider use of electronic commerce technologies, it still suffers from a number of weaknesses including breaches of privacy, which is a main concern of consumers. M-commerce suffers from the same weaknesses as the cyber nature of interacting with the systems leads consumers to perceiving potential risks, such as privacy violations, a concern among others which poses a threat to M-commerce popularity and widespread use. The researchers investigated the impact of Perceived Risks on consumers' Behavioral Intention to use an M-commerce technology, and their Actual Use of it. The underlying hypothesis related to the Perceived Risk construct assumes that Perceived Risk has a negative direct effect on consumers' Behavioral Intention to use M-commerce technologies. Wu and Wang's theoretical model was tested in a business to consumer –B2C M-commerce context in Taiwan, where consumers conducted four online transactions: banking, shopping, investing and online services. The results showed that Perceived Risk have a significant direct impact on Behavioral Intention to use the technology, which ranked second in significance after compatibility. Though the significance of perceived risk was confirmed, the results did not support the hypothesis underlying the relationship between perceived risk and the behavioral intention to use an M-technology, which stated that "Perceived Risk has a negative direct effect on Behavioral Intention to use". The researchers stated that the most striking and puzzling finding is that Perceived Risk had a positive impact on the Behavioral Intention to use the technology. That is, the higher the risk the more likely consumers will conduct M-commerce transactions. The reason for this counter-intuitive finding is not clear.

In the area of E-business, Min and Dong in 2007 (Min and Dong 2007) explored acceptance of online informediary by web surfers in the Chinese context. The researchers presented an extension of TAM2, which aimed to study the effect of a number of acceptance determinants, one of which is Risk Awareness, on consumers' Behavioral Intention towards usage of E-business services. Min and Dong assumed that the influence of Risk Awareness on Behavioral Intention is mediated by Perceived Usefulness, such that Risk Awareness has a positive influence on Perceived Usefulness. The results of this work did not support this hypothesis.

In 2008 Hossian and Prybutok (Hossain and Prybutok 2008) presented a theoretical model that explores consumers acceptance of radiofrequency identification- FRID technology. The model is an extension of Davis's technology acceptance model- TAM that includes additional determinants, two of which are Perceived Privacy and Perceived Security. The inclusion of the Perceived Privacy construct was based on the fact that the use of RFID-based applications endangers privacy of personal information, which not only involves disclosure of consumers' information to unauthorized parties, but also tracking consumers' physical location. The researchers assume that the higher the perceived importance of personal privacy, and the less a consumer is willing to give up their privacy, the lower their intention to use the RFID technology. In a similar manner, the Perceived Security construct is concerned with the cyber security aspect of the information being transmitted over and maintained by the system. Its underlying hypothesis states that the higher the consumers' perceived importance of personal information security, and the less willing they are to sacrifice their personal information security, the lower their intention is to use RFID technology. The results confirmed that among other indicators, Perceived Security is a significant predictor of consumers' Intention to Use RFID technology, and that it's related hypotheses are supported. Perceived Privacy on the other hand was deemed as insignificant predictor of consumers' Intention to Use RFID technology.

A revised version of the UTAUT model was developed by Qingfei et al. (Qingfei, Shaobo et al. 2008) in 2008. The model incorporated acceptance determinants that are related to consumers' acceptance of mobile commerce technologies in the Chinese financial applications context. Trust and Privacy was included as a combined determinant in the model among six other acceptance determinants to study their direct influence on consumers' Behavioral Intention, and indirectly on Use Behavior. The importance of studying the effect of privacy on consumers' acceptance is due to the fact that via usage of M-communication technologies the discretion of users' location and travel patterns are compromised, which consequently raises consumers' concerns over the protection of their privacy and in turn has an influence on the variance in consumers' acceptance of such technologies. Though this study does not offer empirical results, the authors recommend that constructs such as trust, privacy and cost be included in the UTAUT model.

Another variation of the UTAUT model in the area of M-commerce was devised by Shin (Shin 2009). The aim of this model was to study factors that influence consumers' acceptance of mobile wallets. The author extended Venkatesh's UTAUT model with a number of determinants, one of which is Perceived Security. Shin assumed in his model an indirect influence on Use Behavior that is mediated by Intention. Perceived Security is defined as the "degree to which a [consumer] believes that using a particular mobile payment procedure will be secure" (Shin 2009). Based on this definition Shin formulated the underlying hypothesis linking Perceived Security to Intention as follows: Perceived Security has a positive effect on the intention to use mobile wallet. The results of his analysis supported this hypothesis. Perceived Security proved to be the most important acceptance determinant of user intention to use mobile wallet services, especially among respondents of high-income group.

The investigation of security and privacy factors has also taken place in the medical context. Egea and Gonzalez (Egea and González 2011) presented a theoretical model that explains physicians' acceptance of a central health information technology: electronic health care records- EHCR system. Egea and Gonzalez's model -an extension of Davis's TAM- included the following acceptance determinants among others: Information Integrity, Trust, Attitude Towards Usage, and Perceived Risk, where the latter encompasses several notions such as: physicians assessment of performance, time, privacy and psychological risk. The aim was to investigate the impact of the above mentioned acceptance determinants on physicians intention to use the EHCR technology. The inclusion of the privacy factor was based on the fact that potential information security breaches and the associated privacy risks can lead to uncertainty in using health care systems. This was captured in Egea and Gonzalez's model by the hypothesis underlying the relationship between the risk and intention to use constructs, which assumes that perceived risk has an indirect negative impact on the intention to use that is mediated via Trust. The results confirmed the significance of the Perceived Risk construct, such that it is highly inter-related and indirectly linked to original TAM constructs. Furthermore, the results confirmed that the hypothesis assuming a direct negative impact on

Trust holds, as trust proved to be fully mediating Perceived Risk. This finding, in addition to a strong negative influence of Information Integrity construct on Perceived Risk, and a positive influence of Information Integrity on Trust emphasizes the importance of security measures to ensure patients' digital medical records' integrity. The researchers concluded that "reduced levels of Perceived Risk and enhanced trust will contribute greatly to physicians' adoption and continued use of health information technology systems such as EHCR.

Table 5.1 lists the reviewed literature investigating the impact of Perceived Security and Privacy Risks on technology adoption and diffusion.

Table 5.1: Summary of literature reviewed for the impact of the perceived security and privacy risks on technology adoption

Domain		Study	Country	Determinant	Observed Behavior	Hypothesis	Results
Financial	E-commerce	(Pavlou, 2001)	U.S.	Privacy Perceptions, Security Perceptions	Intention to Transact	- Privacy perceptions are positively related to trust toward transactions with a Web retailer - Security perceptions are positively related to trust toward transactions with a Web retailer	- Security Perception proved to be a significant predictor of Trust - Privacy Perception has no significant impact on Trust - security and privacy perception are non-significant predictors of Risk as their impact was mediated by Trust
Financial	M-commerce	(Wu & Wang, 2005)	Taiwan	Perceived Risk	Behavioral Intention to Use, Actual Use	Perceived risk has a negative direct effect on behavioral intention to use	Perceived Risk had a positive impact on the Behavioral Intention to Use the technology
Financial	M-commerce	(Qingfei, 2008)	China	Trust and Privacy	Behavioral Intention, Use Behavior	*Not stated*	No empirical data analysis
Financial	M-commerce	(Shin, 2009)	South Korea	Perceived Security	Intention, Use Behavior	Perceived security has a positive effect on the intention to use a mobile wallet	Perceived Security was the most important acceptance determinant of user intention to use M-commerce services
E-business		(Min & Dong, 2007)	China	Risk Awareness	Behavior Intention	- Risk Awareness has an influence on Behavioral Intention mediated by Perceived Usefulness - Risk Awareness has a positive influence on Perceived Usefulness	There were no evidence to accept the hypothesis

RFID	(Hossian & Prybutok, 2008)	U.S.	Perceived Security, Perceived Privacy	Intention to Use RFID Technology	- The higher the perceived importance of privacy, the lower the intention to use RFID technology - The less willing a consumer is to sacrifice privacy, the lower their intention to use RFID technology - The higher the perceived importance of personal information security, the lower the intention to use RFID technology - The less willing consumers are to sacrifice their personal - information security, the lower their intention to use RFID technology	- Perceived Security is a significant predictor of consumers' Intention to Use RFID Technology - Perceived Privacy is an insignificant predictor of consumers' Intention to Use RFID Technology
Medicine	(Egea & Gonzalez, 2011)	Spain	Perceived Risk	Intention to Use	- Perceived Risk will have a negative direct effect on Trust in electronic health care records (EHCR) systems - Trust will have a positive direct effect on Intention to Use EHCR systems	- Perceived Risk has direct negative impact on Trust - Results did not support the proposed direct influence of Trust on Intention to Use

The literature summarized in Table 5.1 investigated the impact of security and privacy notions on technology adoption mainly in the context of financial technologies and a few studies conducted in Medicine, RFID and E-Business. Despite the various results of these studies, security had a negative impact of the intention to adopt a technology mainly in the context of RFID, E-Commerce and M-Commerce technologies. It would be of interest for the current study to investigate how meter readings data compare to financial-related transaction data, in terms of security and privacy importance to consumers.

In addition, the notion of the adverse impact of security and privacy on technology adoption was applied differently across these reviewed theories and models. It was measured via concepts such as security, privacy, trust, risk, and the perception of these concepts. The studies listed in Table 5.1 included one or more of these concepts in their respective models, either as separate or combined constructs. The construct(s) were related to the observed behavior in each model differently, such that some models predicted a direct impact, where others assumed an indirect one via other constructs in the model. Furthermore, another difference is how these concepts, e.g. security and privacy, are defined. Some studies regarded it as the perceived risks, others as consumers' awareness of these risks. Moreover, the definition of consumers' perception of these notions such as security varies among studies based on the context in which a model is applied. This difference in definitions inevitably influenced hypothesis formation. For example, in (Min and Dong 2007) the researchers assumed that Risk Awareness has a positive influence on Perceived Usefulness, as opposed to many studies that focused on consumers' perception of the adverse effects of security and privacy, thus predicting a negative impact on technology adoption. All these differences among the studies listed in Table 5.1 in terms of the applied security and privacy-related notions, the definition of these notions, how these notions relate to the observed behavior (direct/indirect) and the direction of this relationship (negative /positive), give a strong incentive to explore the impact of the Perceived Security and Privacy Risks on consumers' acceptance of a smart meter and their intention to use it.

Furthermore, the afore listed studies differ further in the range of observed behavior. Most of these studies focused on the intention to use a technology and some even investigated actual usage of a technology. This contrasts with the convention used for the current study, where the observed behavior of interest is consumers' acceptance to have a standard-operation smart meter installed at their homes, and their intention to use the meter. This choice of observed behavior results from the nature of the smart metering as a system, which differs in its operation and properties than the technologies reviewed in Table 5.1 in the following sense: smart meters are not a commercial technology to be obtained/used in a commercial context, it is a technology that came into existence in compliance with European Union directives, and which energy companies aim to deploy among consumers. Furthermore, the actual usage of the smart meters cannot be measured at this point of time, when smart meters are being deployed on an extremely limited scale.

Results presented in the studies in Table 5.1 also varied. For example, the hypothesis predicting a positive influence of risk awareness on technology adoption was not supported. On the other hand, studies that assumed a negative impact of security and privacy perception on technology adoption resulted in diverse outcomes; in some studies these hypotheses were supported, other studies revealed an insignificant impact, whereas one study stated that the assumed negative impact was proved to be a positive one. In addition to the ultimate significance of the perceived security and privacy risks as a predictor of technology acceptance, some studies reported its relative significance among other predictors included in their respective models. In light of the inconsistent results of previous research, it is of particular interest for the current study to explore the impact of Perceived Security and Privacy Risks on consumers' willingness to accept the installation of a smart meter in their homes in order to: establish its significance, direction of impact, and its relative significant among other acceptance determinants. The hypothesis used for the current work is presented below.

Hypothesis

H_0: Perceived Information Security and Privacy Risk have a negative impact on consumers' acceptance of smart meters.

Perceived Financial Costs

Definition

The Perceived Financial Costs acceptance determinant is the financial obligation enforced by service providers on consumers in return for acquiring a smart meter. These additional costs were not present prior to the introduction of the smart metering system.

Justification

This determinant is considered significant due to two reasons. The first reason is the fact that in many cases, the decision to accept or reject the use of a new technology is motivated by financial costs. The second reason contributing to the importance of this determinant is the additional financial costs that are associated with the introduction of a new infrastructure system. In the case of smart metering systems, the following three main categories of financial costs were identified:

- **Changing Business Process Related Costs**

  The development and deployment of smart metering systems necessitates the change of a number of business processes. The change in these business process incurs costs that are related to the design, development, and deployment of hardware and software components of the system (Deconinck, Delvaux et al. 2010).

- **Communication Medium Related Costs**

  The choice of the underlying communication medium of the smart metering infrastructure, whether wired or wireless, influences to a great extent the related costs.These costs include the procurement of hardware, installation costs, operation costs that can be dependent on the amount of exchanged data, maintenance and upgrade costs. Furthermore, the choice of the underlying communication architecture of the system has an impact on the costs (Deconinck, Delvaux et al. 2010).

- **Household Related Costs**

  The costs at the remote households side that are associated with the deployment and operation of the system are related to procurement of the metering devices, in addition to their installation and maintenance (Deconinck, Delvaux et al. 2010).

Despite the fact that the legislation states that consumers are not to shoulder any excessive financial costs related to the introduction of the system, this determinant remain significant. Experts in the electricity generation and distribution field believe that though the legislation grants consumers the right of a free installation of a smart meter after the launch of the official roll-out in January 2012, yet the aforementioned costs need to be compensated somehow especially when considering that the energy distribution networks operate in the regulated domain of the electricity market.

Upon the rollout of smart metering systems in a number of countries around the world such as the United Kingdom, Australia and Belgium, and the State of Texas in the United States of America, consumers reported an increase in their electricity bills. According to officials from an electricity grid company in Texas, the company has an increase of 17% in complaints. One consumer reported that the electricity bill of an uninhabited home had an increase of more than the double of previous electricity bills after the installation of a smart (Wald 2009, Betz 2010, The Independent 2012).

Furthermore, the significance of this determinant is confirmed by observing the OV-Chipkaart case in the transportation sector. Upon the introduction of the system, its legislation asserted that travelers are not to be subjected to increased financial costs for travelling. However, in reality travelers were obligated to meet additional financial costs in order to be able to continue commuting using means of public transport. In addition to paying an amount of 7,50 Euros for purchasing a card, an average increase of 5 to 10% in fares was noticed in a number of cities (van Kuijk 2010), and in the province of South Holland in particular an increase of 28.7% was cited (SP Verkeer en Waterstaat 2010). There are many suppositions on the cause of such increase in travel fares, one possible explanation reported is that under the OV-Chipkaart system passengers pay for their trips based on the number of kilometers travelled, which can result in travel fares being either cheaper or more expensive than the previous paper-ticket traveling system. Another cause is that train round-trip travelers using the OV-Chipkaart are charged two single-travel fares, which costs more as opposed to the paper return-ticket. Furthermore, in Amsterdam for example, buying a paper disposable OV-Chipkaart card to board trams costs 2.60 Euros regardless of the number of stops travelled, whereas under the previous system the basic charge was 1.45 Euros. It was also reported that different public transport companies do not accept OV-Chipkaart issued by other companies, which implies that travelers switching between different means of transportation are forced to pay the "in-stepping" or travel start charge multiple times. In addition, in 2010 Tineke Huizinga -a Secretary of State of Transport, Public Works and Water Management then-cautioned that public transport fares will inevitably increase due to the fact that operating the chip-based system, i.e. OV-Chipkaart, cost three times as much as dispensing paper tickets (Dutch News 2010).

The increase in travel prices raised the apprehension that more travelers will evade public transport as a result to the increased costs and resort to the use of their own cars, which would naturally result in increased road congestion (SP Verkeer en Waterstaat 2010).

Determinant in the Literature

The influence of financial costs associated with the introduction of various new technologies on consumers' acceptance has been investigated in numerous studies throughout the literature. In the area of information systems, Mathieson et al. in 2001 (Mathieson, Peacock et al. 2001) extended the Technology Acceptance Model by Davis, to study the effect of financial costs among other constructs on consumers' Behavioral Intention to Use information systems, and their Actual Use of these systems. The notion of financial costs was captured in the extended model by the Perceived Resources acceptance construct, which was categorized as a system-related attribute. Results confirmed that the Perceived Resource had a significant impact on consumers' Behavioral Intention to Use an information system and their Actual Usage of the systems.

The impact of financial costs on technology acceptance was also investigated in the different contexts of various communication technologies. In 2004 Choudrie and Dwivedi (Choudrie and Dwivedi 2004) introduced a technology acceptance model that included a Cost construct, to investigate consumers' acceptance of broadband connections. This construct covers two types of costs: the cost of monthly broadband access and costs associated with upgrading personal computers owned by household members or even purchasing new ones. The underlying hypotheses related to the Cost construct assume negative relationships between these costs and consumers' adoption of broadband in their homes.

In the area of financial applications, researchers applied several technology acceptance models and theories to investigate consumer acceptance of different systems. Laurn and Lin presented a model in 2005 that aimed to gain an understanding of consumers' Behavioral Intention to Use mobile banking systems (Luarn and Lin 2005). The researchers studied the impact of Perceived Financial Costs on consumers' Behavioral Intention to Use mobile banking systems. The results confirmed that financial costs pose significant barriers that hinder consumers from adopting mobile banking systems. Furthermore, the researchers recommended that banking authorities should take countermeasures to diminish the effect of financial costs, by means of creative promotional and pricing strategies.

Mobile commerce applications received a lot of attention by researchers whom were interested in investigating consumers' acceptance of such systems. In 2005 Wu and Wang (Wu and Wang 2005) presented a technology acceptance model that incorporated a Cost construct among others. The aim of the model is to study the impact of financial costs on the Behavioral Intention to Use and the Actual Usage of mobile commerce systems. The results revealed that Cost has a significantly negative effect on the Behavioral Intention to Use mobile technology systems. Further investigation of consumers' acceptance of mobile commerce applications was conducted by Qingfei et al. (Qingfei, Shaobo et al. 2008). The researchers presented an initial stage model, which included a Convenience and Cost acceptance determinant as an extension to the UTAUT model, to explore the impact of the costs associated with wireless transactions on the Behavioral Intention and Use Behavior of consumers towards mobile commerce applications, where they assumed that consumer's acceptance is significantly affected by financial cost.

Another study that incorporated the financial costs perspective in consumers' acceptance and adoption of technology, was conducted by Tung and Chang in 2008 (Tung and Chang 2008) in the education sector. The context of the study was the use of online courses systems by nursing students. The researchers investigated the influence of Perceived Financial Cost among other constructs on students' Behavioral Intention to Use Online Courses. The outcome of the analysis confirmed a negative impact of the Perceived Financial Cost on the Behavioral Intention of students to use online courses.

In 2009 Kuo and Yen (Kuo and Yen 2009) explored the influence of financial costs on acceptance in the context of 3G mobile value-added services. The researchers included a Perceived Cost construct in their theoretical framework, to study its impact on consumers' Behavioral Intention towards adopting such services, under the assumption that financial costs have a negative impact on consumers' willingness to adopt 3G technologies. The analysis confirmed the underlying hypothesis of Kuo and Yen's work, which predicted that costs have a significantly negative impact on consumers' attitude towards 3G technologies.

Furthermore, consumers' acceptance of mobile commerce applications was investigated in the Malaysian context by Wei et al. in 2009 (Wei, Marthandan et al. 2009). The researchers studied the effect of a number of acceptance determinants, one of which is the Perceived Cost, on consumers' acceptance of mobile commerce systems. Results showed that the Perceived Cost significantly affects Consumers' Intention to Use mobile commerce applications, it also revealed that Perceived Costs ranked in importance equally to Social Influence, both of which were ranked second to the Perceived Usefulness and Trust acceptance determinants.

Further investigation of consumers' acceptance of communication technologies was conducted in 2010 by Pan and Jordan-Marsh (Pan and Jordan-Marsh 2010). The study focused on elder consumers' adoption of Internet in the Chinese context. Though their Internet adoption theoretical model does not include an explicate construct related to financial costs, yet the notion of financial costs was captured under the Facilitating Conditions construct. The results showed that facilitating conditions was a significant predictor of Internet Use Intention. Another work that investigated consumers' acceptance of communication technologies was presented in 2010 by Shin. The study presented a model that aims to explore acceptance of Mobile Virtual Network Operator- MVNO services. (Shin 2010). Shin included in his model a Price acceptance construct to study its effect on the Behavioral Intention and Behavior of Usage of MVNO services, by comparing three levels of prices: high, medium, and low. The results indicated that consumers respond to price sensitivity and in turn it has an effect on the overall acceptance and usage of MVNO services.

In 2011 Verdegem and De Marez (Verdegem and De Marez 2011) explored acceptance determinants of ICT systems. They tested their model using two case studies: mobile news applications and mobile television services. The researchers grouped technology acceptance determinants under two categories: adopter-related characteristics and innovation-related characteristics, where the financial cost factors were included under the latter. Results revealed that financial costs had a significant influence on consumers' Behavioral Intention to Adopt in the case of mobile television applications only. A summary of the literature reviewed above is listed in Table 5.2.

Table 5.2: Summary of the literature reviewed on the influence of the perceived financial costs on technology adoption

Domain		Study	Country	Determinant	Observed Behavior	Hypothesis	Results
Financial	M-Banking	(Laurn & Lin, 2005)	Taiwan	Perceived financial costs	Behavioral intention to use M-banking	Perceived financial cost will have a negative effect on behavioral intention to use mobile banking	Confirmed- significant negative impact
	M-Commerce	(Wu & Wang, 2005)		Cost	Behavioral intention to use, Actual Use	Cost has a negative direct effect on behavioral intention to use	Confirmed- cost has a significantly negative effect on the behavioral intention to use mobile technology

		(Qingfei et al., 2008)	China	Convenience and Cost	Behavioral intention , Use behavior	cost factor will significantly affect M-commerce user acceptance	No empirical data analysis
		(Wei et al., 2009)	Malaysia	Perceived Costs	Consumer intention to use M-commerce	Perceived cost has a negative effect on consumer IU M-commerce in Malaysia	Confirmed- Perceived cost is one of the barriers that prevent Malaysian from using M-commerce
Telecommunication	Internet	(Pan & Jordan-Marsh, (2010)	China	Financial cost was included under Facilitating Conditions	Internet Use Intention, Internet Adoption	- Facilitating conditions will have a positive effect on Internet use intention. - Facilitating conditions will have a positive effect on Internet adoption	Facilitating conditions was confirmed to have a positive effect on Internet use intention
	Mobile virtual NT operator	(Shin, 2010)	South Korea	Price	Behavioral Intention, Use Behavior	Perceived price level negatively influences customers' usage behavior	Consumers respond to price sensitivity and in turn it has an effect on the overall acceptance and usage of MVNO services
	Mobile news, mobile television	(Verdegem & De Marez, 2011)	Belgium	Cost included under Innovation-Related Chars	Behavioral Intention to Adopt	Cost is assumed to negatively relate to innovativeness	Cost has a significant influence on consumers' behavioral intention to adopt mobile television
Information Systems		(Mathieson et al., 2001)	U.S.	Cost was included under Perceived Resources construct	Behavioral Intention to Use, Actual System Usage	Perceived Resources affect an individual's intention to use an information system	Perceived Resource had a significant impact on consumers' behavioral intention to use an information system and their actual usage of the systems
Education		(Tung & Chang, 2008)	Taiwan	Perceived Financial Cost	Behavioral Intention to Use Online Courses	Perceived financial cost will have a negative effect on the behavioral intention to use online courses	Perceived Financial Cost has a negative impact on the Behavioral Intention of students to use online courses

The literature reviewed in Table 5.2 can be divided into two categories in the manner the concept of financial costs was included in their respective models. A number of studies included financial costs as an explicit construct in their technology acceptance models, whereas other studies included financial costs implicitly under generic constructs such as: facilitating conditions, perceived resources and innovation-related characteristics. However, the results of the studies reviewed -except Qingfei et al.- confirmed a negative influence of the perceived financial costs on individuals' willingness to adopt technologies, despite whether financial costs were included implicitly or explicitly in their models. This consensus in results stresses the significance of perceived financial costs as a predictor of a wide range of technologies such as financial applications, telecommunication, information systems and education systems. This is a precursor to the prediction that perceived financial costs will retain its significance as an acceptance determinant in the context of the smart metering. For this purpose the concept of perceived financial costs was included in the I^3S^2 model to confirm its significance and to explore its rank of importance among other smart metering acceptance predictors that are included in the I^3S^2 model. The predicted influence of perceived financial costs on consumers' willingness to adopt a smart meter is captured in the following hypothesis.

Hypothesis

H_0: Perceived Financial Costs have a negative impact on consumers' acceptance of smart meters.

Perceived Loss of Control

Definition

The Perceived Loss of Control is consumers' concerns regarding energy grid operators' ability to remotely disconnect services of an energy consumer at any time without consumers' permission or prior notification.

Justification

Upon using new technologies, consumers seek assurance of remaining in control of both the technology and whatever consequences that may occur as a result of its usage. This becomes more so in the case of ICT-based technologies that involve interacting with remote systems, by sending private information via means of digital networks. This can create hesitation within consumers to use such technologies without some guarantees for the safety of their information and a sense of control over the usage of the technology (Xu 2007, Gupta and Xu 2010).

The impact of Perceived Loss of Control on technology acceptance in the context of the smart metering system is significant. This is true considering that the system and its new functionality dictate a different way of operation, e.g. how consumers' energy supply is being managed. Via a smart meter, energy companies are technically capable to connect and disconnect consumers' energy supply. In addition, the system enables energy companies to control different home appliances operating within the household. This can be carried out both remotely and instantly, a manner which was not used before in the context of the conventional mechanical metering system. This additional "power" that energy companies now have, created a negative sense by consumers of control loss over their energy supply and the appliances within their own household. Therefore, the perceived loss of control was included as an acceptance determinant in the I^3S^2 model to help achieve a comprehensive view of factors that have the potential to influence the level of consumers' acceptance of smart meters.

Determinant in the Literature

The influence of perceived control loss determinant on consumers' acceptance of various technologies was investigated throughout the literature. Some studies showed that in cases where the perceived risks associated with technology usage are high, consumers can still accept and use the technology if they feel in control of the usage of the technology, e.g. conducting online transactions (Dinev and Hart 2006, Wang, Lin et al. 2006, Xu 2007).

In the area of E-commerce, Koufaris (Koufaris 2002) devised a hybrid model by integrating acceptance determinants from information systems, marketing and psychology fields to study consumers' behavior towards online stores. The theoretical framework, based on the Technology Acceptance Model, Consumer Behavior, and Flow and Environmental Psychology, explores the impact of emotional and cognitive responses to online stores by first-time visiting consumers on their Intention to Return to these stores and make Unplanned Purchases. The importance of the Perceived Control construct in the context of online shopping stems from consumers' need to make purchases online for different reasons, and the massive amount of information available on these sites. These factors led consumers to require shopping websites that allows the completion of purchase transactions that are minimum in effort, higher in efficiency and allow for more control over advertisements and exposure to promotional material that may lead to unplanned purchases. Koufaris predicted perceived control is positively related to intention to return, and that consumers with higher Perceived Control are less likely to make Unplanned Purchases. The result of empirical data analysis showed that the Perceived Control construct was insignificant, and that no relationship can be established between Perceive Control and Unplanned Purchases.

In 2008 Lee and Park presented the Technology Satisfaction Model –TSM (Lee and Park 2008). The model aims to investigate adoption and usage of technologies, by studying the relationship between mandatory adoption of mobile information technology and market performance in the business to business -B2B context. TSM is an extension of Davis's TAM that included a Perceived Loss of Control determinant as a mandatory technology acceptance-specific variable. The researchers aimed to explore the influence of Perceived Loss of Control on User Satisfaction, and predicted that the Perceived Loss of Control -triggered by the mandatory use of the information technology- plays a significant role in explaining the relationship between Market Performance in B2B context and the acceptance determinants in the TAM model. The empirical results supported that the Perceived Loss of Control has indeed a negative impact on User Satisfaction.

A study of a particular relevance to the current work was conducted by Kranz et al. in 2010 (Kranz, Gallenkamp et al. 2010).The researchers extended Davis's TAM with a subjective control acceptance determinant, originating from the field of social psychology, to study consumers' acceptance of smart metering in Germany. Among other goals, the model aims to study the influence of consumers' concerns regarding the loss of control of their energy connection on their intention to use a smart meter. The model is based on the assumption that consumers' acceptance of smart meters depends on their beliefs regarding if and to which extent a smart meter can be controlled. Therefore the underlying hypothesis states that the attitude towards use mediates the relationship between subjective control and intention to use a smart meter. The analysis revealed that subjective control has a significant effect on the Intention to Use a smart meter and Attitude Towards Usage.

Another work that explored the impact of perceived loss of control on consumers' acceptance of technology was presented by Gupta and Xu (Gupta and Xu 2010). The study investigated the influence of risk and control factors on consumers' acceptance of what they refer to as risky technologies, such as: electronic commerce, mobile payments, internet and mobile banking applications. These technologies require consumers to transmit their personal data over communication mediums that interconnect the distributed system components. The study presents a theoretical model that attempts to investigate the roles that risk and control factors could play in influencing consumers' adoption of technology, and which of the two factors has a stronger significance. The model incorporates two acceptance determinants: Technology Risks and Safety Awareness, both which are linked to Security Concerns and Intention to Adopt. The notion of consumers' perceived control over mobile phone transactions is included under the Safety Awareness construct, such that the more consumers are aware of safety features in mobile banking transactions, the more in control they would feel regarding such transaction. The underlying hypotheses underlying the relationships among these constructs assume that Safety Awareness is negatively related to Security Concerns, such that the more consumers know about the safety features in conducting mobile banking transactions for example the less they are concerned about the security of the transaction. Another hypothesis assumes that the perceived control over a transaction conduced over mobile phone is strongly and positively related to the intention to adopt the technology. And finally, the authors hypothesized that Safety awareness has a stronger effect than technology risk on Adoption Intention. The analysis results supported the last hypothesis in addition to revealing that the technology adoption rate increases as customers feel in control of their transaction, even if the perceived risk in a technology is considered high. The above reviewed literature is summarized in Table 5.3.

Table 5.3: Summary of the literature reviewed on the influence of the perceived loss of control on technology adoption

Domain		Study	Country	Determinant	Observed Behavior	Hypothesis	Results
Financial	E-Commerce	(Koufaris, 2002)	Multi-national	Perceived Control	Unplanned Purchases, Intention to Return	Perceived Control is positively related to Intention to Return	No relationship can be established between Perceive Control and Unplanned Purchases
	E-Commerce, M-banking	(Gupta & Xu, 2010)	India	Safety Awareness	Adoption Intention	Safety Awareness is positively related to Adoption Intention	Safety Awareness significantly influence intention to adopt mobile banking

Mobile technology	(Lee & Park, 2008)	Korea	Perceived Loss of Control	User Satisfaction, Perceived Market Performance	Perceived Loss of Control is predicted to have a negative effect on User Satisfaction	Perceived Loss of Control has a negative impact on User Satisfaction
Smart metering	(Kranz et al., 2010)	Germany	Subjective Control	Attitude Toward Use, Intention to Use	Attitude toward use mediates the relationship between subjective control and intention to use a smart meter	Subjective Control was found to be the second-strongest predictor of Attitude

The manner in which the perceived loss of control was applied in the literature listed in Table 5.3 differs from one study to another, and yielded variant results, which contributes to the significance of studying the impact of the Perceived Loss of Control on consumers' willingness to adopt a smart meter. For example, the study carried out by Kranz et al. showed that the concept of control loss ranked the second strongest predictor of the observed behavior, and though this study was applied in the field of smart metering, yet it differs than the current study in two aspects. First, the model studies the influence of control on Attitude as an observed behavior, as opposed to the intention to adopt a smart in the current study. Furthermore, the model presented by Kranz et al. is extension of the TAM model that consists of three acceptance determinants. This simple model is less complicated than the model presented in the current study, therefore it is worth investigating how perceived control would rank among the many other acceptance determinants in the I^3S^2 model.

On a different level, the concept of perceived loss of control was applied differently in some models. For example, Gupta and Xu applied an inversed version of the concept of perceived loss of control, such that customer's consciousness about safety implies their possession of partial control over the technology. Consequently, this has led to a hypothesis that predicted that Technology Awareness has a positive influence on their intention to adopt a technology. This approach contradicts with the method applied in the current work. In addition, by examining the Results column in Table 5.3 it is evident that the results across the reviewed literature show an inconsistency. Though the influence of loss of control was confirmed for three studies, yet the fourth study's findings reported no support for this influence. Furthermore, the observed behavior on which the influence of perceived loss of control is investigated differs among the studies listed in Table 5.3. To summarize, none of the studies reviewed explored the influence of the perceived loss of control on the intention to adopt a technology via a direct relationship. Thus, the hypothesis for the current work that relates the Perceived Loss of Control to the intention to adopt a smart meter is formulated as follows:

Hypothesis

H_0: Perceived Loss of Control has a negative impact on consumers' acceptance of smart meters.

Perceived Health Risks

Definition

The Perceived health risks determinant is defined as consumers' concerns in relation to the adverse effects of the presence of a smart meter in their premises, or its usage on the health of household members.

Justification

The notion of perceived health risks associated with technology usage is not new, it dates back to debates regarding the dangers of long hours of computer usage, as well as the adverse health consequences of mobile phones usage (Cocosila, Turel et al. 2007). In the case of the introduction of smart meters the situation was not much different. Soon after attempts to roll out the system in a number of countries, activists started campaigning against the system's adverse health effect due to its underlying communication mediums employed by the grid operators to remotely obtain the hourly meter readings, and the digital components within the meter device.

In the United States, several campaigns have erupted in opposition of smart meters, mainly in the states of California and Maine. In California, the opposition to smart meters installation at remote households was fierce and took several forms including: blocking the roads in front of utilities trucks to prevent the installation of the meters, and online campaigns such as "www.StopSmartMetersNow.com" (StopsmartmetersNow.com 2010). This resistance was from both citizens as well as politicians under the claims that the meter jeopardizes individuals' liberties and health due to the meters' radio-frequency radiation. In two California counties: Santa Cruz and Marin, officials extended a suspension on smart meter installations for another year in the former, and approved a ban on smart meters in unincorporated, largely rural areas in the latter. In a similar manner, E-mail campaigns have been launched against the roll-out of smart metering systems in the state of Maine, in addition to applying system roll-out suspension partly due to health-related concerns (Barringer 2011). A response to these concerns came in the California Legislature Assembly Bill AB 37, which requires the Public Utilities Commission- CPUC, regulatory authority over public utilities- to identify alternative communication mediums for consumers whom decline the installation of wireless advanced metering infrastructure services (Huffman 2010).

In January 2011, the California Council on Science and Technology-CCST issued a report (California Council on Science and Technology 2011) as a response to the health risks concerns related to the exposure to radio frequency emitted from smart meters, that were expressed by assembly members of the California Legislature. The report mainly addressed whether the communication standard applied for smart meters in the state provide sufficient protection to consumers' health, taking into consideration current exposure levels to radiofrequency and electromagnetic fields, and whether additional standards are necessary to provide counter measures for adverse health effects (California Council on Science and Technology 2011).

The report was not well-received among groups of activist and academics whom investigated the impact of wireless smart meters operating at households on household members' health. Consequently, this created a roar as some scientists claimed that the report undermined the seriousness of the adverse effects of smart meters on public health, and thus misinforming legislators of the State of California, which as a result hinders proper action from being taken. One example of the many responses to the CCST report came from Dr. Karl Maret, president of the Dove Health Alliance, a nonprofit foundation based in Aptos, California. Dr. Maret concluded his commentary by saying: "In summary, we find that the CCST report is incomplete and misleading giving California State regulators a false sense of security while potentially endangering the future health and well-being of Californians. It is requested that the current Smart Meter deployment be halted pending a more comprehensive scientific investigation of the biological response and health impacts of the non-thermal aspects of this technology" (Maret 2011).

In The Netherlands, though those voicing concerns over the adverse impact of the radiofrequency emitted from smart metering devices were not as extreme as those in California, yet energy distribution networks experts express their concern regarding this matter, and speculate to which extent health risks perceived by consumers can influence their acceptance and intention to use a smart meter.

Determinant in the Literature

The literature investigating the impact of perceived health risks on consumers' acceptance of new technologies is scarce regardless of the type of technology. Cocosila et al. (Cocosila, Turel et al. 2007) investigated the role of perceived health hazard concerns among consumers on their intention to use a cell phone. The authors emphasized that many studies have explored the potential impact of perceived risks on intention to use various technologies. However, those studies addressed the influence of general risks, but hardly any included a health risk determinant. Thus, confirming the rareness of literature tackling that matter. The authors argue that risk perceptions have many facets that must be addressed by researchers. These facets are: financial, performance, social, physical (including health), psychological, time, privacy and overall risks (Cocosila, Turel et al. 2007, Huffman 2010, StopsmartmetersNow.com 2010, Xin Luo, Han Li et al. 2010, Barringer 2011) and that research efforts that followed that approach have consistently found that physical risk was the least important determinants of intention of technology adoption. This, in addition to the scarce literature covering health hazards, could be attributed to the marginal health risks associated with usage of technology. The aim of Cocosila's et al. work was to investigate consumers' perception of health risks, and investigate the impact of Perceived Health Risks on Perceived Usefulness and the Behavioral Intention to adopt cell phone technology, by extending Davis's TAM model. The model was applied to cell phone users in a Canadian context. Respondents to the survey used to estimate the model were presented randomly with either information supporting claims that the user of a cell phone is safe or otherwise. The findings of the analysis revealed that consumers whom were presented with "safe" information reported lower health risk perception, than others. Furthermore, Perceived Health Risk has a small negative indirect influence on intention to use cell phones, which was mediated by Perceived Usefulness. Another finding was that the impact of Perceived Health Risk is negligible compared to Perceived Usefulness such that users hardly care about these risks when determining the usefulness of a cell phone. Finally, the results revealed that mature people have a stronger health risk perception than younger individuals.

Another study that tackled perceived health risks that are associated with usage of new technologies was conducted by Pozzi (Pozzi). In his work, Pozzi devised a theoretical framework to measure acceptance of smart home technologies that included a Health determinant, which explores the influence of the use of smart home technologies on consumers' acceptance of such technologies. The framework was tested by means of a survey, to which respondents were divided into two groups, those older than the age of forty and those younger than forty. For both groups the results showed that health concerns did not prove to be a significant indicator of smart home technologies acceptance.

The studies reviewed above proved Perceived Health Risks to have an insignificant and even negligible influence on an individual's intention to adopt a technology, or even mediated by other acceptance determinants to form an indirect relationship with adoption intention. This is makes worthy to explore the influence of Perceived Health Risks on the intention to adopt a technology in the context of smart metering system, to verify whether health concerns expressed by groups of consumers are of a magnitude that requires attention, and if proven to be significant then to what extent does it rank among other acceptance determinants in the I^3S^2 Model. For the purpose, the following hypothesis is formulated that predicts the influence of the Perceived Health Risks on consumers' willingness to adopt a smart meter.

Hypothesis

H_0: Perceived Health Risk has a negative impact on consumers' acceptance of smart meters.

5.3.2 Smart Metering Acceptance Stimulants

Mass Media

Definition

The Mass Media acceptance determinant refers to the extent to which consumers are exposed to public messages from the government or energy companies regarding the smart metering system.

Justification

Mass media has several different interpretations and perspectives such as frequency of exposure, sort of media, media content

Determinant in the Literature

The mass media acceptance determinant is included in a number of technology adoption theories and models throughout the literature. Its definition however, and how it relates to other acceptance determinants differs from one model to another, depending on the researchers' perspectives and predictions. The results of the empirical data analysis of these studies vary based on several factors such as: the focus of the study, researchers' perspective of mass media, and how they perceive its impact on technology adoption. Some of these viewpoints that were tackled in previous research efforts are mentioned below.

In 1999 Leung and Wei (Leung and Wei 1999) aimed to identify the characteristics of individuals whom do not own a cell phone, and what factors may be leading to that. The researchers presented a theory based on the Innovation Diffusion Theory. The concept of Mass Media Use was included in the theory among several factors, which were hypothesized could explain the lack of willingness to adopt cell phone technology. The angle of interest of mass media for Leung and Wei was the frequency of exposure; they asked respondents via a phone-survey to report the number of minutes per day they spent watching television and listening to radio, in addition to the number of days they spent reading newspapers and magazines per week. The results of this work revealed that fifty nine percent of cell phones non-adopters are females and that they are seven years older than those owning a cell phone. Furthermore, the non-adopter group appeared to be blue-collar workers whom earn an average of 1290 dollars per month less than cell phone owners, and hold a lower level of education. The most relevant finding for the current study is that cell phone non-adopters seem to read newspapers and magazines less than cell phone adopters. These findings were deemed consistent with numerous technology-adoption studies, which proved that technology non-adopters are usually from lower socioeconomic strata (Leung and Wei 1999). The authors initially predicted that the more exposure to mass media a cell phone non-adopter has, the more likely they would be to obtain a cell phone. Based on the results of the analysis, this hypothesis was not supported and therefore it was dropped. The authors argue that the insignificant relationship between mass media and cell phone adoption intention could perhaps be due to their 'measure being too broad without attention to types of media content" (Leung and Wei 1999), which leaves room for future work recommendation to refine the items used for measuring the Mass Media Use construct.

The influence of mass media on technology acceptance was investigated by Vishwanath and Goldhaber in 2003 (Vishwanath and Goldhaber 2003) from a slightly different perspective in terms of mass media definition. The researchers presented a model that is an extension of a TAM and Innovation Diffusion Theory hybrid model. It aims to examine factors that could contribute to the adoption of cell phones among late technology adopters. The included mass media construct encompasses two aspects: Media Use, and Media Ownership. The Media Use construct was based on Leung and Wei's (Leung and Wei 1999) definition of Mass Media, which was the number of minutes per day spent watching TV and listening to radio plus to the number of days per week spent reading newspapers and magazines. Vishwanath and Goldhaber extended this definition by adding the number of minutes of internet use. In a similar manner, the authors adapted Leung and Wei's Media Ownership construct, which is defined as the type of media consumers owned or subscribed to including pagers, fax machines and internet services among others. Fundamentally, the model assumes that exposure to mass media has a significant influence on making decisions to adopt an innovation. The model depicts an indirect relationship between the mass media constructs and the Behavioral Intention to adopt cell phones. This indirect relationship is via five belief variables (perceived ease of use, perceived compatibility, perceived observable benefits and perceived usefulness) that originally come from either the TAM model or the Innovation Diffusion Theory, and an Attitude construct. The underlying hypothesis of this relationship states that “Media Use and Media Ownership will have a significant direct effect on perceived ease of use, perceived compatibility, perceived observable benefits, and perceived usefulness” (Vishwanath and Goldhaber 2003). Furthermore, the model is also based on another hypothesis that assumes a mediating role of mass media constructs in the following manner: “Media Use and Media Ownership will mediate the relationship between socio-demographic variables: age, income, occupation, education, gender, and the belief variables” (Vishwanath and Goldhaber 2003). To identify the model, the researchers gathered a dataset by means of a phone-survey using Computer Aided Telephone Interview -CATI system in Buffalo, New York. All calls were made between Tuesday and Friday to eliminate problems relating to different Media Use levels between weekdays and weekends. The analysis results were consistent with results of previous research efforts in the field that focused on late technology adopters. The results showed that cell phone non-adopters were individuals whom were distinguished by several characteristics, one of which is lower levels of mass Media Use. The hypothesis originally predicted a direct impact of Media Use and Media Ownership on belief variables, the results however showed that the significant impact of Media Use was proven only for one belief: Perceived Observability, such that Media Use had an indirect impact on Attitude by influencing perceptions of Perceived Observability. Whereas Media Ownership had a significant impact on Relative Disadvantage, Perceived Incompatibility and Lack of Observability. Furthermore, Media Ownership was proved to significantly mediate demographic variables that significantly influenced the intention to adopt the technology, in contrast to the original hypothesis that predicted that Media Use and Media Ownership would mediate beliefs about an innovation.

In 2008 Lopez-Nicolas et al. (Lopez-Nicola, Molina-Castillo et al. 2008) investigated the acceptance of advanced mobile services, such as banking and E-commerce, within a Dutch context. Like many other studies in the area of innovation acceptance and diffusion, the researchers based their theory on a hybrid model that is based on the TAM model and the Innovation Diffusion Theory. The aim of Lopez-Nicolas et al. model is to predict factors that could potentially contribute to consumers' usage of advanced mobile services. Market research analysis revealed that consumers are hesitant to utilize advanced mobile services via their mobile phones despite their knowledge of these services. This stresses the importance of service providers' efforts to discover effective means of communication to reach their consumers' and inform them about the advantages to be gained by usage of their offered services. The authors studied the role of subjective norm on consumers' adoption of technology from two different perspectives: interpersonal influence and external influence, which were represented in the model respectively by a social influence and mass media acceptance constructs. The authors defined Media influence as the “degree to which people had the impression that mass media reports encouraged them to use a new system” (Lopez-Nicola, Molina-Castillo et al. 2008).

The impact of Mass Media construct on the Intention to Adopt technology was predicted to be indirect via the Social Influence and Attitude constructs. Based on the Innovation Diffusion Theory; the influence of Mass Media is dominant in the initial stages of innovation adoption. This is true due to the small number of technology users, which in turn diminishes the influence of word-of-mouth. Therefore, the hypotheses underlying the relationships between Mass Media, Social Influence, Attitude and Intention to Adopt an innovation are: Mass Media influence has a positive effect on Social Influence, Social Influence has a positive effect on Attitude, and Attitude has a positive effect on Behavioral Intention. These hypotheses were supported by analysis of empirical data to test the model. Furthermore, the researchers compared their original model to an alternative one where a direct relationship between Social influence and Behavioral Intention was depicted and proved to be significant. In summary, the results proved that Media Influence has a significant impact on consumers' intention to adopt advanced mobile services and that Social Influence was determined by mobile services perception. These results should be taken into consideration by service providers in order for them to promote their services among the public (Lopez-Nicola, Molina-Castillo et al. 2008). The afore reviewed literature is summarized in Table 5.4.

Table 5.4: Summary of the literature reviewed on the influence of mass media on technology adoption

Domain	Study	Country	Determinant	Observed Behavior	Hypothesis	Results
Mobile phones	Leung & Wei, (1999)	Hong Kong	Mass Media Use	Adoption Intention	The more exposure a cell phone non-adopter has to Mass Media, the more likely they would be to obtain a cell phone	Cell phone non-adopters seem to read newspapers and magazines less than cell phone adopters
Mobile phones	(Vishwanath & Goldhaber, 2003)	U.S.	Media Use, Media Ownership	Behavioral Intention	- Media Use and Ownership, have significant direct effect on belief variables (Perceived Ease of Use, Perceived Compatibility, Perceived Observable Benefits, and Perceived Usefulness) - Media Use and Ownership mediate the relationship between demographic and belief variables	- Non-adopters had lower levels of Media Use - Media Use and Ownership have a significant direct effect on Perceived Observability - Media Ownership had a significant impact on Relative disadvantage, Perceived Incompatibility and Lack of Observability - Media Ownership significantly mediate demographic variables that significantly influenced the intention to adopt
E-Commerce, Mobile banking	Lopez-Nicolas et al., 2008)	The Netherlands	Media Influence	Behavioral Intention	- Media Influence has a positive effect on Social Influence - Social Influence has a positive effect on Attitude - Attitude has a positive effect on Behavioral Intention	All three hypotheses were confirmed

The literature reviewed of the influence of mass media on technology adoption showed a significant influence of the exposure to media or positive media message regarding a technology, on consumers' willingness to adopt said technology. The technologies reviewed in Table 5.4 are all variants of ICT-intensive, privacy-sensitive innovations, such as: cell phones, E-commerce and M-banking technologies. Though the smart metering system share these two characteristics with the afore mentioned technologies, yet it differs than them by it being a critical infrastructure as opposed to an ICT infrastructure that is utilized for commercial purposes. This property could have an influence to how individuals perceived and respond to a technology, since for example one's adoption of a cell phone is not only voluntary but self-initiated, which opposes to a technology like a smart meter that is state-initiated and in some countries its adoption is mandatory. Furthermore, the influence of media on the intention to adopt a technology in the studies listed in Table 5.4 was mainly investigated by an indirect relationship via other constructs such as: Perceived Ease of Use, Perceived Compatibility, Perceived Observable Benefits, attitude and Perceived Usefulness. This differs than the approach adopted in the current work in two ways: first, in the current work the influence of mass media exposure on the intention to adopt a smart meter is investigated both directly and indirectly. Second, the indirect relationships between media and smart meter adoption is mediated by concepts that differ than those applied in the literature, these concepts are perceived organization image and technology awareness, both of which are described in further detail in subsequent sections of this chapter.

In light of the differences listed above, the hypotheses below were formed to govern the hypothesized relationships among mass media, technology awareness, perceived organization image and acceptance of a smart meter.

Hypotheses:

H_{0a}: Mass Media has a positive impact on consumers' acceptance of smart meters.

H_{0b}: Mass Media has a positive impact on Technology Awareness.

H_{0c}: Mass Media has a positive impact on Perceived Organization Image.

Technology Awareness

Definition

Technology awareness is the extent of consumers' knowledge about the newly introduced technology.

Justification

An important factor of understanding consumers' acceptance of newly introduced technologies is consumers' knowledge of such technology. An IBM survey of over ten thousand respondents across fifteen countries revealed that 60% of people do not know what a smart meter is (IBM News Room 2011, Schwarts 2012).

The inclusion of the concept of technology knowledge as an acceptance determinant in the I^3S^2 model stems from the fact that people are most likely to reject what they do not know. The exposure of consumers to technology-related information, and their level of knowledge about a such technology, its advantages and disadvantages has an impact on its rate of adoption (Rogers 1995), such that the more the consumers know about the benefits to be gained via the usage of a technology, the more likely they will adopt it. Empirical data analysis results of related research efforts throughout the literature reveal that technology-related knowledge is an essential factor of consumers' acceptance of technologies and especially for E-government systems that are being deployed by many governments around the world (Chan, Thong et al. 2010). In a similar manner, the launch of a smart metering system in The Netherlands shares a trait with E-government systems, such that it is an initiative by the government and it is originally intended for mandatory use by citizens.

In addition, as governments and governing organizations of such systems commit significant financial investments in such innovations, they should consider the importance of informing the population about these innovations, and should invest in such a process to avoid consumers' reluctance to use these technologies or even reject them. Increasing consumers' awareness about newly introduced innovations and technologies can be achieved by broadcasting public messages via the different media channels such as television, radio, articles in the popular press and websites (Gefen, Karahanna et al. 2003).

Determinant in the Literature

In the area of E-commerce, Gefen et al. in 2003 (Gefen, Karahanna et al. 2003) extended the TAM model to investigate experienced online shoppers' intention to make repeat purchases. They extended the original TAM model by adding a Trust construct along with four trust antecedent constructs, one of which is Knowledge-Based Familiarity. The aim of the model is to investigate the indirect impact of the four trust antecedents on the consumer's intention to make an online purchase via the Trust, Perceived Usefulness, and Perceived Ease of Use constructs. The impact of Knowledge-Based Familiarity construct on shoppers' intention to make purchases was studied via the Trust construct given that trust is a vital key within the context of E-commerce to retain consumers. The underlying hypothesis of the model, which is based on previous research efforts, states that higher levels of consumers' trust in E-vendors lead to higher levels of Intention to Use a technology. The authors argue that theirs is a novel approach of combining two perspectives of trust: consumers' trust in E-vendors and their trust in the information technology, i.e. the commercial website in this case, both of which were studied separately by information systems researchers. It is claimed that the integration of these two perspectives, in addition to exploring factors that could lead to building online trust in a virtual context as opposed to a real context in which consumers experience human interaction, can result in a deeper understanding of technology acceptance constructs and how they relate to the Intended Use of business-to-consumer website, i.e. intention to shop online. Knowledge-Based Familiarity is defined as "experience with the what, who, how and when of what is happening" (Gefen, Karahanna et al. 2003). It encompasses a spectrum of concepts such as:

- Its ability to reduce social uncertainty through increased understanding of what is happening in the present.
- Familiarity with the way other business partners work and their limitations.
- Its ability to counteract concerns that the other party may be opportunistic.

However, in E-commerce familiarity corresponds to how well a consumer comprehends the website procedures such as when and how to enter credit card information. Gefen et al. based their model on literature that proved that familiarity aids in forming trust in an E-vendor as it allows for understanding the behavior of the trusted party. In addition, familiarity with ICT services in addition to an E-vendor leads to a higher level of trust. Furthermore, less confusion experienced by online shoppers in using an ICT service leads to lower chances of consumers mistakenly feeling that they are being taken advantage of (Gefen, Karahanna et al. 2003). In a similar manner, the authors assume that the more familiarity a consumer has with an ICT service, i.e. a website, due to previous visits, the more such consumer would perceive the website to be easy to use. The impact of familiarity on consumers' intention to shop online was investigated via an indirect relationship in Gefen's et al. model, the underlying hypotheses of the relationships between familiarity, trust, perceived ease of use, and intention to use are listed in Table 5.5.

Table 5.5: Relationships and hypotheses underlying Gefen's et al. model

Relationship	Hypothesis
Familiarity – Trust	familiarity with trustworthy e-vendor will positively affect trust in the e-vendor
Familiarity – Perceived Ease Of Use	familiarity with e-vendor will positively affect perceived ease of use
Trust- Intention to Use business to consumer website	Trust in the e-vendor will positively affect intended use of business to consumer website
Perceived Ease Of Use- Intention to Use business to consumer website	Perceived Ease Of Use will positively affect Intended use of business to consumer website

The results of this work based on empirical data showed that the Perceived Ease Of Use was increased by familiarity, i.e. a conventional and familiar website. On the other hand, familiarity with an E-vendor, as trust antecedent, is significantly correlated with Trust. However, it did not significantly increase Trust when the other three Trust antecedents were present in the model. Furthermore, a modification to the existing theory which was showed by the results is that the effect of Familiarity with a website on Trust in an E-vendor was fully mediated by Perceived Ease Of Use (Gefen, Karahanna et al. 2003).

The relationship between consumers' awareness about a certain technology and their willingness to accept or adopt such technology was investigated by several research efforts within different domains. Choudrie and Dwivedi (Choudrie and Dwivedi 2004) conducted in 2004 a review of the literature addressing consumers adoption of broadband technologies, based on which a theoretical framework was devised. The authors offer no results based on empirical data, however, they suggested that the adoption of broadband technologies needs an understanding among potential technology adopters regarding benefits gained by usage of the technology, and thus the related hypothesis stated that the lack of knowledge on broadband, its availability and benefits inhibit broadband adoption. Furthermore, they assumed that consumers' ignorance of potential benefits to be gained by adopting a technology affects the level of their perceived need of the technology, which in turn can result in consumers rejecting it. The related hypotheses stated that "the lack of knowledge on broadband, its availability and benefits inhibit broadband adoption, and that the lesser the perceived needs of obtaining the broadband, the less likely that it will be adopted".

In 2010 Chan et al. (Chan, Thong et al. 2010) studied citizens satisfaction with mandatory adoption of E-government technologies. The researcher adopted the UTAUT model and extended it with eight external variables, each of which belongs to a different stage of the process of launching a technology product. These stages are: market preparation stage, targeting stage, positioning stage, and execution stage. The model is aimed to measure the impact of all eight variables on consumer satisfaction with E-government services via acceptance determinants of the UTAUT model. The external variable "Awareness" belongs to the market preparation stage. The purpose of this stage is to prepare the market for the introduction of new technology by providing the public with relevant information promoting awareness among them regarding the new technology. The authors argue that with the launch of mandatory systems governments should pay special attention to recruiting media channels to broadcast public service announcements in order to effectively increase public awareness and promote social norms, such that "the more effective the public service announcements are in creating citizens' awareness about public issues, the greater is the normative pressure being created in society". The model predicted an impact of awareness of social influence, the underlying hypothesis of this relationship is "Awareness will positively influence social influence for using mandatory E-government technology", which was tested and supported by empirical data. Awareness proved to have a significant influence on social influence, implying that informing consumers about a technology can potentially increase normative pressures. However, among the other seven external variables awareness appeared to be the only variable that has an insignificant effect on satisfaction, where the relationship between every variable and satisfaction was captured by an indirect effect via every variable's respective UTAUT acceptance construct.

Another effort that explored the potential impact of consumers' technology-related knowledge on technology acceptance was conducted by Verdegem and de Marez in 2011 (Verdegem and De Marez 2011) in the area of mobile TV and news services. They introduced a framework that focused on studying consumers' behavioral intention to adopt and their actual adoption of technology, with special attention paid to late technology adopters. The framework is an extension of the UTAUT model using a comprehensive approach that integrates exiting but scattered acceptance determinants throughout the literature. The researchers divided the factors hypothesized to impact the observed behavior under three categories, which in turn influences the innovativeness or actual adoption. These categories are innovation related characteristics, adopters related characteristics and marketing strategies, where the latter is a group the authors' claim that is often neglected by existing literature and that not enough insight exists on the profile of such a group. The influence of technology awareness on technology adoption was studied by including a product knowledge determinant in the model under the adopter related characteristics. The model was validated by its application to a number of research projects in preparation to the launch of two mobile innovations in Belgium, these technologies are mobile news, which was conducted in 2006, and mobile TV service conducted in 2007. The results of this work showed that influence of product knowledge on technology adoption was lower for mobile TV services than it is for mobile news, these results were used as input for launching 3G mobile telephony and digital TV services in Flanders.

Reviewing the literature summarized in Table 5.6 showed variance in the manner in which the concept of Technology Awareness was included in the technology acceptance models of these studies, to study its effect on technology adoption. One study included technology awareness in an implicit manner, whereas another study provided no empirical results that supported their hypothesis. Furthermore, two studies that explicitly included technology awareness as an acceptance construct in their respective models and provided empirical results, have studied the influence of technology awareness on consumers' willingness to adopt an innovation via an indirect relationship rather than directly, via concepts such as social influence, perceived ease of use and trust. Moreover, the field in which these studies have been applied encompasses a range of ICT-intensive, privacy-sensitive innovations, which -as discussed under the Mass Media construct- are technologies that differ than a smart meter in the sense that they are self-adopted technologies rather than state-deployed.

In this work the influence of Technology Awareness on consumers' willingness to adopt a smart meter is investigated by including the concept explicitly as an acceptance determinant in the I^3S^2 Model. The said influence is examined via a direct relationship between the two constructs representing both Technology Awareness and the intention to accept a smart meter.

Hypothesis

H_0 Technology Awareness has a positive impact on consumers' acceptance of smart meters.

Perceived Organization Image

Definition

The Perceived Organization Image refers to the extent of consumers' knowledge of an organization that governs the newly introduced technology, which in the case of the smart metering system are the energy grid operators.

Table 5.6: Summary of the literature reviewed on the influence of technology awareness on technology adoption

Domain	Study	Country	Determinant	Observed Behavior	Hypothesis	Results
E-Commerce	(Gefen et al., 2003)	U.S.	Knowledge-Based Familiarity	Intended Use of business-to-consumer website (IU)	- Familiarity with E-vendor positively affect Perceived Ease of Use(PEOU) - Familiarity with a Trustworthy E-vendor will positively affect trust in that E-vendor - PEOU will positively affect IU - Trust in the E-vendor will positively affect IU	- PEOU was increased by - familiarity with an E-vendor - Familiarity significantly correlated with Trust, but did not significantly increase trust when other trust antecedents were present in the model - Familiarity's effect on Trust was fully mediated by Perceived Ease Of Use
Broadband technology	(Choudrie & Dwivedi, 2004)	U.K.	Requisite Knowledge	Broadband Adoption	Lack of knowledge on broadband inhibits broadband adoption	No results based on empirical data
E-Government	(Chan et al., 2010)	Hong Kong	Awareness	Satisfaction	- Awareness will positively influence Social Influence for using mandatory E-government technology - Social influence will positively influence satisfaction with mandatory E-government technology	- Awareness has a significant influence on Social Influence - Awareness had an insignificant effect on Satisfaction
M-news, M-TV	(Verdegem & De Marez, 2011)	Belgium	Product Knowledge	Behavioral Intention to Adopt	Product Knowledge is assumed to positively relate to innovativeness	Influence of Product Knowledge on technology adoption was lower for mobile TV services than it is for mobile news

Justification

Organization or company image received a varying degree of attention from one body of technology acceptance literature to another depending on the technology which its acceptability is being investigated. In general, the number of studies throughout the literature investigating organization image and how it relates to behavioral intention is scarce. These studies encompass a spectrum of varying definitions of organization image as a concept, the behavior observed, and how image relates to this behavior. Some example definitions are mentioned next from different fields of research.

In the marketing of goods literature, company image was defined as "the impressions and associations, the beliefs and attitudes that are held in consumer's memory with regard to the company" (Barich & Kotler, 1991; Keller, 1993) cited in (de Ruyter and Wetzels 2000). It has been defined as "personality" by (Arons, 1961) cited in (de Ruyter and Wetzels 2000), "a collection of symbolic associations with regard to the product" (Finn, 1985) cited in (de Ruyter and Wetzels 2000), and "the picture that an audience has of an organization through the accumulation of all received messages" (Ind, 1997) cited in (de Ruyter and Wetzels 2000).

In this current work, organization image is tackled differently, as this acceptance determinant aims to capture how well consumers are familiar with energy grid operators as the organization providing the meters. Furthermore, the model aims to capture the relationship between the extent of familiarity with a grid operator and consumers' willingness to accept the installation of an operational meter in their homes.

The motivation behind the inclusion of the organization image as an acceptance determinant in the I^3S^2 model stems from two reasons. The first one is the observation that many people either do not know, or are not sure who the energy grid operator in their region is. This is mainly attributed to the recent vertical unbundling of services in the energy market, which lead to consumers' unfamiliarity of the now separated energy grid operators. The second reason is that interviews with practitioners from some of the energy grid operators in The Netherlands revealed that these organizations face this problem during the process of smart metering infrastructure rollout. Upon visiting consumers' homes for meter installation, technicians from these organizations are sometimes faced with consumers rejecting the installation of the meter at their homes as they never heard of the organization and hence will not let the technicians enter their homes. The fact that the problem was confirmed from both sides (consumers and energy grid operators) proves the significance of organization image as an acceptance determinant and led to its inclusion in the model.

Determinant in the Literature

The impact of the image of an organization and how such image is perceived by consumers on their willingness to adopt a newly deployed technology has been addressed by many researchers for various technologies and in different areas. However, each one of these studies presents a unique perspective in terms of how the concept of a company's image is defined and in what manner researchers hypothesize how it impacts a varying range of behaviors. Some of these studies are presented below. In general, all of these research efforts differ from the current work as none of them investigated the impact of organizational image as it is defined in the current study on technology acceptance as an observed behavior.

In the telecommunication domain, Ruyter and Wetzels (de Ruyter and Wetzels 2000) studied in 2000 the role of the company image in a company's ability to extend their service brands to either new or traditional telecommunication markets. The authors stated that the concept of organization image has not received much attention in the service marketing literature as opposed to the goods marketing literature. Where company image was proven in goods marketing literature to play an important role in forming consumers' impressions, believes, and attitudes regarding a company; notions that are developed through the knowledge that a consumer accumulated regarding such company. Ruyter and Wetzels further argued that in comparisons between services and goods, companies of the former in particular require a positive image to ensure a higher quality perception and promote word-of-mouth communication. This is true due to two reasons: first, as opposed to goods, services are intangible as they can't be seen, felt or touched. Thus, they are often perceived as performance instead of tangible entities. Second, when competing service providers become equally ranked by consumers based on their performance, price and availability, the role of company image becomes more significant as it acts as an “information cue which may create a halo effect on customer judgments relating, for instance, to service provider credibility or the perceived quality of its services” (Andreassen & Lindestad, 1998) cited in (de Ruyter and Wetzels 2000). Ruyter and Wetzel's theory represented the company image concept with a Corporate Image construct. The theory is based on a number of hypotheses that predicted the role of the company image on service extension by means of three most frequently addressed extension criteria throughout the literature: (1) corporate credibility; (2) expected service quality; and (3) purchase intention. The first hypotheses stated that due to the intangible nature of service and the difficulty for consumers to evaluate such services before purchasing them, then consumers will evaluate innovative late service providers more favorably than providers with innovative pioneers’ image. The second hypothesis which took the interaction between innovation entry image and market relatedness into consideration stated that: “Consumers will evaluate service extensions by companies with an innovative late mover image in a related market more favorably than services extensions by companies with an innovative late mover image in an unrelated market in terms of the” three evaluative criteria listed above. The third hypothesis stated that the “relative difference between companies with a late mover image and companies with a pioneer image will be larger in unrelated markets than in related markets in terms of the” three evaluative criteria listed above. The analysis of Ruyter and Wetzels work revealed that service extension by companies with an innovative late mover advantage are perceived more favorably than companies with an innovative pioneer image in terms of corporate credibility and expected service quality. Furthermore, service brand extension by companies with an innovative late mover image in a related market are more favorably evaluated than service brand extension by companies with an innovative late mover image in an unrelated market in terms corporate credibility and expected service quality. Finally, results showed that relative difference between companies with an innovative late mover image and companies with a pioneer image will be larger in unrelated markets in terms of corporate credibility and expected service quality.

Another research effort that tested the role of the company image on technology acceptance was carried out by (O'Donnell 2010), whom formulated a model for a continuous audit innovations adoption. The theoretical model -which is based on the Innovation Diffusion Theory- IDT by Rogers (Rogers 1995)- is intended to aid auditors and members of financial communities in developing an understanding of individuals' adoption of auditing-related technologies, to devise strategies for promoting the use of such technologies. In their model, the authors included seven factors that are hypothesized to have an influence on the Continuous Auditing Adoption, these factors are: Relative Advantage, Compatibility of technical resources, Company Innovativeness, Observability, Security, Trust and Company Image, of which the last was adopted from (Benbast 1991) cited in (O'Donnell 2010). In this work, the research applied a unique perspective of the Company Image in studying its effect on technology adoption; they investigated whether the adopter's image has an influence on their intention to adopt the new technology. This perspective stems from the fact that the rapid growth in Internet and E-commerce technologies have led to a change in how business operate by utilizing these technologies. This created a situation where businesses ran the risk of having negative reputation (image) as being inflexible and not keeping up with modern technologies and innovations. From this perspective, O'Donnel believes that audit firms would be more likely to adopt continuous auditing technologies to demonstrate an image of being innovative, flexible and keeping up with modern technology. Therefore, the hypothesis of this work that relates the Company Image to the Continuous Audit Adoption technologies stated that: continuous audit innovations "adoption will be positively associated with the perception that adopting [these innovations] will improve the audit firm's image". This theoretical framework was presented without the support of empirical data.

Loiacono et al. (Loiacono, Watson et al. 2007) presented a technology acceptance framework in the area of E-commerce. The framework investigates the influence of consumers' perception of websites on their intention to revisit a website or commit a purchase. Furthermore, it is theoretically founded on the TAM model and Theory of Reasoned Action, and which captures consumers' assessment of a website. Among the many various determinants included in the framework is a Consistent Image construct. The significance of this work stems from the fact that in the information age websites have become the front line of businesses that projects its image and therefore they inevitably have an influence on consumers' perception of these businesses. The acceptance determinants in the model were divided into four categories: ease of use, usefulness in gathering information, usefulness in carrying out transactions, and entertainment value; where Consistent Company Image is included under the last category. The concept of company image in Loiacono's et al work was applied from a different perspective than in this current work, as the researchers were particularly interested in the influence of a Consistent Company Image projected by a website to consumers. The framework was tested by having a group of respondents complete four rounds of questions after spending some time using a set of E-commerce websites. The websites were divided into four categories: books, CDs, hotels reservation and airline reservation. The result of the analysis of the four rounds of questionnaires revealed that a significant relation between company image and intention to reuse via the entertainment as a mediating construct. The authors concluded that the framework serves as a handy indicator for E-commerce companies as it acts as an evaluation tool that not only assess a company's websites with regards to various set of criteria but also aid competing companies to know how they rank against this benchmark.

A different perspective of employing the company image construct in technology acceptance and diffusion theories was carried out by Cho et al. in 2011 (Cho, Lee et al. 2011) in the area of recruitment. In their model, which is an extension of TAM model, the researchers investigated the willingness of job seekers to utilize websites of companies to apply for positions within these companies. The use of internet for job seeking has increased during the past years as companies started advertising their vacancies on their recruitment pages of the official company's website, as it helped companies in reducing the hiring costs of new employees. As a result companies report that their recruitment page is the second most visited page of their respective websites. The proposed model by Cho at al. explores the influence of a group of technology acceptance dominants on individuals' attitude towards Corporate Image and their intention to use the company's website for recruitment purposes. As with the rest of the literature reviewed for the company image construct, the work of Cho et al. tackles the relationship between the Corporate Image and the acceptance of technology from a different perspective compared to the approach used for the current study. The researchers anticipated a relationship between enjoyment derived from using a technology (i.e. a website in the context of their study), Corporate Image and intention of applying for a vacancy within the corporate (i.e. technology usage). This approach is based on results of previous studies (Hoer and Macinnis, 2009) cited in (Cho, Lee et al. 2011) that when individuals are in a good mood they are highly likely to like a brand or company. The authors further argue that a positive experience of using the website can generate sense of enjoyment and interest which in turn gives an individual a positive image of a company and promotes the use of the website to apply for a job. Thus the hypotheses relating Perceived Enjoyment, Corporate Image, and intention to use a company's website stated that perceived enjoyment will have a positive impact on Corporate Image and on job seekers' intention to apply. Furthermore, the authors predicted another relationship between job seekers' attitude towards a company's website, company's image and a job seeker's intention to use the website, such that a positive attitude towards a company's website can lead to a job seeker's perception of a positive company image, where the latter play a mediating role between attitude and intention. Results of the empirical data analysis of Cho et al. work revealed that the company image indeed has a significant impact on a job seeker's intention to use a company's website when searching for a job. In addition, the results also showed that attitude has an influence on individuals' perception of the image of a company. The literature reviewed for the influence of the Perceived Organization Image on individuals' willingness to adopt technology is summarized in Table 5.7.

The literature reviewed in Table 5.7 presents different angles from which the concept of company image was tackled. For example, Loiacono et al. applied the concept of a consistent image of a company rather than the overall impression of a company that is perceived by individuals. Another difference that is related to the structure of the technology acceptance model is observed in the work of Cho et al., where corporate image as an acceptance determinants acts as a mediator between other acceptance determinants and the observed behavior. Furthermore, the studies listed in Table 5.7 investigate the influence of company image on variants of observed behavior, or notions that fall within a wide spectrum such as: corporate credibility, service quality, purchase intention, or attractiveness.

In this work, the concept of company image is applied to test the influence of how well consumers are familiar with an energy company on their willingness to adopt a smart meter. The aim is to confirm the predicted positive influence of the perceived company image on technology adoption in the field of smart metering, as was proven for other technologies such as telecommunication, E-Commerce and E-Recruitment. The hypothesis underlying the relationship between the perceived company image and consumers' willingness to accept a smart meter is presented below.

Table 5.7: Summary of the literature reviewed on the influence of perceived organization image on technology adoption

Domain	Study	Country	Determinant	Observed Behavior	Hypothesis	Results
Telecommunication	(Ruyter & Wetzels, 2000)	The Netherlands	Corporate Image	Corporate Credibility (CC), Expected Service Quality (ESQ), Purchase Intention (PI)	- Late service providers perceived more favorably than those with innovative pioneers image (PI) - Service extensions (SE) by companies with innovative late mover image in (ILMI) a related market are more favorable than those with ILMI in an unrelated market - Relative difference between ILMI companies and PI ones is larger in unrelated markets	- SE by companies with an innovative late mover advantage are evaluated more favorable than companies with an innovative pioneer image in terms of CC and ESQ - SBE by companies with ILMI in a related market are more favorably evaluated than SE by companies with an ILMI in an unrelated market in terms of CC and ESQ - Relative difference between companies with ILMI and companies with a PI will be larger in unrelated markets in terms of CC and ESQ
Audit innovations	(O'Donnell, 2010)		Company Image	Continuous Auditing Adoption	CA adoption will be positively associated with the perception that adopting CA will improve the audit firm's image	No empirical data analysis
E-Commerce	(Loiacono et al., 2007)		Consistent Company Image	Intention, ReUse of Website	Consistent Company Image has an impact on Reuse of a Website	Significant relation between Company Image and Intention to Reuse via the Entertainment as a mediating construct
E-Recruitment	(Cho et al., 2011)	U.S.	Corporate Image	Attractiveness	Corporate Image will mediate the relationship between job seekers' attitude toward a hotel's Web site and their attraction to the hotel	Corporate Image had a positive impact on job applicants' attraction to the corporation as an employer

Hypothesis

H_0: Perceived Organization Image has a positive impact on consumers' acceptance of smart meters.

Data Architecture

Definition

Data Architecture refers to the data storage architecture of the system. Whether it is a centralized architecture where the data resides at the Central Access Server shown in Figure 3.2, or distributed one where the data resides at the smart meter device installed at consumers' homes.

Justification

Data architecture is part of a broader discipline, i.e. ICT architecture, which "involves the structural organization of hardware, applications, processes and information flow" (Jacobs 2010). In general, data architecture is concerned with the specification of different aspects related to the data handled by the system such as: data items, structures, stores, and flows among others. This work focuses on the architectural layout of data stores of the system, which is whether a system adopts a centralized or distributed data architecture, and the impact of the chosen architecture on the acceptance level of such technology by consumers. A centralized approach or a "repository model" (Sommerville 2000) dictates that the data is stored in a central point (servers) of the system, in the case of the smart metering system this would be the central access server. Whereas a decentralized or a distributed approach is based on storing the data at scattered locations across the system, where in the case of the smart metering system this implies storing the meter readings on the metering device itself rather than forwarding the detailed meter readings to the central access server of the system. Both the smart metering and the OV-Chipkaart systems in The Netherlands adopt a repository model, where information obtained from data acquisition points reside in a central point within each of these systems.

The importance of this determinant stems from the fact that data gathered from this data acquisition system can reveal a lot of information about an individual's life patterns -as stated previously in this chapter and previous chapters. This information can be and most likely is of interest to malicious-intending parties that may gain unauthorized access to such information, which can adversely impact consumers and violate their right for privacy. Hence a data architecture depicting where data is stored and by whom is accessed will have a crucial impact on the level of privacy preservation offered by the system and in turn peoples willing ness to adopt such a system. Data architecture of a system is driven by many factors such as laws or organizational policies. Jacobs (Jacobs 2010) argues that this issue takes a political dimension as "centralized informational control supports centralized societal control" (Jacobs 2010), hence such issue is best discussed within a political context. However, in this work it is believed that though it might be a political issue, data architecture is also a societal one, for which obtaining the public's opinion and exploring their public values becomes of importance. This would result in a data architecture that is not only policy-driven but also consumer driven, which can aid in gaining consumers' trust and an increased level of adoption. Such approach would be most beneficial to eliminate the risk of having to retrofit physical and logical measures for an alternative data architecture after system deployment. A goal which can be achieved by applying the I^3S^2 model in the early stages of the system's lifecycle, before designing and implementing the system.

Determinant in the Literature

The discussion in the literature of a system's data architecture as an acceptance determinant, and its impact of consumers' acceptance of technology is almost non-existing. However, data architecture was discussed by Jacobs in 2010 (Jacobs 2010) in the context of three privacy-sensitive, ICT-intensive infrastructure systems: smart meter system in the energy sector, and OV-Chipkaart and the Kilometer Charger systems in the transportation sector. Where the latter is an example of yet another privacy-sensitive infrastructure system that failed to see the light due to information security and privacy risks.

Jacobs points out that with the rollout of the smart metering system the metering system-data architecture has made a transition from a distributed approach of the conventional mechanical energy meters that stores meter readings locally at remote households, to a centralized one for the new smart metering system architecture, where the data is stored in central points, i.e. central access servers of the system. The impact of this transition becomes even more crucial when considering that within the new system, energy companies gather more data per consumer than was previously collected with the conventional meters in light of the 15-minute interval readings or even the two month interval (Jacobs 2010).

The second example of an ICT-intensive infrastructure system discussed by Jacobs in relation to system data architecture was the OV-Chipkaart system in the transportation sector, which was introduced in chapter 4 of this thesis. The OV-Chipkaart system is yet another system that employs a centralized data architecture. The data obtained from data acquisition points within the system are logged in central databases that offer transportation companies access to individuals' travel patterns. Considering the consequences associated with the revelation of such private and detailed information, especially in light of the information security and privacy vulnerabilities of the system –mentioned in chapter 4- it becomes rather crucial to consider the applied data architecture and what effect it may have on travel's safety and their right for privacy. Finally, Jacobs mentions the Kilometer Charger system as third example where the chosen data architecture would have a significant impact on the system. Jacobs compares two possible data architectures: centralized versus distributed and the trade-off between the two. In a centralized design each vehicle is equipped with an on-board box that transmits on a pre-defined time interval location data to pricing authority, while the processing power of the system resides at the pricing authority side, where periodic calculations are run to estimate fees. Despite the simplicity of this architecture, it poses serious privacy concerns and implications. These concerns are a result of the authorities' ability to possess databases containing detailed travel pattern-related data of vehicles. This notion was faced with disapproval from a group of people within society due to the violation of the right for privacy -as was and still is the case for the smart metering and OV-Chipkaart systems. This is especially true when considering that this detailed information would pose an appealing target to malicious parties, or can even be misused by individuals with an authorized access rights. On the other hand, within a decentralized design the on-board box would be equipped with processing power and required information such as road maps and tariffs, to enable local processing to take place, which eliminates the need to send detailed information periodically to a central storage location within the system. At the time of which Jacobs' work was conducted (2010) the author compared two possible data architectures and the trade-off between the two in an argument that the system can still be designed and implemented properly to avoid the problems encountered with both the smart metering and the OV-Chipkaart system. However, the proposal for the Kilometer Charge system was not approved by the government due to information security and privacy concerns, making it an example of a system that actually failed due to the lack of both proper planning, and accounting for societal values. Jacobs concludes that privacy preserving data architectures are possible and that it is "a political issue whether or not we, as a society, wish to use them" (Jacobs 2010).

Hypothesis

H_0: Data Architecture has a positive impact of consumers' acceptance of smart meters.

Effective Feedback

Definition

Effective feedback is providing consumers with detailed and meaningful information regarding their energy consumption that can motivate them to take an active role in demand response. Effective forms of feedback include: real-time pricing, sound alerts, receiving SMS message, which can be received via different kinds of devices such as attractive easy-to-use meter displays, or hand-held devices applications to monitor consumption.

Justification

One of the main problems that can prevent the smart metering system from satisfying few of the desired outcomes, e.g. energy efficiency and savings, is the lack of innovation with regards to informing consumers about their energy consumption. For example in Italy, energy companies are the only party benefiting from the deployment of the smart metering system with fraud detection (Parliamentary Office of Science and Technolgy 2008) and accuracy of billing (European Regulators' Group for Electricity and Gas 2007) being their main drivers for smart metering. With such a focus, other desired effects such as demand response are difficult to achieve, which in turn, negatively affect energy saving and efficiency.

The concept of feedback is based on the principle that shaping human behavior stems from both negative and positive consequences (Ehrhardt-Martinez, Donnelly et al. 2010). Hence, feedback as an acceptance determinant is of a particular significance in the context of the smart metering system, since the introduction of smart meters transformed consumers from passive agents to active ones, whom their active participation is crucial to help fulfill some of the goals behind the launch of the system. Furthermore, consumers cannot attempt to participate in energy and cost conservation activities without a form of meaningful feedback regarding their energy consumption.

Feedback was proven to have a positive influence on consumers' tendency to take part in energy conservation measures in a number of research efforts (Dobson and Griffin 1992, Ueno et al 2006, Fischer 2008, Froehlich 2009, Wood and Newborough 2003) cited in (Hauttekeete, Stragier et al. 2010). An energy saving of 8.5% was reported in The Netherlands via means of an interactive webpage usage by 173 Dutch households (Benders et al., 2005) cited in (Darby 2006).

Previous research show that a more frequent feedback is more effective than infrequent one (Darby 2006, Fischer 2007, Abrahamse et al. 2005). Moreover, the point of time at which feedback is presented to a consumer has an influence on the effectiveness of such feedback. Literature (Wood and NeBorough 2003, Parker et al 2006, Stern 2000) cited in (Hauttekeete, Stragier et al. 2010) shows that instant feedback that is provided to a consumer during or immediately after the use of an appliance is extremely effective. Several studies, such as (Wood and NeBorough 2003) cited in (Hauttekeete, Stragier et al. 2010), reported that by using energy consumption feedback via a smart meter energy consumption can be reduced by ten percent and even up to twenty percent whereas (Darby, 2010; Allen and Janda, 2006) cited in (Paetz, Becker et al. 2011) stated that energy conservation between five and twenty five percent can be achieved by using a feedback via a smart meter.

According to (van Raaji and Verhallen 1983) cited in (Hauttekeete, Stragier et al. 2010) Energy consumption feedback serves mainly three functions: first, learning: as feedback informs consumers of consequences of particular actions. Second, habit formation: feedback contributes to the formation of new energy conservation-related habits. Third, internalization of behavior: feedback aids in the creation of new attitudes and habits, which become submerged into an individual's behavior.

Consumers can receive feedback regarding their energy consumption by either direct or indirect means. Indirect feedback is mainly in the form of conventional bills, whereas direct feedback is one that is presented via digital means such as displays attached to the smart meter or through online applications (Paetz, Becker et al. 2011).

Determinant in the Literature

Studies in the literature that investigated the impact of energy usage feedback on consumers' acceptance of smart meters are scarce, this is mainly due to the limited number of research carried out in relation to the smart metering system as the system is relatively new. However, those few studies throughout the literature addressing energy consumption feedback have studied its influence on technology adoption from different perspectives. Below, details of previous studies are presented, where each study differs than the others in the observed behavior, which feedback is hypothesized to influence.

Robinson investigated the effect of energy-use feedback on individuals' behavior and attitude of electricity consumption of households equipped with smart meters (Robinson 2007). The study highlights the importance of consumers' participation in energy conservation activities and suggests that energy use feedback could be a potential enabler, the study however does not account for the problem of meters rejection among consumers. Rather, it goes one step further to assess whether providing consumers with feedback via smart meters would impact their consumption behavior. This is analogous to the belief underlying the current study that feedback can influence consumers' intention to use a smart meter to achieve goals such as energy and financial conservations. The different between Robinson's work and the current work is that the current work investigates this influence via the smart meter acceptance determinant as we acknowledge the problem of smart metering rejection by consumers for the various reasons discussed in previous chapters, and that we anticipate that acceptance of a technology is a precursor to its usage. In her work, Robinson proposed a conceptual framework that is based on findings reviewed throughout the literature. This framework suggests that feedback can contribute in raising awareness among consumers regarding the levels of their energy consumption, which in turn can lead to incurring a pro-conservation attitude or behavior change. The framework is based on existing attitudinal and behavioral theories to explain the use of different mechanisms that can lead to a cycle of pro-conservation behavior changes and encourage pro-conservation attitude. The cycle is assumed to either or strengthened attitude could results in further change either attitudinal or behavioral, or behaviors and attitudes are sustained over a "long-enough" period of time in order for habits to form and behaviors to internalize. The framework assumes that individuals have some intrinsic motivation to manage their consumption, and that energy use feedback information trigger attitude and behavior change by engaging motivation with individuals. A survey was administered to assess the framework among 1422 households in the town of Milton in Ontario, Canada. The participating households all had smart meters installed in the premises and bills were calculated based on the time-of-use tariffs since 2005 for these homes. The results of Robinson's framework did not show any significant impact of receiving feedback toward change or shift in consumption behavior, which leads to rejecting the hypothesis underlying the framework. The author argued that the lack of support this hypothesis could have resulted from a number of reasons such as: the fact that the targeted individuals of the study were already involved in energy conservation activities. Another reason related to the design of the study is that the groups involved in the study showed pro-conservation attitude and behavior, therefore whatever role feedback had is negligible. Furthermore, the fact that the participating households were energy-efficient to begin which could be a possible cause for the insignificant results in addition to the possibility that the provided feedback was not informative enough or did not provide sufficient information on how households can conserve energy. Despite the lack of support to the main hypothesis some significant differences were reported, some in the opposite direction of the hypothesis. These differences were related for example to shifting consumption from on-peak and decreasing monthly consumption. Robinson stated that her study suffered from a number of limitations such as a small sample size and the changed pricing structure during the period of the study.

In 2010 Hauttekeete et al. (Hauttekeete, Stragier et al. 2010) investigated the influence of providing consumers with customized feedback on the level of their energy consumption in the Flanders. The study focused on the usage of a wide variety of energy innovations for energy consumption management, which form part of the smart grid such as smart appliances, rather than study consumers' intention to use smart meters per se. This study is of a particular relevance for the current work as Hauttekeete et al. stated that success of such technologies that require active user participation depends to a certain extent on careful consideration of both consumers and their interaction with these innovations. The authors stated that a distinguishing feature of their work is that the feedback that is part of the study is personalized per consumer. Furthermore, the study avoided some limitations of other studies throughout the literature, such as: the use of survey for data gathering; this could raise the issue whether answers to questions regarding levels of energy consumption for example can be considered reliable. Furthermore, Hauttekeete et al. claim that most of the previous studies are not based on "theoretical assumption or valid measurement batteries", the authors stated that the questions are institution-specific and intention-based for assessing users' intention to adopt or accept a technology, which supposedly leads to "false realities" (Hauttekeete, Stragier et al. 2010). To overcome these issues, the authors proposed a method to assess user acceptance of smart meters and smart appliances and identify a proper communicated message that can lead to an increased level of awareness. The proposed method is based on combining data from two sources: energy monitoring sources and consumers' responses to a survey. Furthermore, this method aims to gain an insight into consumers' opinion as getting to know consumers is a must before attempting to offer energy innovations (i.e. smart meters and smart appliances) to consumers. To do so, the authors proposed profiling Flamish households into different categories based on their attitude and behavior towards smart appliances. To assess consumers' impression of smart meters and their acceptance of this technology, the authors used an adapted version of the TAM model, which excludes the construct relating to capturing the actual use of a technology. This was necessary as smart meters were not yet deployed in Flanders at the time of conducting the study and therefore the actual use of the system could not be captured.

A different perspective of the relationship among energy usage feedback, smart meters as energy innovation and consumer behavior was presented by Paetz et al. in 2011 (Paetz, Becker et al. 2011). The study investigated the impact of feedback and smart meters on consumers' willingness to shift their energy usage loads. As opposed to other research efforts, the work of Paetz et al. focused on investigating the shift of energy consumption loads as an observed consumer behavior instead of energy conservation or financial cost saving as observed behaviors of consumers. The authors conducted an experiment to study the behavior of four test-residents of an experimental smart house to investigate consumers' acceptance of smart meters and the effectiveness of smart meters as energy innovation. The experiment was conducted in three phases: where the first phase investigated the impact of extensive feedback and the level of energy consumption. The second phase investigated the impact of different tariffs on shifting demand. Whereas the last phase introduced automated energy management systems that enabled smart appliances to automatically react to changes in energy prices. The empirical data of this study was gathered from real-time metering of energy consumption, by conducting in-depth interviews with the test-residents, by administering pre-post questionnaires, and from online blogs maintained by the test-residents. The data was subjected to quantitative and qualitative analysis in order to evaluate the underlying hypothesis of the study. The experiment setting consisted from two groups, each consisting of a male and a female with a ranging age between 22 and 31, where participants of the first group were students as opposed to non-student adults in the second group. The results of the analysis revealed high interest by the test-residents in detailed information regarding their energy consumption, which resulted in residents making intensive use of the energy management system. Furthermore, the non-student group exhibited load shifting activity in response to dynamic pricing but not energy conservation behavior. The results also revealed that feedback changed the daily habits of the test-residents and triggered changes in their perception and attitude regarding consuming energy. Furthermore, the results showed that there was no significant increase in load-shifting upon the use of automated energy management systems. A limitation of Paetz's et al. work is the lack of representative sample due to the experimental design of their research. Therefore the authors clearly stated that the results strongly depend on the sample and that selecting test-residents is an important step, which inevitably introduces the difficulty of generalizing the results. Another limitation is that the design of the smart home and the variety of the smart appliances present may result in different behaviors.

Despite some differences between the studies reviewed above, yet they share a common perspective; exploring the influence of feedback -or even customized feedback- on individuals' consumption behavior or attitude. This perspective ignores social acceptance of energy innovations as an issue, it assumes that consumers' are willing to adopt these technologies and rather focuses on how feedback can influence their energy consumption behavior and pattern. In the current work, attention is paid to acceptance of a smart meter as a prerequisite for its utilization, where the influence of effective feedback as an acceptance determinant on consumers' willingness to adopt a smart meter is explored. The hypothesis below defines this relationship.

Hypothesis

H_0: Effective Feedback has a positive impact on consumers' acceptance of smart meters.

5.4 ICT-Intensive Infrastructure Service Systems- I^3S^2 Model

Integrating different technology acceptance models to investigate users' acceptance of certain information technology system is not uncommon. The aim of these attempts usually is to combine the different points of strength of each model to devise a hybrid technology acceptance model that is high in its predictive power. In this work a blend of the UTAUT model and IDT theory is devised into a hybrid model, i.e. H-Model illustrated in Figure 2.12. The hybrid model was further extended with additional acceptance determinants derived from the context of the smart metering system in the energy sector, and the OV-Chipkaart system in the transportation sector. Each of the two systems is an example of an ICT-intensive infrastructure system, which is adopted as a case study for the current work. The extension of the H-Model yielded a model that is tailored for investigating social acceptance of ICT-

Intensive Infrastructure Service Systems, hence the I^3S^2 model. The nature of the acceptance determinants encompassed in the I^3S^2 model makes the model suitable for application within the context of any ICT-intensive infrastructure systems, which resides within any society.

In this work, the I^3S^2 model is applied in the context of the smart metering system to investigate social acceptance of the system within the Dutch society. The proposed I^3S^2 model is presented in Figure 5.1. Description of the observed consumer behavior of interest for this study is given next.

Observed Behavior

An important component of any technology acceptance theory is the observed behavior of interest. That is the behavior exhibited by a consumer in response to the technology being diffused. For many of these theories the main focus is to study the influence of the acceptance determinants in the model on a certain observed consumer behavior, such as their intention to adopt a technology, their intention to use or their satisfaction with such technology. For the I^3S^2 model shown in Figure 5.1, the influence of the afore-presented acceptance determinants on consumers' behavioral intention to accept a smart meter is investigated. Consumers' acceptance of a smart meter is represented in the I^3S^2 Model by the construct: Acceptance a Smart Meter, which is defined as consumers' positive perception of a smart meter by acquiring it or agreeing to the operational presence of a smart meter in consumers' premises.

The model shown in Figure 5.1 illustrates a number of constructs, all of which except one represent the acceptance determinants presented thus far in this book. The remaining construct, i.e. Acceptance of a Smart Meter denotes the observed behavior of consumers that is under study. All acceptance determinants are hypothesized to have a direct influence on acceptance, except for Mass Media which is expected to have both a direct and indirect influence on acceptance. The distinction between constructs with a direct influence and those with an indirect one is illustrated in the Figure by blue and pink colors respectively.

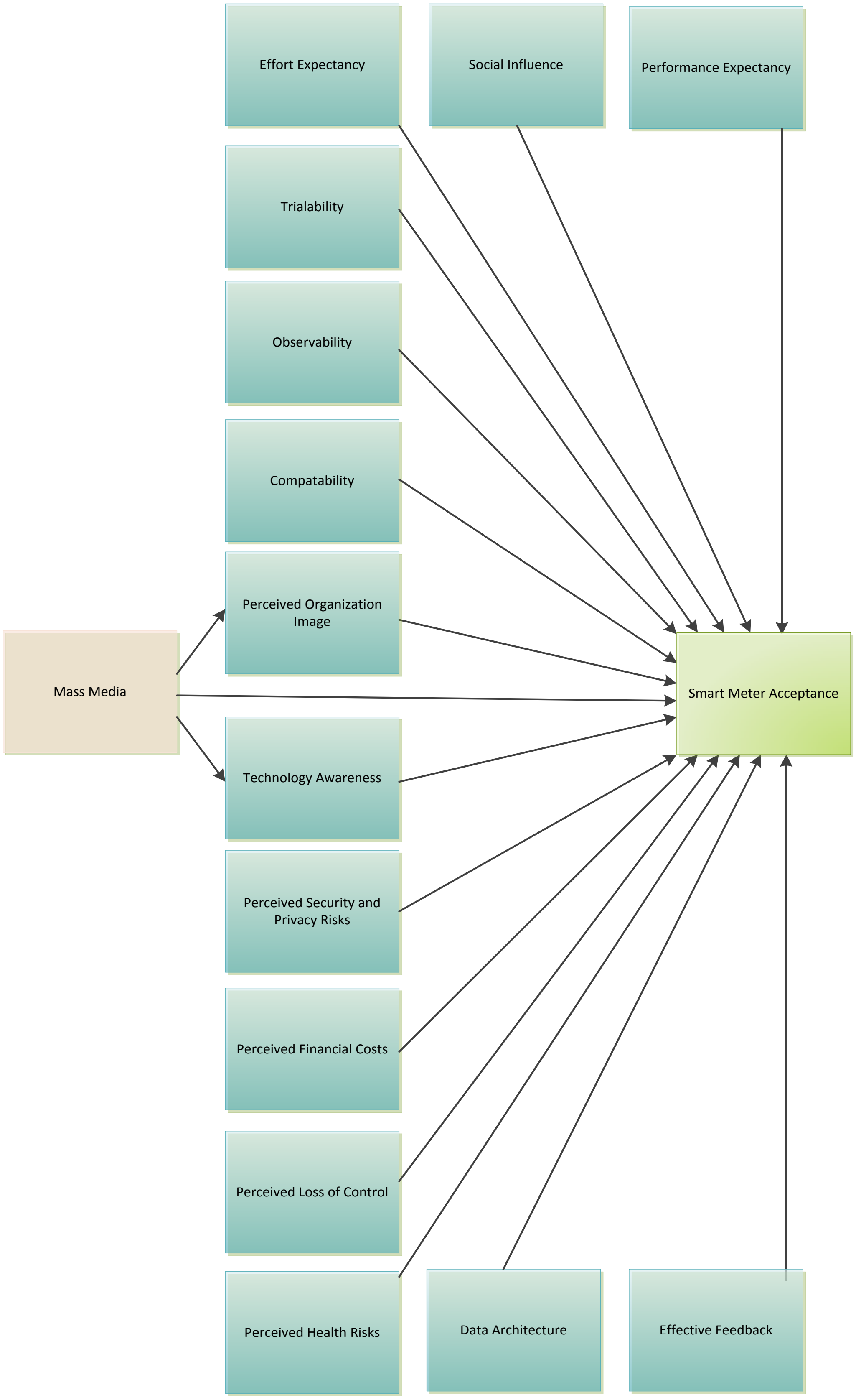

Figure 5.1: ICT-Intensive Infrastructures Service Systems -I^3S^2

5.5 Estimation of the I^3S^2 Model

To estimate the I^3S^2 Model to investigate the significance of the hypothesized influences a survey was developed as measurement instrument, which captures consumers perceptions of the notions included in the model as constructs, such as: Perceived Security and Privacy Risks, and Perceived Health Risks among others.

To design the measurement instrument, the I^3S^2 model is translated into a survey where each construct in the model is mapped into a latent variable, which is also referred to throughout the literature as a factor or dimension. Acceptance determinants are regarded as latent variables as they represent notions that cannot be quantified or measured directly, such as: beliefs or attitudes. This posed a challenge in designing a survey that can accurately measure respondents' opinion regarding the latent variables in the I^3S^2 model. Thus, designing a survey to measure latent constructs is not a straight forward process, and requires caution to be practiced. The difficulty of measuring latent variables is partly due to the ease with which a slight variant of the variable under study is measured. To eliminate this risk, it is imperative to formulate clear and precise definition of each latent construct prior to formulating the survey questions, to ensure that the resulting questions represent their respective latent variable. An additional challenge is the formulation of survey questions that measure the intended concept, such as: beliefs, values, knowledge, or attitudes or respondents. Overcoming this difficulty requires careful formulation of survey questions, pilot administration of the survey to discover pitfalls, and having the survey reviewed by psychometrics experts from both academia and market research companies.

To measure Latent variables in the I^3S^2 model, each variable is represented in the survey by a set of survey questions or items. The combined responses to these items give a "reasonably accurate measure of the latent construct" (Hair, Black et al. 2010), i.e. attitude or belief of a respondent. The responses to the survey items were captured within a Likert scale, which made it possible to measure respondents' opinion towards the latent variables by indicating their degree of agreement or disagreement with the items of the latent variable, by choosing one level that falls within the following range: strongly disagree, disagree, neutral, agree, strongly agree. The use of a Likert scale makes it possible to capture both the direction and the strength of a respondent's attitude, where the former is measured by respondents' agreement or the lack of regarding a given item, and the latter is decided by whether or not they choose a strong alternative of their chosen direction (Likert, 1932) cited in (Albaum 1997).

The process of generating a set of items for each latent variable was grounded on the I^3S^2 Model, and a knowledge-base of the subject matter, i.e. the smart metering system. The knowledge-base consists of experiences gained from various sources, such as the body of literature on technology acceptance and diffusion. Another source of information is the legislation of the smart metering system not only in The Netherlands but also in the State of California in the United States. This was useful as both states suffered from consumers' rejection of smart meters mainly due to the perceived security and privacy risks. In addition, a clearer picture was formed of the system by reflecting on its history, how it started and how it evolved. Furthermore, other less formal yet equally important sources of information were used to tap into the public opinion towards smart meters. Such sources include: news articles, activists' blogs, interviewing industry practitioners –i.e. professionals from energy grid operators- and last but not least talking to the public. These informal sources made it possible to get a feel of the society's position on smart meters, and issues that matter the most for private individuals as opposed to stakeholders whom govern or own the system. Thus, it was a way through which consumers' voice as newly active actors is heard.

In compliance with good practices dictated by the used method of statistical analysis, i.e. Structural Equation Modeling-SEM, which is discussed in further details in Chapter 6, a minimum of three items per latent variable were formulated. This ensures that there are just enough information to estimate all parameters (Hair, Black et al. 2010). Though in principle, the more item a latent variable has the better, caution had to be practiced to limit the number of items included in the survey for two reasons: first, the longer a survey becomes the less likely people would be willing to complete it. Second, the number of items included in a survey dictates a minimum size of the dataset of responses. The recommendations given throughout the literature regarding the item-response ratio vary, it can be as lenient as suggesting five responses per item or go to the extent of suggesting a minimum of twenty responses per item. But perhaps a more common sample size would adhere to the ratio of 10:1 (Hair, Black et al. 2010).

Before administering the final version of the measurement instrument developed for this work, several versions were drafted. The formulation of items followed conventions suggested throughout the literature of psychometrics. Many versions existed that evolved as refinements to the survey based on reviews from psychometrics experts from both academia and market research companies.

The subsequent steps in the process of the measurement instrument design include: survey translation to the Dutch language, survey pre-test, and data collection. These steps in addition to respondents' overview are described in detail in appendix B, whereas the measurement instrument is presented in appendix C.

5.6 Conclusion

In this chapter a comprehensive smart metering acceptance model was presented. The model was devised by first combining two well-known theories from the technology acceptance literature: the Unified Theory of Usage and Acceptance of Technology, and the Innovation Diffusion Theory. The model was further extended with a number of acceptance determinants that are based on limitations associated with either the smart metering system or the OV-Chipkaart system as two exploratory case studies for this work. This was done in an effort to account for consumers' opinion regarding the hypothesized acceptance determinants to elicit important public values to society that should be translated into social requirements to be addressed at early stages of system life cycle.

Furthermore, the development of the survey as a measurement instrument was presented. The next step is to identify the model, this was done by analyzing a dataset of responses collected from the Dutch population to the survey. The statistical analysis process applied to estimate the I^3S^2 model is explained in further details in the next chapter.

Chapter 6 : Estimation of the I^3S^2 Model in the Smart Metering System Context

6.1 Introduction

In chapter 5, the I^3S^2 model was introduced as a theory that hypothesizes influences of a number of smart meters acceptance determinants on consumers' willingness to accept a smart meter. Later, chapter 6 presented the measurement instrument used to collect consumers' response regarding the acceptance determinants encompassed in the I^3S^2 model, in addition to an overview of the dataset acquired. In this chapter, the I^3S^2 model is identified to obtain empirical support to the hypothesized influences or possible unpredicted influences among the model's construct. Doing so consequently aids in understanding of how the acceptance determinants influence consumers' acceptance of smart meters.

Thus, to be able to deduce influences of the acceptance determinants in the I^3S^2 Model on consumers' acceptance of smart meters two steps are carried out as illustrated in Figure 6.1. Each step of the process denotes a main section in this chapter, i.e. sections 6.2: Model Identification and 6.3: Results Interpretation.

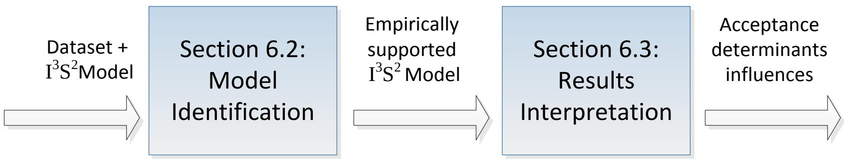

Figure 6.1: Acceptance determinants influences elicitation process

In section 6.2, the I^3S^2 Model is identified to investigate whether the theory underlying the model is empirically supported. The statistical analysis process applied to identify the I^3S^2 model using the acquired dataset is presented in detail in section 6.2. Further, in section 6.3 the resulting –and empirically supported- modified I^3S^2 Model is subjected to interpretation, to elicit meaningful influences among the model's constructs. Finally, the conclusions of this chapter are presented in section 6.4.

6.2 Model Identification

To identify the I^3S^2 model, the dataset acquired by conducting the survey described in Chapter 6 is analyzed. In this section the statistical analysis process illustrated in Figure 6.2 is described in detail.

The first phase of the statistical analysis process is dataset preparation, which entails processing the dataset prior to running the statistical analytical process. This phase is described in section 6.2.1 in detail. Processing the dataset yields a "clean" dataset that is subsequently used for the intended statistical analysis. Section 6.2.2 presents the second phase of the statistical process, i.e. Confirmatory Factor Analysis –CFA. The aim of CFA is to confirm the suitability of using a set of observed items to collectively measure a latent variable. This phase results in a confirmed measurement theory that is described in further detail in section 6.2.2. Further, in section 6.2.3 the third and last phase of the statistical process is presented, i.e. Structural Equation Modeling. During this phase, the paths or causal relationships in the I^3S^2 model are finally estimated using empirical data. The outcome of this phase is an empirically supported model, which may be different from the original I^3S^2 model.

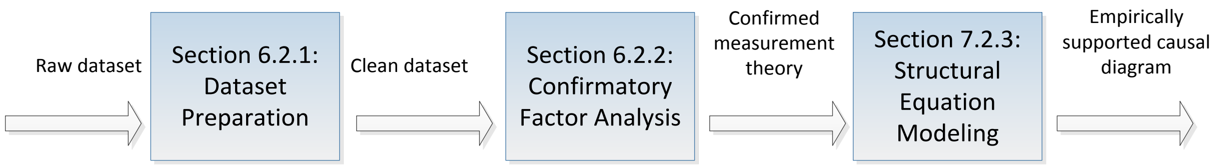

Figure 6.2: The statistical process applied to identify the I^3S^2 Model

6.2.1 Dataset Preparation

Prior to analyzing the acquired dataset to identify the I^3S^2 model, a number of steps must be carried out to prepare the dataset for the statistical analysis process. First, attention had to be paid to negatively worded items in the survey. Scales' wording of some items was reversed in the survey to help prevent response bias (Pallant 2010). It is important to ensure that for each construct, all items are worded in the same direction, i.e. negative or positive before attempting to create total scales, which are described in section 6.2.3. Doing so ensures consistency among the items, and retains the accuracy of the measurement scale. Thus, the scale for negatively worded questions had to be reversed to a positive one.

Second, the dataset had to be inspected for missing data. In general, missing data can result from either systematic external events to a survey respondent -such as: data entry errors or data collection problems- or actions of a respondent such as refusing to give responses to a set of the items in the survey (Hair, Black et al. 2010). Respondents' lack of interest in giving responses can be due to either their unwillingness to complete the entire survey, or to the sensitive nature of some questions, such as questions related to the respondent's income.

The impact of missing data on analysis can be significant especially in the case of multivariate analysis such as Structural Equation Modeling- SEM, which is used to identify the I^3S^2 model. Furthermore, as the relationships among the variables of the analysis become more complex, the ability to detect the cause of missing data decreases along with the impact this may have on the analysis. Therefore, it is crucial that datasets are inspected for missing data and processed adequately prior to running SEM. There exist several approaches to remedy a dataset with missing data. One approach is Complete Case Approach, a.k.a. list-wise deletion, where the entire set of response for a respondent is eliminated from the dataset if the respondent failed to answer at least one question. This approach has been deemed in the literature most suitable for SEM, thus it has been applied in the current work yielding a dataset containing 315 records out of the original 450 (Joseph F. Hair, William C. Black et al. 2010).

The final step in preparing the dataset was recoding the set of items used to measure the Technology Awareness construct in the I^3S^2 model. Since Technology Awareness construct measures the extent to which a respondent knows about smart meters, respondents' knowledge was tested by presenting a respondent with nine statements about smart meters. The statements expressed both factual and faulty information, to which a respondent had to answer with: True, False, or I do not know. Therefore, the responses were recoded as follows: when a respondent answers correctly they are given a score of 1 to that statement. However, if a respondent answers incorrectly or chooses "I do not know", they are given a score of 0.

After carrying out the three steps described above, the dataset was deemed ready to be used for Confirmatory Factor Analysis and Structural Equation Modeling. Both steps are explained in depth in sections 6.2.2 and 6.2.3 respectively.

For an indexed table of the variables used for the analysis, the reader is referred to Appendix C.

6.2.2 Confirmatory Factor Analysis

As previously explained in Chapter 5, each construct included in the I^3S^2 model represents a latent variable LV. One of the challenges related to LV is that they cannot be directly measured as observed variables OV. Thus, in social sciences research a LV is normally represented by a set of OVs, which collectively form a measure of the LV.

The overall structure defined by a researcher that relates a different set of OVs for each LV is referred to as a measurement theory. A subset of the measurement theory underlying the I^3S^2 model is given as an example in Figure 6.3. Before attempting to use a measurement theory as basis for estimating paths of a causal diagram like the I^3S^2 model, it is imperative to attest the reliability of the measurement theory. The reliability of a measurement theory ensures that each set of OVs collectively form a valid measure for their corresponding LV, i.e. the OVs indeed measure the LV they are designed for.

Confirming the measurement theory can be achieved by using Confirmatory Factor Analysis-CFA, which is a statistical technique that is mostly used in social research. CFA aims to assess whether the measure formed by a set of OVs is consistent with the essence of a LV as perceived by a researcher. In other words, CFA tests whether the dataset fits the hypothesized measurement theory.

The significance of ensuring the reliability of the measurement model stems from the inherent nature of LVs. Such variables are normally complex and can have many meanings. Furthermore, each LV is represented by several OVs that are measured via different data collection methods such as: surveys, tests or observational methods. These properties make it

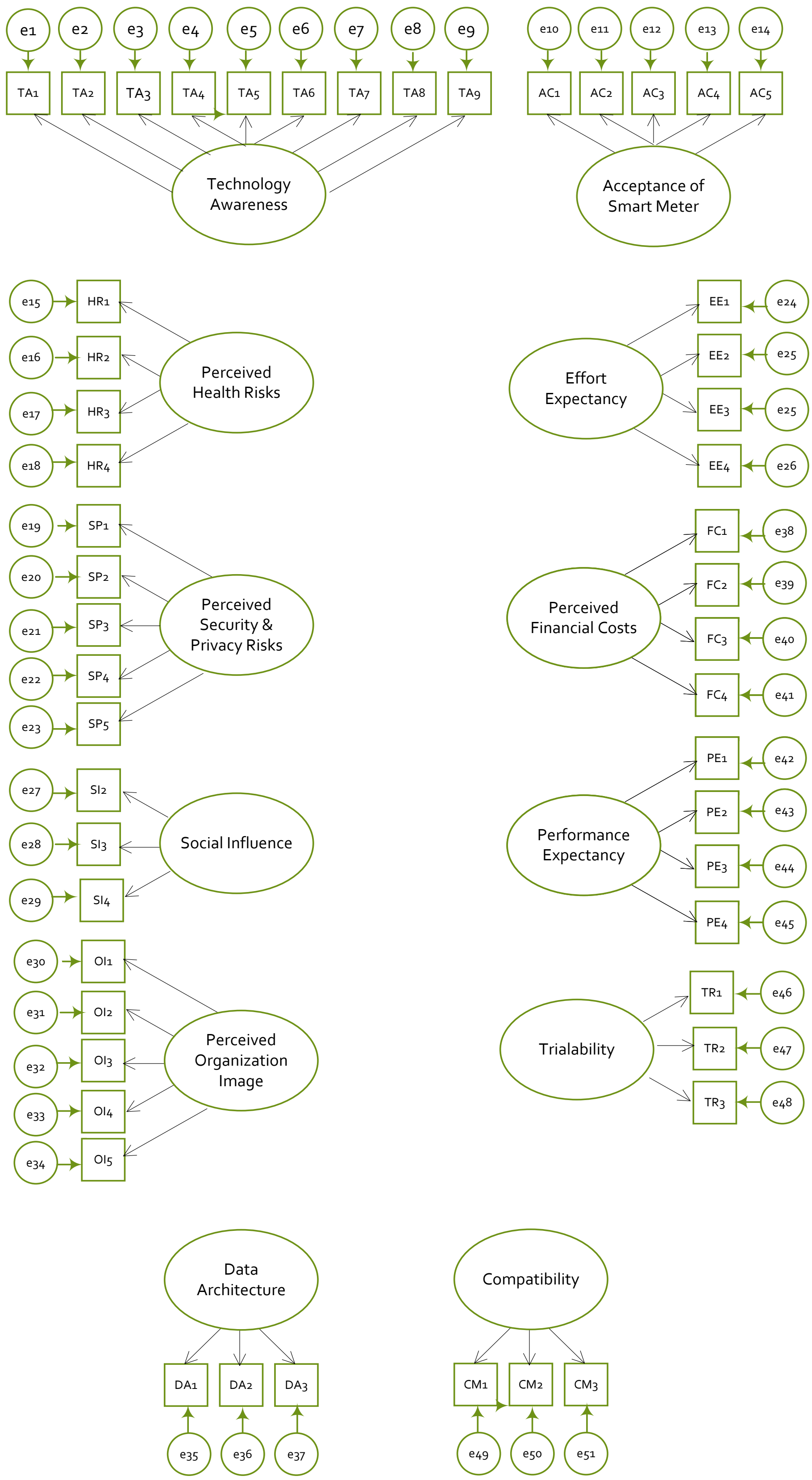

Figure 6.3: A subset of the measurement theory underlying the I^3S^2 Model

fairly simple for a researcher to formulate OVs that capture a slight variant of the intended LV (Joseph F. Hair, William C. Black et al. 2010).

In general, assessment of the measurement theory involves the application of various statistical analytical tests, such as: test of correlations, communality, and measure of sampling adequacy among others. Each statistical test aims to verify a certain aspect of the measurement theory. The statistical tests applied for the I^3S^2 model are explained next in further detail.

Confirmatory factor analysis was applied to all latent variables included in the I^3S^2 model except for the Technology Awareness construct. As explained in the previous section, Technology Awareness as a measure was designed differently than the rest of the I^3S^2 model's latent constructs. To test Respondents' knowledge of smart meters respondents were presented with a set of true/ false statement to which they had to give an answer. The set of answers for each respondent were later transformed into a summated scale that indicates the overall knowledge score of each respondent. The summated scale was tested for reliability, which is discussed in later sections of this chapter.

A- Construct Unidimensionality

Construct unidimensionality implies that the set of OVs that are intended to measure a certain LV are indeed loading on that LV alone; i.e. they share the same underlying latent concept. To verify unidimensionality for the I^3S^2 model, three statistical tests: test of correlations, communalities, and measure of sampling adequacy were applied for each set of OVs, which represent a certain LV included in the I^3S^2 model. The tests and their results are presented next in detail.

- **Correlations**

  A correlation between two variables is an indication of the extent of association between these two variables. Pearson's test of correlation was applied for each set of OVs representing each of the LVs in the I^3S^2 model, such as the Perceived Security and Privacy Risks, Perceived Financial Costs...etc. Pearson's correlation coefficient is a measure of the strength and direction of the linear relationship between any pair of OVs belonging to the same LV. The coefficient is defined in terms of the covariance of two variables divided by their standard deviations. Correlation coefficients can take values that range between +1 to -1, where a 0 value indicates no relationship; greater than 0 value indicates a positive relationship, and a lower than 0 value indicates a negative relationship between variables (Joseph F. Hair, William C. Black et al. 2010). Inspecting correlations among the set of OVs belonging to each LV is one way of ensuring the unidimensionality of that LV, where significant correlations that indicate strong relationships are preferred. Correlations are considered to be significant at a 0.05 level, with coefficients greater than a 0.30 threshold. It is recommended that variables that have more than one correlation that is lower than 0.30 should be dropped from the analysis (Field 2009).

An example output matrix of Pearson's Correlation test that was applied for the Perceived Security and Privacy Risks latent variable is shown in Table 6.1. The test was applied to five OVs -i.e. SP1, SP2, SP3, SP4, and SP5- which are intended to collectively measure the Perceived Security and Privacy Risks latent variable. As shown in the matrix, for each OV three values are calculated. The first value is the correlation coefficient which is displayed under the label “Pearson Correlation”. The second value labeled as “Sig.” is the significance of the correlation. The third value N is the number of cases processed, which is the size of the dataset used for the analysis. The correlation coefficients shown in Table 6.1 demonstrate strong correlations among the OVs: SP1, SP2, SP3, SP4, and SP5, which satisfy the 0.30 threshold. Furthermore, the significance of each correlation was well below 0.05, which satisfies the threshold. These results partly support the suitability of this set of OVs to measure the Perceived Security and Privacy Risks latent variable.

Table 6.1: Correlations matrix for the perceived security and privacy risks latent variable

		SP1	SP2	SP3	SP4	SP5
SP1	Pearson Correlation	1	,823**	,663**	,661**	,540**
	Sig.		,000	,000	,000	,000
	N	315	315	315	315	315
SP2	Pearson Correlation	,823**	1	,611**	,626**	,536**
	Sig.	,000		,000	,000	,000
	N	315	315	315	315	315
SP3	Pearson Correlation	,663**	,611**	1	,669**	,560**
	Sig.	,000	,000		,000	,000
	N	315	315	315	315	315
SP4	Pearson Correlation	,661**	,626**	,669**	1	,569**
	Sig.	,000	,000	,000		,000
	N	315	315	315	315	315
SP5	Pearson Correlation	,540**	,536**	,560**	,569**	1
	Sig.	,000	,000	,000	,000	
	N	315	315	315	315	315

**. Correlation is significant at the 0.01 level (2-tailed).

In a similar manner, Pearson's Correlation was tested for the set of OVs for each LV that is included in the I^3S^2 model. Correlations for each construct proved significant except for the Compatibility LV as illustrated in Table 6.2. The resulting correlation coefficients were insignificant except for the correlation between the OVs: CM1 and CM3, which is lower than the 0.30 threshold. For detailed correlation tables for each LV the reader is referred to Appendix D of this book.

Table 6.2: Correlations matrix for the Compatibility latent variable

		CM1	CM2	CM3
CM1	Pearson Correlation	1	,022	,147**
	Sig.		,699	,009
	N	315	315	315
CM2	Pearson Correlation	,022	1	,008
	Sig.	,699		,893
	N	315	315	315
CM3	Pearson Correlation	,147**	,008	1
	Sig.	,009	,893	
	N	315	315	315

**. Correlation is significant at the 0.01 level (2-tailed).

In addition to examining correlations, Bartlett's Test of Sphericity is also run to further confirm the significance of the correlations. The aim of running this statistical test is to establish the statistical significance of the correlation matrix; i.e. to affirm that the matrix has significant correlations among at least some of the variables (Joseph F. Hair, William C. Black et al. 2010). This is achieved by testing a null hypothesis that a correlation matrix is an identity matrix, where the latter is matrix has a value of 1 for all its diagonal elements, and a value of 0 for all of its off-diagonal elements. Thus, this null hypothesis can –and should- be rejected if Bartlett’s test yields significant results (Institute for Digital Research and Education 2012).

Bartlett’s test was applied for all the LVs encompassed in the I3S2 model. The results are presented in Table 6.3. As show in the table under the “Approx. Chi-Square” column, all LVs resulted in high Chi-Square values, except for Compatibility which had a low value of 7,006. Furthermore, the “Significance” column in Table 6.3 demonstrates that all LVs are significant as their respective significant values were below the 0.05 threshold. An exception to this was the Compatibility LV as it resulted in a significance of 0,072. Thus, as expected, all constructs proved to be significant except for the Compatibility construct.

Table 6.3: Bartlett's test of Sphericity

Construct	Approx. Chi-Square	Significance
Perceived Security and Privacy Risks	946,371	,000
Performance Expectancy	469,850	,000
Effort Expectancy	385,678	,000
Social Influence	273,102	,000
Trialability	326,751	,000
Observability	246.831	,000
Compatibility	7,006	,072
Perceived Organization Image	552.272	,000
Mass Media	138.858	,000

Perceived Financial Costs	305,643	,000
Effective Feedback	505.994	,000
Perceived Health Risks	875.847	,000
Perceived Control Loss	202.367	,000
Data Architecture	633.675	,000
Smart Meter Acceptance	1107,424	,000

- **Communalities**

Communality of an OV refers to the total amount of variance the OV has in common with the LV on which the OV loads. That is, the extent to which the variance of a measured variable is explained by the underlying latent constructs. In CFA, communality is also known as the squared multiple correlations for a measured variable (Hair, Black et al. 2010). A communality value above a threshold of 0.25 is considered acceptable. An example of a test of communalities is shown in Table 6.4 for the Perceived Security and Privacy Risks latent construct.

Table 6.4: Test of communalities for the perceived security and privacy risks latent variable

	Extraction
SP1	,766
SP2	,699
SP3	,617
SP4	,630
SP5	,447

The communalities under the "Extraction" column in Table 6.4 for the OVs: SP1, SP2, SP3, SP4, and SP5 all resulted in high values, thus meeting the threshold stated of a value greater than 0.25. This confirms further the unidimensionality of the Perceived Security and Privacy Risks latent variable.

In a similar manner, communalities were tested for the rest of the LVs included in the I^3S^2 model. All resulting communalities were above the 0.25 threshold, except for observed variable MM3, which is intended to measure the Mass Media latent variable. MM3 resulted in a communality of 0.193. An alarming result of communalities was computed for the Compatibility latent variable as show in Table 6.5, where none of the OVs: CM1, CM2, and CM3 met the 0.25 threshold.

Table 6.5: Test of communalities for the Compatibility construct

	Extraction
CM1	,153
CM2	,001
CM3	,141

- **Measure of Sampling Adequacy**

The measure of sampling adequacy- MSA is another measure that is used to quantify the extent of correlations among the set of OVs of each LV and the appropriateness of factor analysis before proceeding to subsequent steps of the statistical analysis. Values for this test can range between 0 and 1, where a value nearing 1 implies that a variable is predicted without error by other variables. For the I^3S^2 model, the Kaiser-Meyer-Olkin KMO test was applied to examine sampling adequacy, the results are summarized in Table 6.6. The resulting measures are compared to a set of thresholds to establish the suitability of the variable. In general, the values indicate the following:

> 0.80	is meritorious
0.70 – 0.80	is middling
0.60 – 0.70	is mediocre
0.50 – 0.60	is low
< 0.50	is unacceptable and indicate that the set of OVs require some revision before proceeding with further analysis of the model (Hair, Black et al. 2010).

By scanning Table 6.6 it becomes evident that the Perceived Security and Privacy Risks and Perceived Organization Image latent variables are performing the best among the other LVs in terms of sampling adequacy, with values greater than 0.80. These were followed by Effort Expectancy, Observability, Perceived Health Risks, Smart Metering Acceptance, and Data Architecture, with a KMO score between 0.70 - 0.80. LVs that resulted in a KMO between 0.60 – 0.70 were Effective Feedback, Trialability, Social Influence, Perceived Financial Costs, and Mass Media, whereas Compatibility, and Perceived Loss of Control resulted in the lowest scores with values barely greater than 0.50, which are deemed acceptable despite bordering the lower acceptable limit.

Table 6.6: Measuring of sampling adequacy for the I^3S^2 Model latent constructs

Construct	KMO
Perceived Security and Privacy Risks	,845
Performance Expectancy	,767
Effort Expectancy	,781
Social Influence	,648
Trialability	,684
Observability	,762
Compatibility	,501
Perceived Organization Image	,816
Mass Media	,605
Perceived Financial Costs	,648
Effective Feedback	,686

Perceived Health Risks	,751
Perceived Control Loss	,500
Data Architecture	,722
Smart Meter Acceptance	,742

After running the three statistical tests above: correlations, communalities, and the measure of sampling adequacy, it was possible to decide whether the LVs included in the I^3S^2 model were indeed unidimensional. Based on the results of the three tests, all LVs were deemed to be unidimensional except for the Compatibility latent variable.

B- Construct Validity

Assessing a construct's validity implies investigating the extent to which a set of OVs do indeed represent a LV as conveyed in the measurement theory. Thus, LV validity is mainly concerned with ensuring the accuracy with which a LV is measured (Hair, Black et al. 2010). Assessing the validity of each LV can be achieved by evaluating the convergent and discriminant validity of the LV. Both aspects of LV validity are investigated by applying a number of statistical tests as explained below in further detail.

– **Convergent Validity**

Convergent validity implies that the set of OVs that are intended to form a collective measure of a LV should converge or have a considerable amount of variance in common. Ensuring convergent validity among a set of OVs can be achieved via a number of statistical tests such as: factor loading, average variance extracted and construct reliability. These tests are presented below in further detail.

- **Factor Loading**

` Factor loading is a measurement of the relationship between an OV and the LV that it is intended to measure. The size of a standardized factor loading is an indicator of convergence among a set of OVs intended to collectively measure a LV. Thus, the statistical significance of each factor loading coefficient must be assessed. Significant loadings denote the convergence of OVs on a common LV. A factor loading can be deemed significant depending on how it compares to a set of thresholds stated throughout the literature. As a rule, acceptable factor loadings should be at least 0.50 or above, whereas a factor loading of 0.70 or higher is considered ideal. An insignificant factor loading is an indication that the corresponding OV is not suitable for measuring its LV. Hence, OVs with poor factor loadings must be dropped from the measurement theory before proceeding with the analysis.

An example factor loadings matrix is show in Table 6.7 for the Perceived Security and Privacy Risks latent variable. The resulting matrix proved that the OVs: SP1, SP2, SP3, SP4, and SP5 indeed loaded on a single factor, i.e. “Factor 1” in the table, which denotes the latent variable Perceived Security and Privacy Risks. The factor loadings listed in the matrix are all considered acceptable as they fall above the 0.50 threshold, with variables SP1, SP2, SP3, and SP4 considered being ideal as they fall above the 0.70 threshold.

Table 6.7: Perceived Security and Privacy Risks Factor Matrix

	Factor
	1
SP1	,875
SP2	,836
SP4	,793
SP3	,786
SP5	,668

For every LV included in the I^3S^2 model a factor matrix was calculated. Almost all resulting factor loadings were above the 0.70 threshold, whereas some fell above the 0.50 threshold which is still deemed acceptable. However, there were a few exceptions. For example, the OVs: CM1, CM2, and CM3 of the Compatibility latent variable resulted in very low factor loadings as demonstrated in Table 6.8. All factor loadings of the Compatibility construct were rejected as they fell below the 0.50 threshold.

Table 6.8: Compatibility Factor Matrix

	Factor
	1
CM1	,391
CM2	,039
CM3	,376

Furthermore, one OV –i.e. FC4- of the Perceived Financial Costs latent variable exhibited the same problem as shown in Table 6.9. FC4 resulted in a factor loading of 0.495, which is slightly below the 0.50 threshold. Attempts to drop FC4 from the analysis resulted in low factor loading of FC3 as illustrated in Table 6.10.

Table 6.9: Perceived Financial Costs Factor Matrix

	Factor
	1
FC1	,751
FC2	,669
FC3	,604
FC4	,495

Table 6.10: Perceived Financial Costs Factor Matrix excluding FC4

	Factor
	1
FC1	,854
FC2	,732
FC3	,450

To overcome this problem another approach was followed by splitting the Perceived Financial Costs construct into two sub-constructs: Perceived Financial Costs1 and Perceived Financial Costs2. The OVs: FC1, FC2, FC3, and FC4 were divided in a manner that preserved the semantic validity of each sub-construct. Perceived Financial Costs 1 measures consumers' willingness to pay in return of obtaining a smart meter and an external display, whereas Perceived Financial Costs 2 measures consumers' perception of an increased consumption level of electricity following the installation of a smart meter at their homes. In addition to yielding acceptable factor loadings for the two Perceived Financial Costs sub-constructs, this approach served the additional advantage of testing the influence of each sub-construct on acceptance separately.

The reader is referred to Appendix D for the factor loadings matrix of each LV included in the I^3S^2 model.

- **Average Variance Extracted**

Average variance extracted – AVE is a measure that is calculated for each LV in the I^3S^2 model. It is defined as a summary measure per LV of convergence among a set of OVs that represent the LV. In other words, AVE represents the average percentage of variation explained among the OVs of a certain LV. AVE is calculated according to formula 6.1 as the mean variance extracted for all the OVs that load on a LV (Hair, Black et al. 2010).

$$AVE = \frac{\sum_{i=1}^{n} \mathrm{Li}^2}{n} \qquad 6.1$$

In formula 6.1, n is the total number of OVs loading on a LV, whereas Li is the factor loading -such as the ones shown in Table 6.7- extracted for the i^{th} OV. To decide if an AVE of a LV does indeed indicate convergence, its value is compared to predefined thresholds. In general, an AVE value of 0.50 or higher indicates convergence among a set of OVs belonging to a LV (Hair, Black et al. 2010). Table 6.11 lists the AVE values of the LVs in the I^3S^2 model.

Table 6.11: AVE values for LVs of the I^3S^2 Model

Construct	AVE
Perceived Security and Privacy Risks	0,631
Performance Expectancy	0,546

Effort Expectancy	0,509
Social Influence	0,547
Trialability	0,594
Observability	0,529
Compatibility	0,099
Perceived Organization Image	0,500
Mass Media	0,420
Perceived Financial Costs 1	0,624
Perceived Financial Costs 2	0,503
Effective Feedback	0,693
Perceived Health Risks	0,676
Perceived Control Loss	0,689
Data Architecture	0,595
Smart Meter Acceptance	0,685

As can be seen in the table above, the Mass Media LV has an AVE value of 0.420 which is slightly lower than 0.50. However, the value is accepted as the difference from the threshold is marginal. Furthermore, the Perceived Organization Image LV has an AVE of 0.500, which is equal to the acceptable threshold. The Compatibility LV resulted in an extremely poor AVE of 0.099, which is rejected as it is far below the acceptable threshold. The AVE values for the rest of LVs are greater than the 0.50 threshold. Naturally, these values are accepted as they suggest adequate convergent validity of the LVs.

- **Construct Reliability**

Construct reliability-CR is yet another measure of convergent validity of LVs in SEM models. CR is calculated -according to formula 6.2- from the squared sum of factor loadings (L) of the set of OVs belonging to a LV, and the sum of error variance terms (e) associated with these OVs. Error variance is equal to 1- L.

$$CR = \frac{\left(\sum_{i=1}^{n} L_i\right)^2}{\left(\sum_{i=1}^{n} L_i\right)^2 + \left(\sum_{i=1}^{n} e_i\right)} \qquad 6.2$$

In formula 6.2 Li and ei are respectively the factor loading and the error variance of the ith OV associated with the LV. A CR value of 0.70 or higher indicates a good reliability of the construct, whereas a value between 0.60 and 0.70 is also acceptable given that other indicators of constructs' validity are yielding satisfactory results (Hair, Black et al. 2010). CR was calculated for each LV in the I^3S^2 model, the results are shown in Table 6.12.

Table 6.12: CRs of the LVs in the I^3S^2 Model

Construct	CR
Perceived Security and Privacy Risks	0,895
Performance Expectancy	0,828
Effort Expectancy	0,803
Social Influence	0,777

Trialability	0,812
Observability	0,768
Compatibility	0,194
Perceived Organization Image	0,833
Mass Media	0,669
Perceived Financial Costs 1	0,769
Perceived Financial Costs 2	0,669
Effective Feedback	0,869
Perceived Health Risks	0,891
Perceived Control Loss	0,816
Data Architecture	0,811
Smart Meter Acceptance	0,915

Most of the CR values listed in Table 6.12 are greater than 0.70, which indicates an adequate convergence of each LV in the I^3S^2 model. An exception to this was demonstrated by the Mass Media and Perceived Financial Costs2 LVs, which both yielded a CR of 0.669. This value is accepted as its difference from 0.70 is marginal and it still falls above the 0.60 threshold. Furthermore, Compatibility resulted in an extremely low CR value of 0.194. As this value falls way beyond the 0.70 threshold, this result is rejected.

Among the set of LVs in the I^3S^2 model, Compatibility was the only LV that demonstrated poor results for all the statistical results applied as part of the construct's unidimensionality and validity analysis. The results of the Compatibility LV are summarized in Table 6.13 for the OVs: CM1, CM2, CM3, which are intended to collectively measure the Compatibility LV.

Table 6.13: Analysis summary of the Compatibility LV

Statistical Test/ Acceptable Threshold	**CM1**	**CM2**	**CM3**
Pearson's correlation $\alpha = 0.30$ Rule: $x > \alpha$	Corr CM1, CM2 = 0.022 Corr CM1, CM3 = 0.147 Corr CM2, CM3 = 0.008		
Bartlett's test of sphericity $\alpha = 0.05$ Rule: $x < \alpha$	,072		
Communalities $\alpha = 0.25$ Rule: $x > \alpha$	0.153	0.001	0.141
Measure of sampling adequacy $\alpha = 0.50$ Rule: $x > \alpha$	0,501		
Factor loading $\alpha = 0.50$	0.391	0.039	0.376

Rule: x < α			
Average variance extracted α = 0.50 Rule: x > α	0.099		
Construct reliability α = 0.70 Rule: x > α	0,194		

The poor results listed in Table 6.13 were expected considering the difficulty encountered in formulating OVs: CM1, CM2, and CM3 during the measurement instrument development phase. This is due to the novelty of smart metering as a system as it operates in a different manner than a conventional meter, and offers new services that did not exist before. Consequently, measuring compatibility of the smart meter with consumers' past experience was impossible. Therefore, the Compatibility LV was dropped from the I^3S^2 model and was not considered for further analysis.

– **Discriminant Validity**

Discriminant validity aims to ensure that each LV in the model is unique, and measures a distinct theoretical concept different from the other LVs in the model. For this purpose Exploratory Factor Analysis-EFA is applied. EFA is a technique of factor analysis that is used to discover the underlying structure of a set of OVs. This is different than CFA, where the underlying structure of a set of OVs is already known and defined by a researcher and CFA is applied to confirm the hypothesized structure.

EFA is run by calculating a pattern matrix of all OVs used to measure the set of LVs included in a model, where each OV is expected to mainly load on a single LV. The pattern matrix calculated for the OVs representing the LVs encompassed in the I^3S^2 model is presented in Table 6.14.

In the first column of the table, the entire set of OVs that are intended to be used for the identification of the I^3S^2 model are listed. The other 12 columns of the table represent 12 latent factors or concepts on which the set of OVs proved to load on. Ideally, every set of OVs belonging to a LV should load on a single factor without having OVs of other LVs load on the same factor.

Table 6.14: Pattern matrix

	Factor											
	1	2	3	4	5	6	7	8	9	10	11	12
OB1	,698											
OB3	,694											
PE5	,569											
PE2	,475											
OB2	,468											

PE4	,412											,397
EF3	,407										,385	
PE3	,352											
OI3		,771										
OI2		,719										
OI1		,669										
OI5		,658										
OI4		,622										
HR2			,883									
HR3			,827									
HR4			,817									
HR1			,675									
DA1				,961								
DA2				,878								
DA3				,807								
SP1					,863							
SP2					,801							
SP4					,721							
SP3					,703							
SP5					,560							,315
TR3						,859						
TR1						,816						
TR2						,641						
SI3							,846					
SI4							,770					
SI2							,492					
EE3								-,886				
EE4								-,706				
EE1								-,608				
EE2								-,519				
CL2									,867			
CL1									,771			
ACC2										-,987		
ACC3										-,924		
ACC4										-,619		
ACC5										-,608		
ACC6	,340									-,452		
MM2											-,586	
MM1											-,451	
EF2	,351										,377	
MM3											-,323	
FC1												,529
FC3												,489
FC2												,419
FC4												,382
EF1												,307

Table 6.14 was scanned by scrutinizing the resulting loadings for each OV, to verify whether indeed each set of OVs belonging to a LV loaded solely on a single factor that is not shared by OVs belonging to other LVs. This was the case for the following LVs: Perceived Organization Image, Perceived Health Risks, Data Architecture, Perceived Security and Privacy Risks, Trialability, Social Influence, Effort Expectancy, Perceived Loss of Control, Acceptance of a Smart Meter, Mass Media and Perceived Financial Costs. The set of OVs belonging to each of the above listed LVs either loaded solely on a single factor, or had a negligible loading on another factor. This result of EFA is consistent with the hypothesized underlying structure among all OVs, which is also confirmed by CFA. Despite the good results in Table 6.14 for most LVs, there are a few exceptions that required attention and some action to be taken, these are listed below:

- Some OVs loaded on more than a single factor, such as SP5 that is intended to measure the Perceived Security and Privacy Risks LV. SP5 has a loading of 0.560 on "factor 5" along with OVs: SP1, SP2, SP3, and SP4, which is expected and confirms the discriminant validity of the Perceived Security and Privacy Risks LV. Further, SP5 loaded on "factor 12" with a coefficient of 0.315, this value however is much lower than the loading on "factor 5" i.e. 0.560. Thus the loading on "factor 12" is ignored. In a similar manner, ACC6 which is an OV belonging to the Acceptance of a Smart Meter LV loaded on "factor 10" with a coefficient of 0.452 along with ACC2, ACC3, ACC4, and ACC5, again which is expected and confirms the discriminant validity of the Acceptance of a Smart Meter LV. However ACC6 also loaded on "factor 1" with a coefficient of 0.351, which was ignored as it is smaller than the loading of the same OV on "factor 1".

- OV EF1 that is intended to measure the Effective Feedback LV, loaded only on "factor 12" along with OVs: FC1, FC2, FC3, and FC4, which represent the Perceived Financial Costs LV. Considering that this OV did not load on any other factors, and its loading on "factor 12" contradicts the semantic validity of the Perceived Financial Costs constructs, the EF1 OV was dropped from the analysis.

- The following OVs loaded on "factor 1":

    - OB1, OB2, and OB3 originally intended to measure the Observability LV.

    - PE2, PE3, PE4, and PE5 originally intended to measure the Performance Expectancy LV. It can be observed from the pattern matrix given in Table 6.14 that PE4 loaded on another factor as well, i.e. "factor 12". In a similar manner to the approach followed above the loading on "factor 12" was ignored as it is smaller in magnitude than the loading on "factor 1".

- EF2, EF3 originally intended to measure the Effective Feedback LV. Analogous to PE4, EF3 loaded on “factor 11” in addition to its loading on “factor 1”, where the former loading was smaller in magnitude than the latter, hence the loading on “factor 11” was ignored. On the other hand, EF2 demonstrated a higher factor loading on “factor 11” along with OVs: MM1, MM2, and MM3 that represent the Mass Media LV. Hence, EF2 was discarded from the analysis.

Though the loading of the above listed OVs on a single factor –i.e. factor 1- was unexpected, yet it is logical within the context of smart metering. This becomes clearer when revisiting the definitions of the three LVs.

Observability stands for the extent to which the result of using a smart meter is evident to a consumer. Examples of the results of using a smart meter which can be observed by a consumer include a decrease in the amount of energy consumed, or a reduction in the amount of energy bill charged to the consumer.

Effective Feedback denotes providing consumers with detailed and meaningful information regarding their energy consumption, which can enable consumers to manage their energy consumption.

The concept of Performance Expectancy of a smart meter is mainly centered on the feedback a consumer obtains from the meter regarding their energy consumption. As feedback is the sole enabler of consumers to manage their energy consumption, which consequently enables consumers to achieve a number of goals that a smart meter is expected to enable consumers to utilize, such as: reduction in the amount of energy consumed, reduction of energy bill, and easier switching between energy suppliers.

Thus, it is found justifiable that the observed variables: OB1, OB2, OB3, PE2, PE3, PE4, PE5, and EF3 loaded on the same factor. Consequently, the three LVs that are represented by the above listed OVs were merged into one LV under the label of Performance Expectancy. The above listed amendments to the I^3S^2 model are demonstrated in Figure 6.4.

After applying confirmatory factor analysis using SPSS as described above to confirm the measurement theory underlying the I^3S^2 model, a SEM measurement model was built using IBM SPSS AMOS statistical package to ensure additional confirmation of the measurement theory. A measurement model illustrates how a set of OVs logically and systematically represent LVs encompassed in a theoretical model, such as the I^3S^2 model. Confirming the measurement theory via a measurement model offers two advantages: First, confirming the suitability of each set of OVs to collectively measure a LV, while taking into consideration other LV in the model. This is the contrary to confirmatory factor analysis, which confirmed the validity and reliability of each LV separately without taking correlations among LVs into consideration. Second, unlike confirmatory factor analysis, a SEM measurement model accounts for measurement error. This is beneficial considering that OVs normally have a measurement error. The resulting measurement model confirmed the suitability of the measurement theory. Thus, proceeding to the next step in SEM of building a structural model is possible.

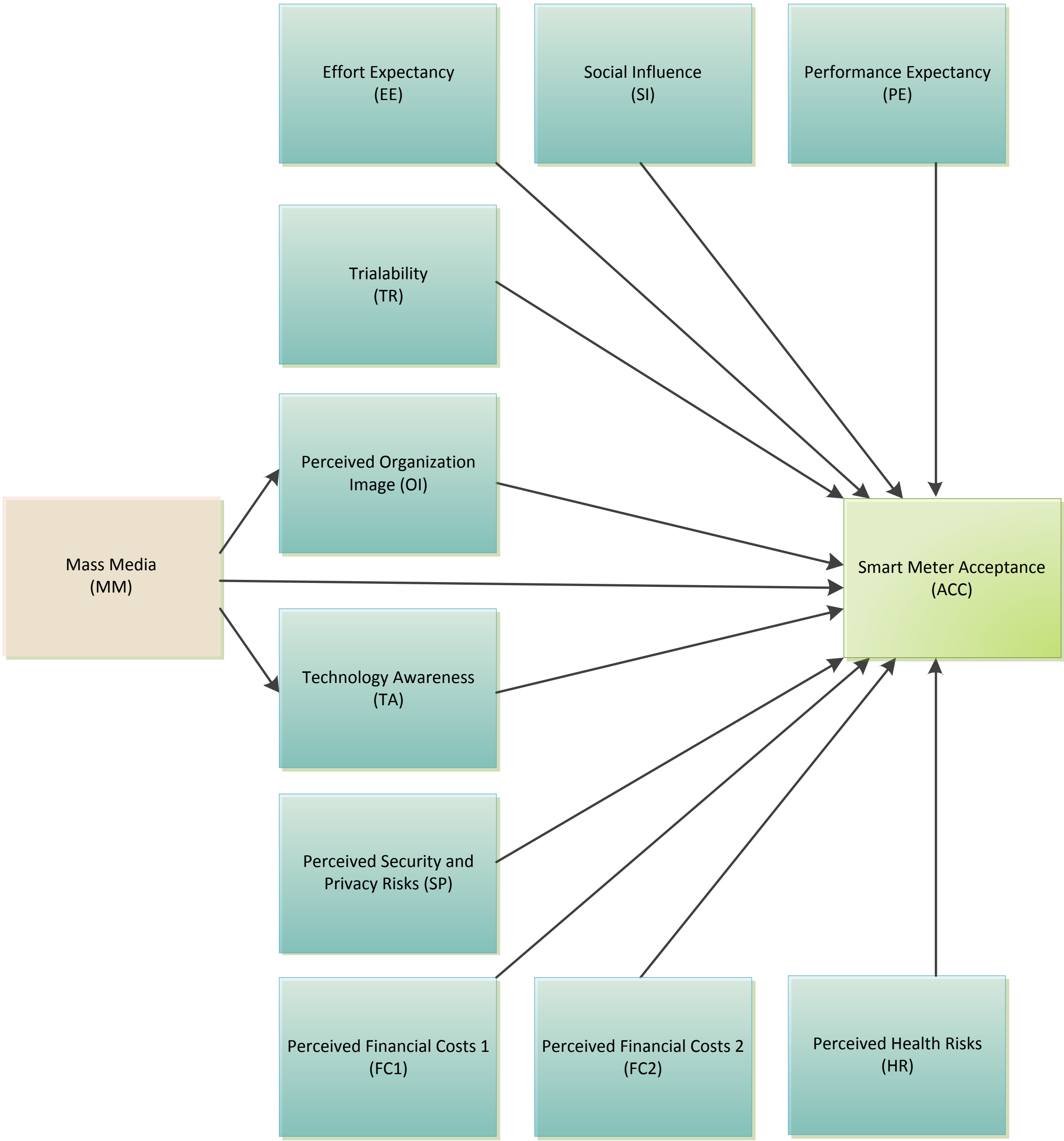

Figure 6.4: The amended I^3S^2 Model

6.2.3 Structural Equation Modeling

Structural Equation Modeling –SEM is a statistical analysis method that consists of a set of statistical models, which aim to explain relationships among a group of variables. SEM is well suited for analyzing models (theories) encompassing constructs that represent latent variables, where each latent variable is represented by a set of observed variables. The method basically inspects the structure of interrelationships in the model that are expressed in a series of equations that are similar to a series of multiple regression equations. The set of regression equations collectively captures the relationships that exist among all LVs in the original theory.

SEM as a statistical method encompasses two well-known multivariate techniques: factor analysis and multiple regression analysis, where the former is suited for the multiple OVs per LV property and the latter is capable of analyzing the interrelationships among the LVs. In general, SEM has some distinguishing features that make it suitable for analyzing models such as the I^3S^2 model. These features are:

- Estimation of multiple interrelated dependence relationships: SEM is capable of estimating simultaneously a set of separate but interdependent multiple regression equations, which collectively represent the structure of the theoretical model.

- Incorporating latent variables: Latent variables- LV as explained earlier in this chapter are unobserved concepts that can be represented by a set of observed variables- OV. Applying LVs in models rather than using self-reported responses by survey respondents serves a number of purposes. First, representing a LV with multiple OVs reduces the measurement error in the LV. Second, it enhances the statistical estimation of the relationships among the LVs in a model by taking into consideration the error of measurement of LVs (Hair, Black et al. 2010).

In general, the process of applying SEM includes running a series of statistical tests that fall under one of two phases: assessing the measurement theory, and building the structural model. The first phase has already been carried out in section 8.2.2, whereas the second phase is described next in further detail.

Building the Structural Model

Building a structural model in SEM is the step following the confirmation of the measurement theory. A structural model is a path model that depicts a set of dependence relationships among a number of LVs, which collectively represent the structural hypotheses of a predefined theory, i.e. in this case the I^3S^2 model. The aim of this SEM step is to assess the validity of the hypothesized relationships among LVs in the original theory. That is, to investigate whether the influences that are assumed among LVs are supported.

A- Creating Total Scales

Before building a structural model, a preliminary step of creating a total scale for each LV was first carried out. Creating a total scale is a process during which the set of OVs representing a LV are combined into a summated scale. The main advantage gained by using total scales is the reduction of model complexity. In the current work 58 OVs are used to identify the I^3S^2 model. The inclusion of all these variables in the structural model would result in an extremely complex model, which in turn complicates the interpretation of the results (Hair, Black et al. 2010). The problem of model complexity was confirmed when creating the measurement model; hence total scales were used for the structural model.

Using total scales in a model requires first ensuring their reliability, i.e. confirming that the total scale consistently reflects the LV that it measures (Field 2009). A widely used statistical test of scale reliability is Cronbach's Alpha α, which is calculated according to formula 6.3.

$$\boldsymbol{\alpha} = \frac{\boldsymbol{N^2\overline{Cov}}}{\sum \boldsymbol{s^2_{item}} + \sum \boldsymbol{Cov_{item}}} \qquad 6.3$$

Where N denotes the number of items included in the total scale, $\overline{\text{Cov}}$ stands for the average covariance among OVs, and s is the sum of all the OVs variances. A Cronbach's Alpha coefficient is deemed acceptable if it falls above 0.80 or 0.70. However, it is also argued in the literature that coefficients lower than 0.70 could be expected when dealing with psychological constructs (Field 2009). The resulting Cronbach's Alpha coefficients for each LV in the I^3S^2 model are shown in Table 6.15.

Table 6.15: Cronbach's Alpha for latent constructs in the I^3S^2 Model

Construct	Cronbach's Alpha
Perceived Security and Privacy Risks	,892
Performance Expectancy	,884
Effort Expectancy	,791
Social Influence	,754
Trialability	,781
Observability	,761
Perceived Organization Image	,831
Mass Media	,646
Technology Awareness	,703
Perceived Financial Costs 1	,769
Perceived Financial Costs 2	,670
Effective Feedback	,860
Perceived Health Risks	,887
Perceived Control Loss	,812
Data Architecture	,902
Smart Meter Acceptance	,915

It can be observed from Table 6.15 that almost all LVs encompassed in the I^3S^2 model demonstrated a high level of internal consistency, with a Cronbach's Alpha value above 0.70. Two LVs which were an exception are Mass Media and Perceived Financial Costs 2, which scored 0.646 and 0.670 respectively. Though these values are below the 0.70 threshold yet they were accepted due to their small difference from the lower limit, in addition to the fact that LVs in the I^3S^2 model are of a psychological nature. Thus, the total scores of the LVs are deemed acceptable to use for the structural model.

B- Resulting Structural Model

A structural model was built using the IBM SPSS AMOS statistical package, which encompassed the entire set of LVs included in the I^3S^2 model except for Compatibility. The resulting model is shown in Figure 6.4, whereas Table 6.16 lists the standardized regression coefficients of the paths shown the structural model. Path coefficients denote the magnitude in which one LV influences the other.

The model shown in Figure 6.5 includes constructs –i.e. LVs- that proved to have a significant influence in the causal relationship diagram. The curved double headed arrows depicted in Figure 6.5 denote correlations between LVs, whereas the straight single headed arrows denote paths of influence between LVs. The resulting structural model differs from the original theory depicted in the I^3S^2 model in two ways. First, three constructs were dropped from the model, these are Compatibility as its measurement scale was deemed unsuitable for analysis, and Perceived Loss of Control and Data Architecture as they did not demonstrate any significant influences on any of the remaining LVs in the structural model. Second, only half of the causal relationships in the resulting structural model conformed to the hypothesized relationships among constructs in the original theory. The interpretation of the relationships depicted in the causal diagram in Figure 6.5 based on the standardized regression weights listed in Table 6.16 is presented in subsequent sections of this chapter. Next, the goodness of fit of the structural model is discussed.

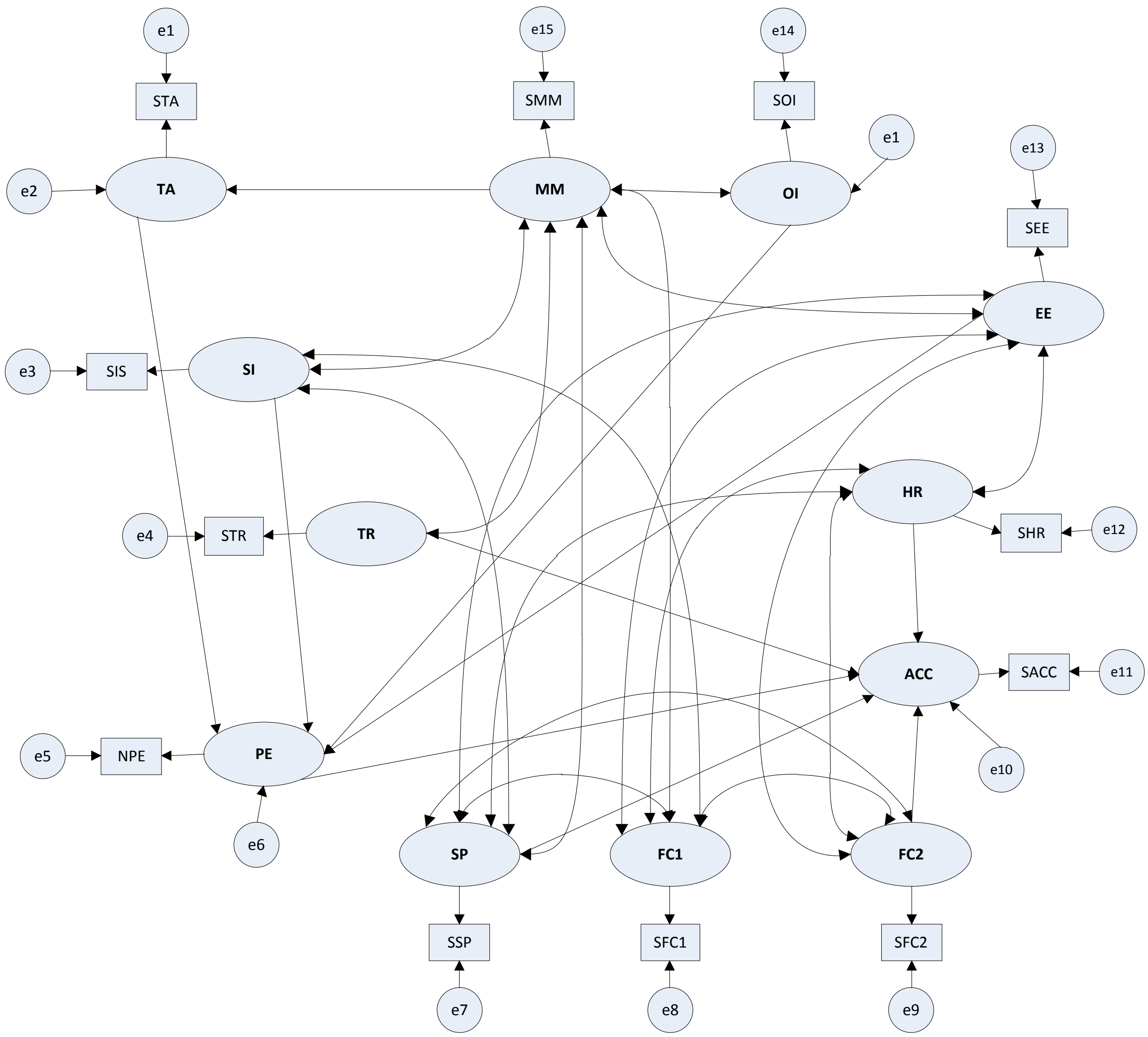

Figure 6.5: The resulting structural model

Table 6.16: Standardized regression weights for paths in the structural model

Path	Estimate
OI ← MM	0.504
PE ← FC1	0.181
PE ← FC2	0.519
PE ← OI	-0.147
PE ← TA	0.179
PE ← SI	0.254
PE← EE	0.123
ACC ← FC2	0.147
ACC ← SP	0.225
ACC ← PE	0.683
ACC ←TR	0.115
ACC ← HR	0.190

SEE ← EE	0.887
SSI ← SI	0.868
STR ← TR	0.884
SFC1 ← FC1	0.872
SHR ← HR	0.942
SSP ← SP	0.942
SOI ← OI	0.911
SMM ← MM	0.796
SACC ← ACC	0.955
SFC2 ← FC2	0.817
STA ← TA	0.838
SPE ← PE	0.937

C- Structural Model Fit

Throughout the literature there exists a wide spectrum of statistical tests that are used for ensuring model validity. Goodness-of-fit (GOF) measures indicate how well a model reproduces the observed covariance matrix (representing reality), compared to the estimated covariance matrix (representing theory) among the set of OVs that are included in the model (Hair, Black et al. 2010). In this work three of the most commonly used fit indices are used to assess the fit of the structural model depicted in Figure 6.5. These indices are: Chi-square, root mean square error of approximation, and comparative fit index. Each one of these indices is described next in further detail.

- **Chi-square $\chi 2$**

The Chi-square statistical test is a GOF measure that is applied for comparing the estimated and observed covariance matrices. The closer the two matrices are to being identical, the stronger of an indication it is that the conceptual model representing the theory is a good representation of the data. Therefore, when applying the χ^2 test within a SEM framework insignificant results are expected -i.e. lower χ^2 values- which denote no significant difference between the estimated and observed covariance matrices. The calculation of χ^2 is carried out using formula 6.4, where N represents the sample size.

$$\chi^2 = (N - 1)(S - \Sigma_k) \qquad 6.4$$

Formula 6.4 suggests that as N increases χ^2 increases as well. Furthermore, χ^2 is also influenced by the number of variables in the model, such that: the value of χ^2 is more likely to increase as the number of variables included in the model increases. The fact that χ^2 is influenced by both the sample size and the number of variables included in the model poses a serious problem is estimating model fit. This is especially true for complex models that include a significant number of variables and require a substantial sample size. These properties of χ^2 make it difficult for models to achieve statistically insignificant GOF, as the resulting p-value becomes less meaningful. This in turn makes the reliance on χ^2 as a sole measure for assessing model fit problematic and often not done. To resolve this problem, additional GOF measures are used in combination with χ^2, which correct for the bias against model complexity and large sample size (Hair, Black et al. 2010). Examples of such measures include: the root mean square error of approximation, and the comparative fit index. Both measures were applied for the current work and are described next in further detail.

The χ^2 statistics for the structural model resulted in a value of 55,635 with 36 degrees of freedom, and a probability level of 0.019. These values cannot be used a sole GOF index due to χ^2 sensitivity to both the sample size and the number of variables included in the model, which poses a problem for complex models such as the model of the current study. Thus, additional GOF measures, e.g. RMSEA and CFI, are used in combination with χ2, which correct for the bias against model complexity and large sample size (Hair, Black et al. 2010).

- **Root Mean Square Error of Approximation- RMSEA**

The root mean square error of approximation- RMSEA is a measure of how well a model fits an observed covariance matrix. This measure has gained popularity throughout the literature during recent years due its corrective ability against model complexity -i.e. increased number of variables included in the model- and a large sample size. RMSEA threshold recommendations indicating model fit have varied over the years. A recommended RMSEA threshold in the early nineties was in the range of 0.05 to 0.10, which was considered to indicate a good fit, whereas a value greater than 0.10 indicates poor fit. Later, a RMSEA value falling between 0.08 and 0.10 was deemed to indicate poor fit, whereas a value falling below 0.08 was decided to show a good fit of the model (MacCallum et al, 1996) cited in (Hooper, Coughlan et al. 2008). Other thresholds or cutoffs were also suggested throughout the literature, such as: 0.06 (Hu and Bentler, 1999) cited in (Hooper, Coughlan et al. 2008), 0.07 (Steiger, 2007) cited in (Hooper, Coughlan et al. 2008), 0.05 or 0.08 (Hair, Black et al. 2010).

The RMSEA value calculated for the structural model is 0.042, which is deemed acceptable as it falls below 0.05, which is the RMSEA threshold applied in the current work.

- **Comparative Fit Index- CFI**

Comparative Fit Index- CFI is an incremental fit index that accounts for model complexity and sample size, a property which made it one of the most widely used measures. CFI values can range between 0 and 1, where higher values indicate a better fit. A threshold of 0.90 is normally used to assess model fit, where a CFI value of 0.90 or higher is an indication of a good model fit (Hair, Black et al. 2010). Computing CFI for the structural model resulted in a model fit of 0.977, a value which deems the model of good fit as it falls above the 0.90 threshold.

In the light of the results of the three model goodness-of-fit indices summarized in Table 6.17, the structural model was deemed of a good fit and therefore the relationships it encompasses are well-suited for interpretation.

Table 6.17: Structural model goodness-of-fit indices summary

Goodness-of-fit index	Threshold	Value
χ^2	--	55,635
RMSEA	< 0.05	0.04
CFI	> 0.90	0.98

6.3 Results Interpretation

The structural model shown in Figure 6.5 is a depiction of the identified I^3S^2 model after running CFA and SEM analysis. The identified I^3S^2 model encompasses less acceptance determinants than the original I^3S^2 model, with a different set of relationships among the determinants than originally anticipated and hypothesized. The structural model in Figure 6.5 is shown again in Figure 6.6 to illustrate clearly the resulting direct and indirect influences among the determinants.

In addition to the Compatibility determinant that was dropped during the CFA analysis, two more determinants were dropped from the structural model due to the lack of significance. These determinants are: Perceived Loss of Control, and Data Architecture, which did not exhibit any significance influences on any of the other remaining constructs in the model. Thus, the determinants that demonstrate significant influence and remained in the model are: Performance Expectancy, Social Influence, Effort Expectancy, Trialability, Perceived Organization Image, Technology Awareness, Mass Media, Perceived Security and Privacy Risks, Perceived Financial Costs 1, Perceived Financial Costs 2, and Perceived Health Risks.

As can be observed in Figure 6.6, the set of acceptance determinants can be categorized according to the level of their influence on the observed behavior, i.e. Smart Meter Acceptance. The categories are: direct influences, 1st tier indirect influences, and 2nd tier indirect influences, which are described next in further detail. Furthermore, the relationships shown in Figure 6.6 either confirm predicted influences with an exception for the direction of some relationships, or were new influences that in some cases were unexpected direction-wise.

Direct Influences

The direct influences category includes acceptance determinants that empirically proved to have a direct influence on Smart Meter acceptance in the same direction as hypothesized in the I^3S^2 model. The determinants included in this category are: the Perceived Health Risks, Trialability, Performance Expectancy and the Perceived Security and Privacy Risk. Table 6.18 lists direct influence acceptance determinants in descending order.

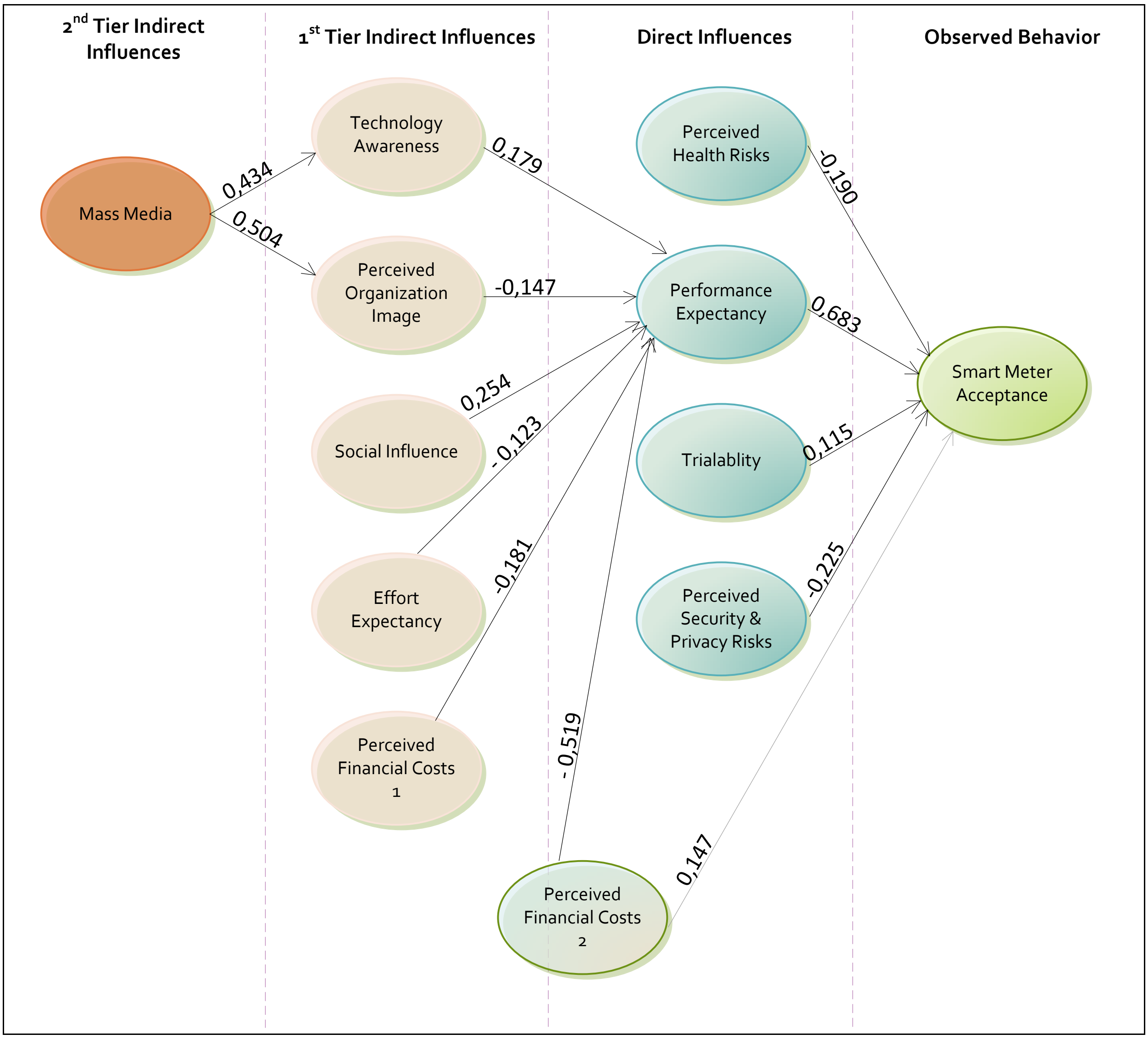

Figure 6.6: The identified I3S2 Model

Table 6.18: Ranked direct influences on smart meter acceptance

Acceptance Determinant	Original Hypothesis	Direction	Actual Influence	Magnitude	Original Hypothesis Supported
Performance Expectancy (PE)	PE →ACC	+	PE →ACC	0.683	Yes
Perceived Security & Privacy Risks (SP)	SP →ACC	-	SP →ACC	-0.225	Yes
Perceived Health Risks (HR)	HR→ACC	-	HR→ACC	-0.190	Yes
Trialability (TR)	TR→ACC	+	TR→ACC	0.115	Yes

As shown in Table 6.18 Performance Expectancy has proved to be the strongest predictor of consumers' acceptance of smart meters with a coefficient of 0.683, such that the more a consumer believed she or he would acquire gains from using a smart meter, the more likely they were to accept a smart meter. The second strongest predictor of acceptance was the Perceived Security and Privacy Risks with a coefficient of -0,225, which implies that the higher consumers perceived information security and privacy risks, then the less likely they are to accept a smart meter. Furthermore, Perceived Health Risks ranked 3rd in significance as a predictor of smart meter acceptance with a coefficient of -0.190, such that the more consumers perceived a smart meter to have adverse impact on their health the more likely they are to reject a meter.

The results above are contrary to the expectation that the Perceived Security and Privacy Risks would be the top ranking predictor of smart meters acceptance among the rest of acceptance determinants in the I^3S^2 model. In general, the influences listed in Table 6.18 can be summarized in formula 6.5, where ACCsm stands for smart meters acceptance, and e stands for error coefficient.

$$ACC_{sm} = 0.683PE - 0.225SP - 0.190HR + 0.115TR + e \qquad 6.5$$

Formula 6.5 implies that increasing social acceptance of smart meters can be achieved if stakeholders focused attention on the performance expectancy of a smart meter, i.e. the gains consumers can attain by using a smart meter. It is important to note that Performance Expectancy has a set of its own predictors, which are discussed further in the next section.

Next, stakeholders must take the necessary actions to ensure the security of the information of the system, safeguarding consumers' privacy, and inform consumers of these measures to avoid misperceptions on consumers' side that can negatively influence acceptance. Furthermore, the communication technology employed by the system must be assessed to ensure a safe technology health-wise. Last, stakeholders should seriously consider possible ways to allow consumers to tryout a smart meter, and explore its functionality. Though Trialability ranks the least significant among the acceptance predictors, yet it proved significant nevertheless.

It is worth mentioning that the influences expressed in formula 6.5 are not exhaustive, i.e. further influences may exist that are not captured in the resulting model, such as combined influences of acceptance determinants on the acceptance of smart meters. Such influences could be investigated as part of future work; however they are outside the scope of the current work.

1st Tier Indirect Influences

The category of 1st tier of indirect influences includes acceptance determinants the hypothesized direct influences of which on acceptance were not empirically supported. However, this set of determinants proved to have an unanticipated influence on another acceptance determinant in the model, which is the Performance Expectancy. A comparison between the influences originally hypothesized and the influences empirically proven for each determinant in this category is presented in Table 6.19.

Table 6.19: Comparing hypothesized and actual influences of 1st tier acceptance determinants

Acceptance Determinant	Original Hypothesis	Direction	Actual Influence	Magnitude	Original Hypothesis Supported
Perceived Financial Costs 2 (FC2)	FC2→ ACC	-	FC2→ PE	-0.519	NO
Social Influence (SI)	SI→ ACC	+	SI→ PE	0.254	NO
Perceived Financial Costs 1 (FC1)	FC1→ ACC	-	FC1→ PE	-0.181	NO
Technology Awareness (TA)	TA →ACC	+	TA →PE	0.179	NO
Perceived Organization Image (OI)	OI → ACC	+	OI → PE	-0.147	NO
Effort Expectancy (EE)	EE → ACC	-	EE → PE	-0.123	NO

It is evident from the table above that Perceived Financial Costs 2 is the strongest predictor of Performance Expectancy with a coefficient of -0.519. This implies that the more consumers believe that using a smart meter will increase the amount of their electricity bill; the less likely they are to perceive a smart meter as a useful device that enables them to achieve gains. With a coefficient of 0.254, Social Influence ranked 2nd in significance in predicting consumers' Performance Expectancy of a smart meter. Such that a consumer is more likely to perceive a smart meter useful and as a mean to obtain gains if:

- Individuals who are considered important to a consumer -e.g. friends, family members, neighbors, coworkers...etc- use a smart meter.
- Idols of a consumer -e.g. politicians or sports figures- support the use of a smart meter.
- A consumer perceives those who use a smart meter to have high status and prestige.

The third strongest predictor of the Performance Expectancy in the identified I^3S^2 model is Perceived Financial Costs 1 with a coefficient of – 0.181. This influence suggests that the more consumers find it unacceptable to pay at least 60 Euros for a smart meter, or 60 Euro for an external meter display, the less likely they perceive a smart meter useful as a means through which consumers can achieve gains. The fourth ranking predictor of Performance Expectancy is Technology Awareness with a coefficient of 0.179. This implies that the more a consumer knows about smart meters, then the more likely it is that the consumer will perceive the smart meter as useful to achieve certain gains. This result is logical when considering that an individual is most likely to appreciate the advantages of using a device when the individual is informed about the device, how it functions, and what services it offers. Furthermore, the Perceived Organization Image proved to have a significant influence on Performance Expectancy with a coefficient of - 0.147, which makes the Perceived Organization Image the fifth ranking determinant in terms of significance as a predictor of Performance Expectancy. The gist of this influence is that the more a consumer knows about her or his electricity grid operator, the less likely the consumer will perceive the meter as being useful. Though this influence was both unexpected and surprising, yet it is not entirely counter intuitive. A plausible explanation of this negative influence is consumers' past negative experience with their grid operator. This argument is confirmed when considering that consumers normally do not need to be in contact with their electricity grid operator unless there exist some sort of a problem with their connection.

The sixth ranking determinant in significance as a predictor of Performance Expectancy is Effort Expectancy, with a coefficient of -0.123. This influence insinuates that the more a consumer believes that a smart meter would be difficult to use, the less likely the consumer is to perceive the smart meter as being useful. Though this influence is not very strong, yet it is consistent with the results of Davis in his original TAM model (Davis 1993).

All of the listed relationships in this category represent influences that were not predicted in the original I^3S^2 model. Each acceptance determinant in this category had a direct influence on Performance Expectancy, which was unanticipated. On the other hand, the originally hypothesized direct influences of all these acceptance determinants on smart meter acceptance were not empirically supported, hence dropped from the identified I^3S^2 model. As a result, the only influences of the above listed acceptance determinants on the acceptance of smart meters that can be deduced from the model are indirect ones. Indirect relationships are the result of the product of coefficients of all the paths leading from the acceptance determinant to the Acceptance of Smart Meter construct.

The indirect influences of Perceived Financial Costs 2, Social Influence, Perceived Financial Cost 1, Technology Awareness, Perceived Organization Image, and Effort Expectancy on the Acceptance of Smart Meters are listed in Table 6.20. The indirect influence coefficient for each acceptance determinant listed in Table 6.20 was computed as the product of the path coefficient between the acceptance determinant and Performance Expectancy, and the path coefficient between Performance Expectancy and Acceptance of a Smart Meter, which is 0.683.

Table 6.20: 1st tier indirect influence on acceptance of smart meters

Acceptance Determinant Influence on Performance Expectancy	Via Performance Expectancy	Indirect Influence on Smart Meter Acceptance
Perceived Financial Costs 2 (FC2) = -0.519	0.683	-0.354
Social Influence (SI) = 0.254		0.173
Perceived Financial Costs 1 (FC1) = -0.181		-0.124
Technology Awareness (TA) = 0.179		0.122
Perceived Organization Image (OI) = -0.147		-0.100
Effort Expectancy (EE) = -0.123		-0.084

To conclude, the influences depicted in Table 6.19 on Performance Expectancy can be summarized in the following formula:

$$PE= -0.519FC2 +0.254SI -0.181FC1 +0.179TA -0.147OI -0.123EE + e \qquad 6.6$$

Formula 6.6 suggests that to increase the Performance Expectancy of smart meters responsible stakeholders must address the public's perception that a smart meter may cause an increase in consumers' electricity bills, or that a smart meter would consume a substantial amount of electricity for its operation, which would consequently cause an increase in consumers' electricity bills. Furthermore, as Social Influence proved to be empirically a significant predictor of Performance Expectancy, efforts should be exerted to explore in what ways Social Influence can be utilized for an increased Performance Expectancy and consequently increased acceptance of smart meters. In addition to consumers' perception of a possible increase in their electricity bill as a result of using a smart meter, another form of Perceived Financial Costs proved to be a significant predictor of Performance Expectancy, i.e. the financial costs associated with acquiring the meter or its external display. Attention must be paid by stakeholders to the affordability of smart meters and their external displays. Moreover, serious consideration of consumers' awareness of smart meters is required. If consumers are not made aware of the services offered by a smart meter and the goals that can be achieved by using it, then consumers cannot be expected to have a high expectation of the meter as a device. In addition to that, electricity grid operators should invest in promoting or improving their image among the consumers in their respective region of operation. Though grid operators reside in the regulated domain of the electricity market (i.e. they do not need to compete for consumers' satisfaction), yet the empirical results of this work showed that those respondents who knew who their grid operator was had low expectations of the meter. Finally, though Effort Expectancy ranked last in terms of the magnitude of its influence on Performance Expectancy, yet it is a significant predictor of the latter. This implies that the responsible stakeholders must pay attention to the ease of use aspects of smart meters and their external displays, as devices that are intended to be used by consumers from different age groups, and varying educational and intellectual backgrounds.

2nd Tier Indirect Influences

The 2nd tier of indirect influences encompasses the Mass Media acceptance determinant, which contrary to the original hypothesis does not have a direct influence on the acceptance of a smart meter. Instead, Mass Media was proved to influence smart meter acceptance indirectly via a sequence of two other acceptance determinants. In fact, Mass Media has two indirect influences on the acceptance of a smart meter as shown in Figure 6.6. The first influence is via the sequence: Perceived Organization Image and Performance Expectancy, whereas the second influence is via Technology Awareness and Perceived Expectancy. Thus, the hypothesized direct influences of Mass Media on Perceived Organization Image and Technology Awareness were empirically proven to be strong with coefficients of 0.504 and 0.434 respectively. Table 6.21 presents a comparison between the hypothesized and actual influences of the Mass Media acceptance determinant on other acceptance determinants in the I^3S^2 model.

Table 6.21: Comparing hypothesized and actual influences of 2nd tier acceptance determinants

Acceptance Determinant	Original Hypothesis	Direction	Actual Influence	Magnitude	Original Hypothesis Supported
Mass Media (MM)	MM → ACC	+	--	--	No
	MM → OI	+	MM → OI	0.504	Yes
	MM →TA	+	MM → TA	0.434	Yes

As mentioned earlier, Mass Media was empirically proven to indirectly influence the acceptance of a smart meter via two different routes in the I^3S^2 model. Indirect influences are calculated as the product of all path coefficients of a certain route between the Mass Media acceptance determinant and the smart meter acceptance construct in the I^3S^2 model. This process is illustrated in Table 6.22 along with the resulting indirect influences of the Mass Media on smart meter acceptance.

Table 6.22: 2nd tier indirect influences of Mass Media on acceptance of smart meters

Mass Media (MM) Influence	1st Tier Acceptance Determinant Influence	Via Performance Expectancy (PE)	Indirect Influence on Smart Meter Acceptance
MM → Technology Awareness (TA) = 0.434	TA → PE = 0.179	0.683	-0.050
MM → Perceived Organization Image (OI) = 0.504	OI → PE = -0.147		0.053

The results presented above are a mixture of confirmed hypothesized influences in the original I^3S^2 model, and new influences that were not anticipated and in some cases surprising. In addition to that, one path in the identified I^3S^2 model diagram was rather peculiar, which is the direct influence of the Perceived Financial Costs 2 on Smart Meter Acceptance. The oddity of this influence ensues from the fact that it suggest that the more a consumers believes that the usage of a smart meter will cause an increase in her or his electricity bill, the more likely the consumer is to accept a smart meter. This results was not only was unexpected but also considered to be counter intuitive, and unlike the negative influence of the Perceived Organization Image on Perceived Expectancy this results could not be explained.

Perceived Financial Costs 2 acceptance determinant was kept as part of the identified I^3S^2 model instead of being dropped due to its significant direct influence of Performance Expectancy, and its significant indirect influence on smart meter acceptance via Performance Expectancy, which cannot be ignored nor dropped from the model.

6.4 Conclusion

In this chapter, the I^3S^2 model was identified by analyzing a sample acquired from 315 respondents in The Netherlands. The aim was to explore the public’s opinion regarding the acceptance determinants in the I^3S^2 model, which are hypothesized to be components that influence the formation of consumers’ intention to accept a smart meter. In other words, the objective of this chapter is to investigate whether the determinants that were presumed to have an influence on the public acceptance of smart meters indeed play that role.

In general, almost all constructs encompassed in the original I^3S^2 model exhibited excellent results for the statistical tests run as part of the CFA, which conveyed an acceptable level of reliability and validity. This in turn confirms the suitability of the survey presented in Chapter 6 as a measurement instrument. An exception to this was the Compatibility construct, which performed poorly in all the statistical tests. Such poor results falling outside the range of acceptable values for almost each test have caused the Compatibility construct to be eliminated from the I^3S^2 model, and excluded from further processing. Though undesired, this outcome was not entirely unexpected due to the challenges encountered in formulating the observed variables –i.e. survey items- of the Compatibility construct. This is attributed to the fact that smart metering is a novel system, hence measuring the compatibility of the smart meter’s services and functionality against consumers’ past experience was somewhat contradictive. Therefore, the adoption of the Compatibility concept that is part of Roger’s Diffusion of Innovation theory for future acceptance models which are formulated for novel infrastructure technologies, could be deemed as unfitting.

Furthermore, the discriminant validity test that is part of CFA revealed that observed variables belonging to Effective Feedback, Observability, and Performance Expectancy constructs all loaded on the same factor. This result is logical when considering that in the context of smart metering systems these latent variables represent a common latent concept. This resulted in merging the three constructs listed above into one labeled as Performance Expectancy. This proves that acceptance determinants can behave differently from one technology to another despite efforts to maintain their original meaning in the case of determinants adopted from the literature. For example, Observability and Performance Expectancy acceptance determinants were adopted from the Diffusion of Innovation and the UTAUT theories respectively. Though originally the two concepts represent underlying latent concept that do not overlap, yet in the case of smart metering the two determinants overlapped each other along with a third determinant, i.e. Effective Feedback. Therefore, it is imperative that researchers keep an open perspective regarding such results in future technology acceptance models, and consider eliminating or merging determinants as seen fit for each technology.

An unanticipated result of the identified I^3S^2 model is that consumers do not attach much importance to the data architecture of the system when it comes to accepting a smart meter. That is, Data Architecture is not among the factors affecting consumers’ intention to accept a smart meter. The same is true for the Perceived Loss of Control. However, the fact that these two determinants proved to be insignificant in the context of smart metering does not imply they should not be investigated for alternative systems, especially when considering that it is already established that acceptance determinants can behave differently in the context of various systems.

Among all the acceptance determinants in the I^3S^2 model, Performance Expectancy proved to be the strongest predictor of the acceptance of smart meters. This result was unexpected as the Perceived Security and Privacy Risks were expected to rank highest among consumers’ priorities. Nevertheless, the Perceived Security and Privacy Risks ranked 2nd in strength of prediction of consumers smart metering acceptance.

The acceptance determinants in the identified I^3S^2 model fall under three categories with regards to their influence on acceptance: determinants with direct influence, determinants with an indirect influence via one other acceptance determinant, and finally determinants with an indirect influence via two other acceptance determinants. The four most influential and direct predictors of smart meter acceptance are the following in descending order of significance: Performance Expectancy, Perceived Security and Privacy Risks, Perceived Health Risks, and Trialability. Resources need to be allocated to these acceptance determinants in proportion of their importance. Furthermore, the five main predictors of Performance Expectancy are the following in descending order of significance: Perceived Financial Costs 2, Social Influence, Perceived Financial Costs1, Technology Awareness, Perceived Organization Image, and Effort Expectancy. Though these determinants influence acceptance indirectly stakeholders do need to pay attention to these factors as they are predictors of the strongest predictor of acceptance, i.e. Performance Expectancy. Thus, the above determinants play a significant role in the formation of consumers' intention to accept a smart meter.

The hypothesized direct influence of Mass Media on acceptance was not empirically supported. However, Mass Media's predicted direct influence on Technology Awareness and Perceived Organization Image proved to be a significant and strong influence. Such results enforce the belief that Mass Media can play a significant role in the diffusion of novel technologies among the public. This is especially true when considering the unexpected negative influence of the Perceived Organization Image on Performance Expectancy. Organizations governing a technology should utilize different mass media outlets to improve their public image and promote their services.

Results showed Effort Expectancy to be a predictor of Performance Expectancy. This is another unpredicted influence but nevertheless consistent with the results of Davis in his original TAM model. Thus, these two widely used acceptance determinants across the literature proved to be significant predictors of smart meter acceptance as well. Therefore, Effort Expectancy and Performance Expectancy should be considered as key components for future technology acceptance models.

Another unpredicted influence was the one from Technology Awareness on Performance Expectancy. This influence conveys the importance of stakeholders giving serious consideration to the process of informing consumers of the new technology to be deployed, to raise their awareness of the services offered by the system and what advantages they gain by using it. The most peculiar result of the identified I^3S^2 model was the positive influence of the Perceived Financial Costs2 on acceptance of smart meters. The influence suggests that the more consumers believed that using a smart meter would cause an increase in their electricity consumption bill, the more likely they are to accept a smart meter. No logical causes for this could be argued; nevertheless the determinant was kept as part of the model mainly due to its significant and logical influence on acceptance, indirectly via Performance Expectancy.

Finally, as part of future works it would be worthy to explore the combined influences of the acceptance determinants in the I^3S^2 model on the acceptance of smart meters.

Chapter 7 : Generalization of the I^3S^2 Model

7.1 Introduction

The requirements engineering phase of a systems' development process is crucial because the requirements elicited dictate not only the functionality of the resulting system, but also its failure or success. One important aspect of systems' requirements investigated in the literature is the improper implementation of the non-functional requirements such as information security. Poor information security assurance leads to the violation of information confidentiality. Furthermore, information security breaches compromise personal information thereby violating individuals' privacy.

The socio-technical nature of ICT-intensive infrastructure systems and the digitized manner in which they operate requires increased consumers' interaction with these systems. The role that consumers play today in the success of ICT-intensive infrastructure systems is novel. In the past, many systems required little or no consumer interaction. However today, their design requires a high level of consumers' active participation to ensure the fulfillment of the systems goals. System owners and designers must consider public values in an early stage of the system's development life-cycle because of the important role played by consumers. To involve consumers in a systems' development requires an understanding of public values, public opinion and attitudes toward a technology. This knowledge can then be translated into social requirements of a system, to ensure a higher level of societal acceptance and utilization of the technology.

As opposed to a system's functional and non-functional requirements that are determined by system owners, capturing social requirements is a more challenging task as it requires social knowledge. This chapter presents a process to generalize the I^3S^2 Model presented in Chapter 5. that aims to elicit and verify social requirements that a certain technology must satisfy to ensure a higher level of acceptance among members of a certain society.

This chapter is organized as follows: section 7.2 discusses the system requirements engineering process and the importance of social requirements, section 7.3 elaborates the role that the I^3S^2 Model plays in the process of social requirements discovery, the generalization of the I^3S^2 model is presented in section 7.4. In section 7.5, a detailed explanation of the process of social requirements elicitation and verification is presented. Finally, section 7.6 presents the conclusions of this chapter.

7.2 Systems Requirements Engineering

Information technology systems, which like many other types of systems, are often realized by a sequence of steps that collectively comprise the system's development life-cycle. Many different system development life cycle (SDLC) models share five basic steps: requirements engineering, analysis and design, implementation, testing, and development. Requirements engineering is a critical phase in a systems' development that specifies its functionality, and how it carries out functions. Consequently all subsequent steps of a system's development are influenced by the requirements engineering.

Systems' requirements can be categorized as functional and non-functional, where the former define what the system should do, the latter describe constraints on the solution space and how functional requirements should be delivered. Though both types of requirements are significant for systems' design and implementation a common problem in systems' development is to treat non-functional requirements as secondary requirements that ultimately are not met in the final product. Take, for example the non-functional requirement information security, i.e. the practices and measures implemented to protect a system from unlawful access by unauthorized parties. Being classified as a non-functional requirement, security measures have been implemented as an afterthought. "Many systems are developed initially without security in mind" (da Cruz, Rumpe et al. 2003), which results in ad-hoc retrofitting of information security requirements. Retroactive security implementation includes poor coding of security measures, cycles of penetrate and patch, or the addition of security requirements in late stages of system development at best (Crook, Ince et al. 2002, Haley, Laney et al. 2004). In all cases, the final product is rendered with a questionable level of information security. The inadequate practices of incorporating information security measures into the development process of ICT systems result from factors in the development process, or the environment in which the system operates. They include financial, regulatory, technical and social.

Financial

The costs incurred by implementing information security measures and the lack of an immediate return on investment, discourage organizations from committing to proper schemes of information security implementation. Thus, financial factors impede the proper implementation of information security when organizations do not invest in information security, thereby neglecting it (Kraemer, Carayon et al. 2009).

Regulatory

The lack of regulation and standardization that dictates rules and guidelines for implementing information security measures contributes to poor information security assurance practices within organizations. Moreover, weak information security implementation can be the result of flawed or poor security policies (Kraemer, Carayon et al. 2009).

Design and Analysis

Security vulnerabilities can surface from a system's design, implementation and configuration processes (Kraemer, Carayon et al. 2009). The lack of thorough analyses of weaknesses, threats and risks, and the relationships among them, can render a poorly-protected system vulnerable to malicious attacks. In addition, system developers cannot devise countermeasures unless they know from what to protect the system. While it is possible to design a system resilient to past and known potential attacks, to ensure a high level of information security it is crucial to plan for the future. Another imperative aspect of system analysis and design is finding the right balance between sound implementation of security as a non-functional requirement of the system and other functional requirements since security effects most aspects of the system. Outsourcing a system's development cycle or parts of it can be another cause for poor security (Sullivan, Knight et al. 1999). One problem that may arise when outsourcing contracts is that it allow for security measures to be implemented during various phases of a system's development, leading to retrofitted information security measures after the system is fully implemented. Another problem with outsourcing is when developers do not understand the sensitivity of the information maintained by the system or the potential vulnerabilities and threats in the system's context, such as application-unique code or workflow-level vulnerabilities (Sullivan, Knight et al. 1999).

Social

The social dimension, i.e. the human interaction with and influence on, systems is both important and often neglected. Social interaction takes several forms, such as decision-making by stakeholders regarding system development or operation, actions carried out by system's designers and developers, and end users utilizing the system. The impact of human interaction with the system should not be underestimated. Weak security implementation can result from the social factors listed below:

- Negative perception of information security; the lack of awareness of its importance by decision making actors (Hu, Hart et al. 2007).
- Lack of proper information security education for system designers and developers to establish a security culture within an organization (Futcher and von Solms 2008).
- Unclear security roles that need to be carried out by members within an organization (Futcher and von Solms 2008).
- Stakeholders' lack of necessary knowledge about risks posed to the information of their system. A study conducted by PricewaterhouseCoopers and CIO magazine surveying executives from different industries including energy, showed that 4 out of 10 respondents were unable to answer basic questions about the risks to their information (Slocumb 2009).
- Understaffing or inappropriate staffing with inexperienced employees because of costs (Kraemer, Carayon et al. 2009).
- Reactive rather than proactive attitude toward security within an organization.

To build a robust defense against security threats, information security should be based on understanding the organization's factors; such as its employees, company policies and the overall organization's culture (Hu, Hart et al. 2007).

A subcategory of social factors is related to the absence of proper appreciation of the sensitivity of information and its value. This is most evident in:

- The lack of understanding of the consequences that can occur from security breaches

- Failure to identify protection-worthy and sensitive informational assets within the system. For example, as (Slocumb 2009) noted “Most energy companies are not sure exactly where sensitive data is located” (Slocumb 2009).
- Lack of proper sensitivity classification of the system’s informational assets (Kraemer, Carayon et al. 2009).

Technical

Delayed or poor implementation of information security also results from technical factors:

- The lack of appropriate technologies such as: system analysis and design tools, secure programming languages, proper testing tools, and models for incorporating information security requirements into the system design.
- Difficulty in security design and implementation for systems that are built from existing commercial components (Sullivan, Knight et al. 1999). The focus of the manufacturers of components is not to ensure the security of information but rather to market and produce user-friendly systems with multiple features.
- Given the heterogeneous nature of critical infrastructure systems which can also be system-of-systems (SoS), the diversity among components (software, hardware, sensors ... etc) makes it difficult to address security properly (Mirjalili and Lenstra 2008).

Socio-Technical

Social and technical aspects of information security must be addressed jointly rather than separately. There is a lack of proper understanding of security processes within organizations, their nature, their evolution, how they interact with one another, and the interdependencies among them. In the literature, various classifications of security processes are explored. One classification is based on preventive, detective, and corrective controls. Another classification categorizes security controls into physical, procedural, technical, and legal. Torres et al (Torres, Sveen et al. 2008) devised a more meaningful classification by dividing security controls into technical, formal and informal capturing both the technical and social aspects of an organization.

Architectural

The implementation of information security within a system can be effected by its architecture. Critical infrastructure systems -such as smart metering- are hardly ever standalone; they operate within a network of systems. The complex and interconnected nature of these systems makes security a challenging task (Sullivan, Knight et al. 1999, Kraemer, Carayon et al. 2009), if these systems are connected via the internet. Furthermore, in some problematic cases these systems are developed on top of legacy systems designed in a time before security was a concern.

Other

Real time requirements of the system, time-to-market pressures (Mirjalili and Lenstra 2008) and deployment deadlines can lead to a late or weak information security implementation. These factors can make developers reluctant to spend time on proper information security in early stages of development. Ensuring the security of a system is challenging because of difficulties in quantifying and measuring security vulnerabilities of a system.

The impact of insufficient attention to non-functional requirements goes beyond the context of the system and its operations. It reaches the public users for whom a system is deployed. This is especially true for ICT systems embedded in critical infrastructure systems such as smart meters and the OV-Chipkaart that are used by the general public. Failure to fulfill non-functional requirements has the potential to violate public values consequently resulting in negative perceptions of the technology by society. For example, poor delivery of information security as a non-functional requirement of the Dutch smart metering system violates privacy a public value.

The socio-technical nature of many ICT-intensive infrastructure systems dictates the necessity to address security as a non-functional requirement during the first stage of system development, i.e. requirements gathering, and throughout all subsequent phases. Moreover, in addition to properly tackling information security as a non-functional requirement, thorough consideration of public values is fundamental. The conversion of the energy metering system, for example, into an intelligent infrastructure transformed energy consumers from passive to active users of the system: without their active participation the system cannot achieve its goals, or may not be deployed. Successful deployment and operation of ICT-intensive infrastructure systems depends on the engagement of members of society at an early stage of a system's development life cycle. This can be achieved by identifying and understanding significant public values and factors, which have a substantial influence on public opinion, and behavior during requirement elicitation phase of the system's life cycle. Yielding systems that comply with social values promises a higher level of acceptance and increased willingness by members of society to utilize the system.

In this work, it is proposed that in addition to functional and non-functional requirements of systems, attention must be paid to a new class of systems' requirements: social requirements, which emerge from the socio-technical nature of ICT-intensive infrastructure systems.

7.3 Objectives of the I^3S^2 Model

The literature on systems' requirements engineering rarely investigates the social components of information technology systems, or the problems evolving from the interaction between the social and technical components of the system. Some studies, explore narrow social aspects by focusing on actors involved in the process of the system's development including the system's designers and developers, or clients who commissioned the system. These studies aim to account for social issues as an inherent property of requirements engineering because of the social, cultural and political contexts of the social actors commissioning the system (Goguen 1993, Viller and Sommerville 1999).

Though this approach indeed discusses some social aspects of systems' development, it is restricted to social agents who act as both systems owners and users. It is well-suited to analyze systems used by the same party who authorized the requirements of the system. However, this process differs from that of critical infrastructure systems development in two ways as illustrated in Figure 7.1.

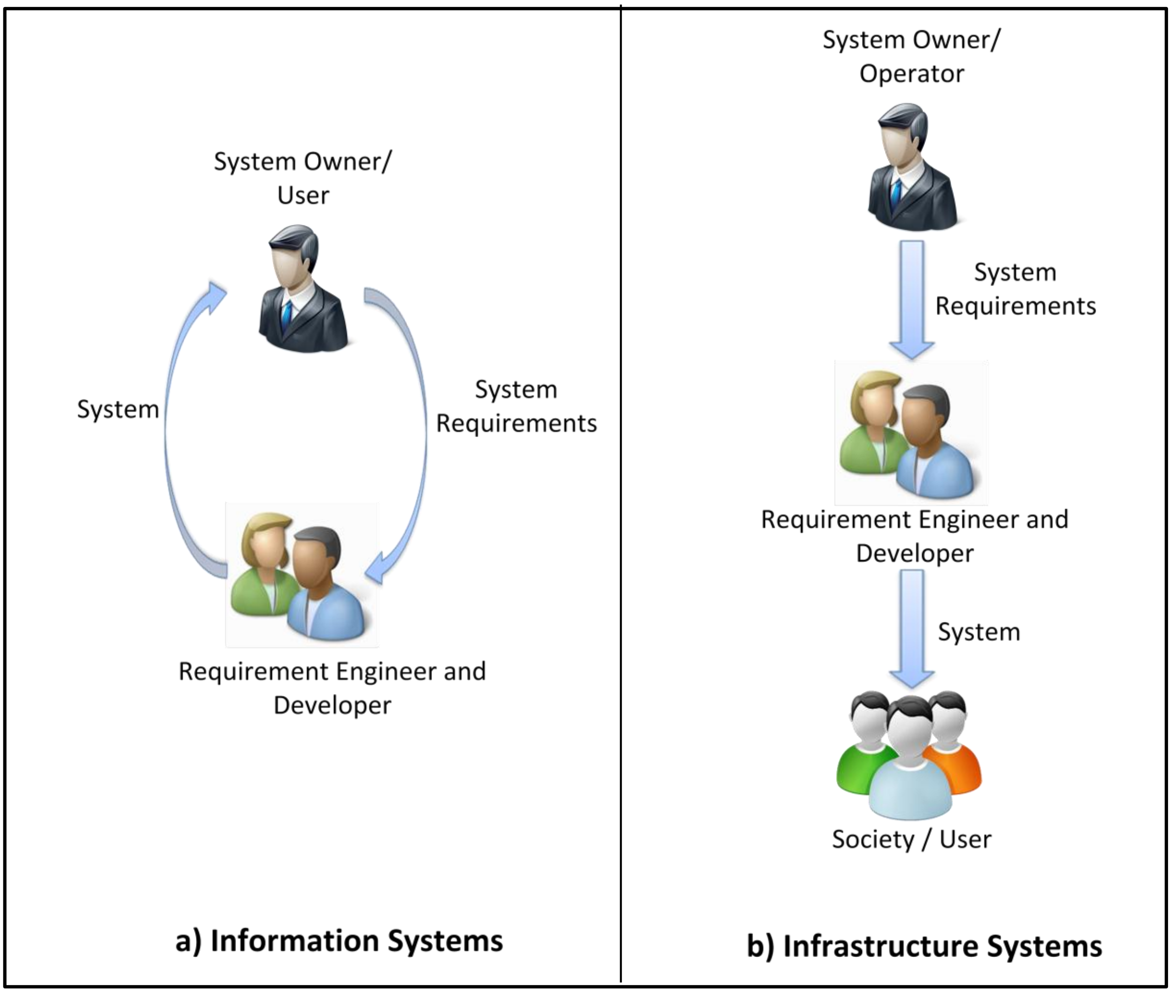

Figure 7.1: Requirements elicitation in a) information systems vs. b) infrastructure systems

First, infrastructure systems are commissioned and used by two social groups, i.e. a system is ordered by a governing institute and deployed among the general public. Second, the requirements of infrastructure systems are specified by the governing institute that owns the system rather than the users of the system. Conventional system requirements elicitation methods are unfit for infrastructure systems because they yield systems developed in isolation from end users. Some researchers state the need for systems' requirements engineers to seek a holistic perspective by "identifying, representing and managing the viewpoints of many different types of stakeholders" (IEEE Computer Society 2004). In reality, infrastructure systems such as smart metering and OV-Chipkaart systems rarely took into consideration members of society as stakeholders in the requirements elicitation process or in other life cycle phases.

To achieve a higher level of acceptance by society, users should be included in an early stage of system development as illustrated in Figure 7.2. Research on public values and opinion during requirements elicitation in the systems' development life cycle, and mapping the findings into a class of system social requirements should be seen as equally significant as functional and non-functional requirements.

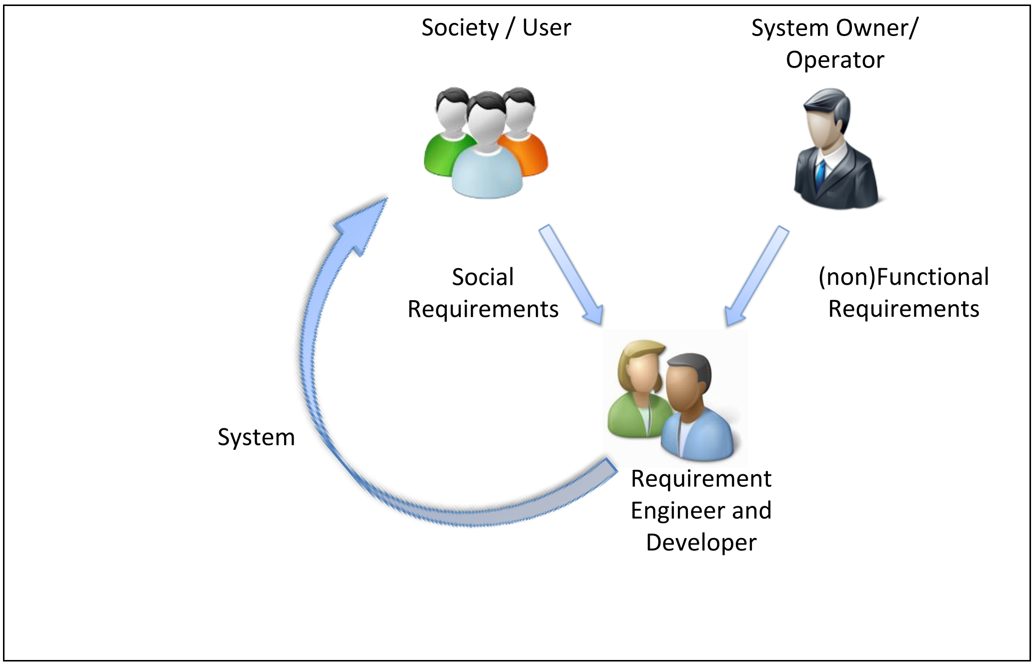

Figure 7.2: The proposed requirements elicitation process for infrastructure systems

In conclusion, ICT-intensive infrastructure systems are a special case of ICT systems in which users play an important role in their success. Thus, addressing public values and opinions in the infrastructure system is imperative for its success. Including public values as social requirements of the system ensures the involvement of the public, as stakeholders, early in the process of systems development. If a system does not incorporate social requirements, the system's commissioning and governing authority risks social resistance to the system that in turn can imperil the successful operation of the system. The I^3S^2 model is an integral component of a social requirements engineering process. It aids in verifying elicited social requirements, establishing their significance, and confirming the need to include the requirements in the system's development process. The social requirements engineering process proposed in this work is described in the subsequent sections of this chapter.

7.4 Generalizability of the I^3S^2 Model Across Infrastructure Systems

The I^3S^2 Model presented in Chapter 5 encompasses a set of technology acceptance determinants of various natures. Some of these determinants were adopted from a number of research efforts in the literature while others were elicited from a smart metering-knowledge base accumulated from different sources, which are mentioned in the subsequent sections of this chapter. Despite the different sources, both sets of technology acceptance determinants conform to a classification system that consists of three classes: ICT-related determinants, system-related determinants, and general determinants. These classes of acceptance determinants are described next in further detail.

ICT-Related Technology Acceptance Determinants

This class of determinants encompasses factors that are related to properties of the system which emerged as a result of the system's reliance on an ICT-backbone infrastructure. These factors can be related to the design of the system, part of its functionality, or adverse consequences ensuing from the technology used in implementing different components of the system. The acceptance determinants that belong to this class include, but are not limited to: perceived security and privacy risks, perceived health risks, data architecture, and the perceived loss of control.

System-Related Technology Acceptance Determinants- Facilitating Conditions

The technology acceptance determinants included in this class are strictly bound to the system under investigation, and are most likely determinants that act as technology adoption-enablers. This is the only class in this classification in which the determinants involved can differ completely from one system to another. To reach a higher level of generalization of this class, the facilitating conditions acceptance determinant is adapted from the UTAUT model. In the original work of Venkatesh et al. (Venkatesh, Morris et al. 2003), facilitating conditions are defined as the “degree to which an individual believes that an organizational and technical infrastructure exists to support use of the system.” (Venkatesh, Morris et al. 2003). Thus, it is recommended to append system-related acceptance determinants that conform to the property of adoption-enablers to this class. Effective Feedback is the only acceptance determinant in the I^3S^2 Model that falls within this class.

General Technology Acceptance Determinants

This class incorporates general technology acceptance determinants that are not bound to any specific technology. Such determinants cover a wide spectrum of concepts that have been demonstrated to have a significant influence on consumer acceptance of a vast range of technologies. The significant influence of these determinants may not necessarily hold for the same technology. Thus , it is prudent to apply the entire set of determinants in this class for future systems to explore which ones are crucial for each system in particular, and to identify them as social requirements of the system accordingly. As with the ICT-related technology acceptance determinants class, the general technology acceptance determinants class is not exhaustive. From the I^3S^2 Model, this class includes the following determinants: performance expectancy, social influence, effort expectancy, trialability, observability, compatibility, perceived organization image, mass media, technology awareness and perceived financial costs.

In general, the entire set of acceptance determinants within each class may not be applicable for future use within the context of other ICT-intensive infrastructure systems. For each adopted technology acceptance determinant, the definitions and the corresponding survey items must be revisited and altered to fit the technology under investigation. This ensures accuracy in the concepts that are being applied and investigated for future systems.

7.5 Elicitation and Verification of Social Requirements in ICT-Based Infrastructures Systems Development

The I^3S^2 model is used to verify acceptance determinants that are hypothesized to be social requirements that must be satisfied by the smart metering system to ensure a high level of social acceptance. Though the I^3S^2 Model was designed for a smart metering case, it can be used in a process of social requirements elicitation and verification of ICT-intensive infrastructure systems generally, irrespective of country (culture) or system.

The requirements elicitation and verification process consists of a number of phases, one of which is formulating a technology acceptance model, i.e. a variant of the X- I^3S^2 Model, which encompasses a set of acceptance determinants. A number of the acceptance determinants included in the model are specific to the technology the acceptance of which being investigated. Thus, a variant of the I^3S^2 model could share a number of common acceptance determinants with the one designed for the smart metering case, but would also include acceptance determinants that are related more specifically to the technology the acceptance of which is under study. Furthermore, smart metering system-specific determinants that were included in the I^3S^2 model would naturally be discarded from the I^3S^2 model variants.

The difference in the acceptance determinants included in each model stems not only from the fact that the I^3S^2 model and its variants are system-specific models but also that they are society-specific. Because considering the elicitation of social requirements is dependent on public values of a specific society, one must adjust for potential cultural differences. Furthermore, varying infrastructure systems may need to address and safeguard different sets of values in varying social contexts.

To discover social requirements that must be satisfied by an ICT-intensive infrastructure system, a process of social requirements elicitation and verification should be followed. This process consists of four stages that cover a number of crucial activities such as: building a broad knowledge base of the system under investigation, identification of a potential set of social requirements, and verification of these requirements.

1- Social Requirements Elicitation

Though social requirements of ICT-intensive systems require an understanding of society, delving into the technical component of such systems is equally indispensable for requirements engineers. Scrutinizing the technical aspects of systems generates a comprehensive perspective of the system and consequently a set of potential social requirements that may have an influence on the level of society's acceptance of the system. Therefore, the process of social requirements elicitation necessitates requirements engineers to develop an in-depth understanding of both the technical aspects of the system, and the society within which the system will be deployed. These two sub-stages of the social requirements elicitation process are described next in further detail.

a. In-Depth Conception of the System

Before a requirements engineer can compile potential social requirements of an ICT-intensive system, s/he must first familiarize him/herself with the system. A thorough understanding of a system can be gained by building a knowledge foundation derived from various sources, each of which can offer insight into the system from different perspectives. A number of knowledge resources that a requirements engineer needs to consult are listed in Table 7.1.

Table 7.1: A list of sources of knowledge regarding a system

Resource	Description
Scientific Literature	Academic research and literature are important assets to requirements engineers to understand the system. A system can be technically fathomed to a great extent by reviewing research conducted regarding various technical aspects of either the system under question if already deployed and its social requirements are to be retrofitted, or other similar systems if the social requirements elicitation is taking place at an early stage of development. Knowledge of the literature aids the discovery of technical shortcomings that may have an impact on the social perception of a system as a whole and the willingness of users to adopt it.
Experts Interviews	Interviews of systems owners and experts in their domains can help shed light on aspects of the systems such as: its functionality, how it delivers its services, system architecture, informational assets, and motivation for the system. System owners can provide detailed system-related information whereas

	external experts can share knowledge of a system's flaws.
Media	The intention of developing or deploying new infrastructure technology does not go unnoticed in the diverse mass media. The media coverage of system development provides a window to the systems evolution, its regulation and legislation in case of already implemented systems. Furthermore, media can also cover issues related to new systems that are not yet implemented.
Legal Documents	Documents that report the legislation and regulation of a system give a crucial knowledge foundation of the system. They clarify the scope of the system, the incentives behind its launch, and the goals of its deployment.
Technical Documents	Technical standards documents report a set of minimum technical and functional requirements, which a system must satisfy. Such documents are a crucial source of gaining an insight into how a system operates and the basic set of functions it is excepted to carry out.

b. **In-Depth Conception of Society**

Identifying the social requirements of systems requires an exploration of the public's impression of the infrastructure technology to be developed or deployed. Public opinion and attitudes toward a technology can be encountered through, for example, media channels, interviews, or consumers' organizations. These resources and how they can be utilized to explore public opinion are explained in further detail in Table 7.2.

Table 7.2: A list of possible methods to obtain an insight of a society's perception of a system

Resource	Description
Media	Inspecting news items that appear in diverse media channels allows requirements engineers to develop an awareness of the overall sentiment among members of society regarding the new infrastructure system to be developed or deployed. News segments often raise consumer concerns regarding different aspects of the system, such as its functionality, how it operates, and secondary consequences of the system's operation that have an impact on consumers' lives.
Laymen Interviews	Conducting laymen interviews with the general population

	reveals popular perceptions of a system Widespread interviews can provide detailed responses from individuals. By conversing with subsets of society, a requirements engineer will encounter diverse opinions and concerns regarding the system.
Consumers Organizations	Consumer organizations are non-profit associations that act on behalf of consumers, to represent consumers' interests and to protect and promote their rights (Consumentenbond). Conferring with organizations offers requirements engineers the opportunity to gain a clear understanding of the consumers concerns and perspectives of a new technology.

In addition to the resources listed in Table 7.2, digital resources make additional methods possible to help one gain insight into the public reactions to and impressions of a technology. The revolution in the information and communication domain allowed for the rise of digital venues, such as forums and blogs, in which individuals express their opinions and discuss them with others. Table 7.3 lists a number of digital resources through which public opinion regarding a technology can be captured.

Table 7.3: A list of digital venues hosting public opinion regarding a system

Resource	Description
Online Blogs	Web logs or blogs are open discussions published on the Internet. A blog is normally a webpage owned and moderated by an individual, who utilizes it to express his or her views. Independent blogs are valuable assets for requirements engineers to gain a clear perspective of society's overall reaction to a certain technology. Via a blog, a requirements engineer can learn about aspects of the system that consumers find appealing or useful, thereby identifying technology adoption enabling factors. Likewise, blog discussions of negative aspects of the technology such as inconveniences or concern for privacy or safety aid requirements engineers in compiling technology adoption hindering factors.
Activists Web Campaigns	Activists' web campaigns are similar to blogs in form but slightly differ in content. They are dedicated to increase awareness of technologies that are perceived of as malicious, or of having adverse effects on individuals' lives. Activists resort to web campaigns to garner public support for their causes and to encourage system owners, regulators and policy makers to change. A key difference between web campaigns and blogs is that the former strictly highlights the negative

	features of a technology without any reference to advantages may be gained from its use. These campaigns are rich sources to understand causes for social rejection of technologies and scientific evidence and arguments used to support activists' claim.

2- Requirements Specification

The holistic perspective of the system and society-related knowledge gained during the requirements elicitation phase allows a requirements engineer to proceed to the requirements specification process. This process has two components: first, a requirements engineer identifies prospective social requirements of the system to be developed or deployed. Both technology adoption hindering and enabling factors are compiled into a list of determinants expected to influence individuals' willingness to adopt a technology. Each determinant is precisely defined Defining each factor is crucial for designing the measurement instrument – i.e. survey- to measure the intended determinant rather than their variants. This consequently influences the actionable recommendations to be given to change agents. Second, the defined technology acceptance determinants and the hypothesized relationships among them must be defined. That is, determining the direction of the influences of each of the determinants on observed behavior. The relationships among determinants encompassing the new-found theory can be articulated in a causal relationship diagram. Furthermore, the model illustrates the relationships between each construct and the observed behavior, i.e. adoption and utilization of the new technology, and the relationships among the constructs. In addition, the conceptual model should depict the direction of each relationship; that is whether an acceptance determinant has a negative or a positive impact on an individual's willingness to adopt a technology. The conceptual model renders a holistic perspective of the hypothesized influences among all the constructs in the model, which will be verified in subsequent phases of the process of social requirements elicitation.

3- Requirements Verification

The social requirements determined that were combined into a technology acceptance model result from the observations and intuition of a requirements engineer. However, there is no empirical evidence that supports the presumed influences of the acceptance determinants on consumers' willingness to adopt a technology. To establish the significance of acceptance determinants, the hypothesized relationships must be verified. In addition, different categories of social actors must be consulted to further confirm the significance of these determinants. As the main users of the new technology, consumers are undoubtedly the pivotal social actors against which the elicited technology acceptance determinants must be verified. Furthermore, consultation with experts from both academia and industry is crucial to ensure a comprehensive perspective. Various methods of consulting with the various types of social actors are described next in further detail.

- Experts Confirmation of Social Requirements

In addition to consulting with technology users to confirm the hypothesized influences of technology acceptance determinants on consumer's willingness to adopt a technology, consultation with industrial and academic experts is essential. Interviews during which experts examine and appraise the proposed technology acceptance model and scrutinize the hypothesized influence of each technology acceptance determinant on consumers' willingness to adopt a technology are important.

Obtaining experts' input regarding the proposed technology acceptance models and their hypothesized influence helps one illuminate social acceptance of technologies from technical and institutional dimensions. Experts' past experience with similar systems and their insight into the institutional and regulatory aspects of the technology can aid in either confirming or discrediting the hypothesized influences in the technology acceptance model. Furthermore, expert feedback can aid in supplementing the proposed technology acceptance model by suggesting additional factors not yet included in the model.

- Societal Confirmation of Social Requirements

Factors identified in steps one and two of the social requirements elicitation process that are assumed to influence consumers' acceptance of a technology were derived, in part, from media outlets believed to represent consumers' opinion. It remains imperative to consult directly with consumers as end users to confirm the conclusions made about consumers' willingness to adopt a technology.

Consumers' confirmation of technology acceptance factors is an indispensable step of the requirements elicitation process for two reasons. One, the elicited factors can be subject to cultural influences. A factor that may influence consumers' acceptance of a technology within a certain society may not necessarily have the same influence on consumers' acceptance of the same technology within another society. Two, the opinion and attitude of society members towards a technology can change in time.

A survey needs to be designed and conducted to investigate public opinion on the set of factors believed to influence the social acceptance of a technology. Surveys serve as a measurement instrument that capture societal attitudes towards the set of factors hypothesized to impact individuals' acceptance of a technology. In principle, a survey reflects the technology acceptance model that was formulated in previous steps of the social requirements elicitation process. Each acceptance determinant encompassed in the technology acceptance model is mapped into a set of statements -or questions- included in the survey, which collectively can measure the influence of each factor on the acceptance of technology. Further details and considerations of designing and conducting surveys are presented in Chapter 6.

The dataset generated by the survey must be analyzed for empirical evidence of anticipated influences of the technology acceptance determinants on consumers' willingness to accept and utilize a technology. The statistical model that results depicts the actual influences among the acceptance determinants rather than the hypothesized ones. A detailed process of a survey's dataset analysis and results deduction is demonstrated in Chapter 7.

Completion of this step yields a list of empirically significant technology acceptance determinants encompassing the views of both technology experts and novice users.

4- Credence and Adoption of Social Requirements in System Development

The statistical model based on the survey data provides a set of empirically-proven influences among technology acceptance determinants. To deduce meaningful recommendations for systems owners, designers and developers the model must be examined to identify the following four elements:

- Remaining technology acceptance determinants that were deemed significant
- Possible new technology acceptance determinants that emerged as a result of merging multiple determinants
- Technology acceptance determinants that were deemed insignificant
- Unanticipated influences among the technology acceptance determinants in the model

These four elements help one recognize which technology acceptance determinants influence consumer acceptance and can be identified as the new social requirements, which system designers and developers need to adopt to ensure that the technology meets social acceptance. Furthermore, scrutinizing the ensuing significant influences in the model entails examining various aspects as follows:

Direct Influences:

Direct significant influences can be found between either original or emergent technology acceptance determinants, and the technology acceptance construct. These relationships or influences imply that their respective determinants have direct impact on consumers' acceptance of a technology that is not mediated by any other construct in the model. To formulate constructive recommendations the following is required: first, the direction of each relationship must be determined as positive or negative. That is, whether the determinant increases or decreases consumers' tendency to accept the technology. Second, the significance of all acceptance determinants with direct influence on technology acceptance must be compared. This is necessary to establish how these determinants rank against each other, and consequently determine which determinants require most attention and resources.

Indirect Influences:

In addition to the direct influence of acceptance determinants in the model, it is important to investigate indirect influences, i.e. those mediated by other acceptance determinants. Indirect influences require special attention to understand how these acceptance determinants may mediate one another, to ensure accounting for these combined influences and how they impact consumers' acceptance of technology. Because some acceptance determinants may have an insignificant influence on consumers' acceptance of a technology, it is important to explore possible indirect influences. However when experimenting with determinants for indirect influence on acceptance via other determinants in the model, indirect influences may prove to be empirically significant. Therefore, they must be acknowledged, rather than discarded.

Compare Direct and Indirect Influences:

In some models, a technology acceptance determinant may have a significant influence on acceptance both directly and indirectly. In such a case, it is crucial to compare the two (or more) influences to establish the strongest of all. This in turn aids to formulate the most effective recommendations to system owners, designers and developers regarding the inclusion of these acceptance determinants as social requirements in the technology to be developed or deployed.

Explore Possible Influences Among Acceptance Constructs:

Additional elements that could impact the deduced recommendations from the model are possible relationships among the acceptance determinants in the model. Understanding these influences is fundamental to understanding the role each technology acceptance determinant plays in influencing the level of consumers' acceptance of a technology.

In addition to reporting the findings based on the four elements listed above, it is also important to examine and disclose technology acceptance determinants that were deemed to be insignificant. Doing so allows the technology's owners and designers to focus on the most influential technology acceptance determinants, translate them to social requirements that need to be complied with by the system, and allocate the required resources for the realization of these requirements accordingly. Thus, enabling technology owners to save resources -i.e. time, money, and effort- by discarding insignificant technology determinants rather than to address them. The process described above of social requirements elicitation and verification is illustrated in Figure 7.3.

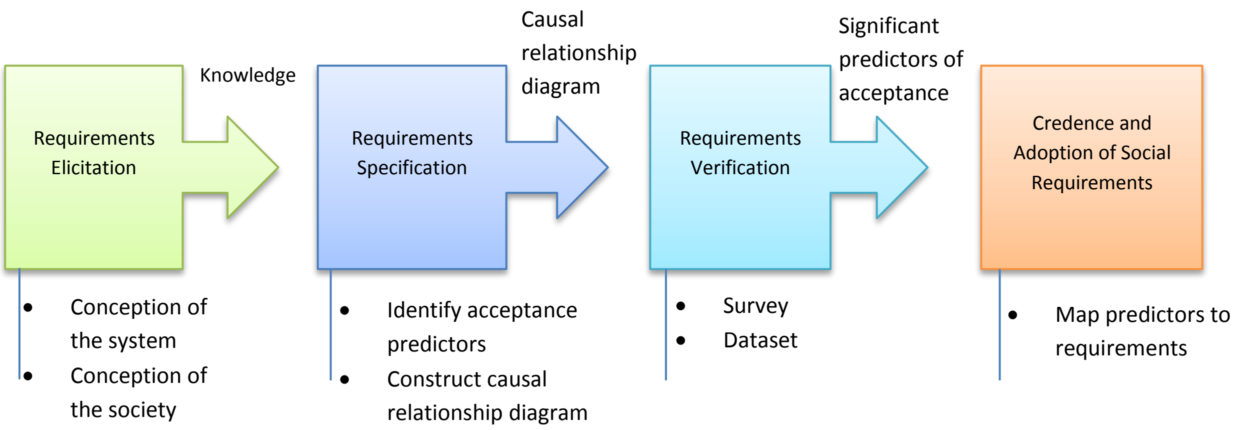

Figure 7.3: Social requirements elicitation and verification process

7.6 Conclusion

The requirements engineering phase of a systems' development life-cycle plays a crucial role in the success of the system. The socio-technical nature of the emerging ICT-intensive infrastructure systems requires a higher level of interaction between society and the technology. The rising level of society-technology interaction suggests that consumer adoption of these technologies has become crucial for a successful deployment and operation of these systems. Consequently, consumer acceptance of technology has become a pivotal issue in the design and development of such systems. This dictates the need for consumer involvement in the development of socio-technical systems in early stages of their development life-cycle, and for an emergent class of *social* system requirements. This new class of social systems' requirements aims to capture the opinion and attitude of society members toward technologies as well as to safeguard public values.

Furthermore, the I^3S^2 model is an instrument to verify social requirements of ICT-intensive infrastructure systems. A generic perspective of the I^3S^2 model divides determinants into three classes: general determinants, ICT-related determinants, and system-related determinants. This classification facilitates the adoption and application of the model within the contexts of other ICT-intensive infrastructure systems, and within various cultures and societies.

Using the I^3S^2 model, a comprehensive process of social requirements elicitation and verification is tailored for discovering public opinion on an ICT-intensive infrastructure system, in addition to recognizing prominent public values which a system must not breach. The opinion and values of consumers are mapped into technology acceptance determinants to investigate their influence on consumer acceptance of the technology that is to be developed or deployed. An important aspect of the social requirements elicitation and verification process is that it not only takes into consideration system-specific traits, which vary from one system to another, but also it accommodates the cultural characteristics that may vary from one society to another. This makes the process and the model applicable within any society and for any ICT-intensive system. Upon the verification of the technology acceptance determinants, those determinants which proved to have a significant influence on consumer acceptance of a technology are translated into social requirements. The accredited set of social requirements is later recommended accordingly to system owners, developers and designs to take into consideration preferably prior to system implementation, to ensure yielding systems with a higher level of social acceptance.

Chapter 8 : Overview of Experts Perspective

8.1 Introduction

To assess the value of the work presented in previous chapters of this thesis and its contribution to both academia and industry, a panel of six experts was interviewed as a validation phase test of this work. Members of the panel represent different organizations, each of which has a unique affiliation with the smart metering system in The Netherlands. The panel consists of: David Kramer from the Ministry of Economic Affairs, Edwin Edelenbos from the National Competition Authority-NMa, Marcelo Masera from the Joint Research Center of the European Commission- JRC, Michiel Karskens from Consumentenbond the Dutch consumers' organization, Charlotte Kobus from Enexis B.V. an energy grid operator in The Netherlands, and Rudi Hakvoort from Delft Univeristy of Technology. Table 8.1 lists an overview of the panel of experts.

Table 8.1: Overview of panel of interviewed experts

Expert	Position	Affiliation
David Kramer	Senior Policy Advisor, Project Leader Smart Metering The Netherlands	Ministry of Economic Affairs
Edwin Edelenbos	Program Manager Metering	the National Competition Authority-NMa
Marcelo Masera	Head of Unit "Energy Security"	Energy Security Unit, Institute for Energy and Transport of the Joint Research Center- JRC, European Commission
Michiel Karskens	Head of Public Affairs	Consumentenbond
Charlotte Kobus	Innovator	Enexis B.V. (energy grid operator)
Rudi Hakvoort	Associate Professor	Delft University of Technology, Faculty of Technology Policy and Management, Section of Energy and Industry

Each interviewee was presented with the hypotheses underlying the current work, the Acceptance-by-Design framework, and the I^3S^2 Model. Furthermore, interviewees were asked a number of questions related to the social acceptance of infrastructure systems, social requirements, systems development lifecycle, and the role of media in the diffusion of a technology such as a smart meter within society.

The aim of conducting the interviews is to probe experienced opinions of the interviewees, who assessed the usefulness of the framework proposed in this work, identified some of its shortcomings, and proposed possible improvements. These insights were shared from different perspectives such as: governmental, regulatory, industrial, societal, and academic, which offered a near-comprehensive outlook regarding the usefulness of applying the proposed method in the elicitation and verification of social requirements. The responses obtained from interviewees aid in shaping the trajectory for the future research needed in the area of social requirements elicitation and inclusion of public opinion in infrastructure systems' development.

The interviews took place during the period from the 28th of August, 2012 until the 13th of September, 2012. It is noteworthy that some interviewees were not presented with the entire list of questions due to time restrictions. Furthermore, the overview of responses presented below is an expression of interviewees' personal views and does not necessarily reflect the views of the organizations they are respectively affiliated with.

In section 8.2 an overview of the six interviews is presented, whereas section 8.3 summarizes the views expressed by the interviewees. A full transcription of each interview is available in Appendix E.

8.2 Overview of Experts' Opinion

Social Acceptance of Infrastructure Systems

There was a consensus among the interviewees regarding the general importance of social acceptance of smart meters. However, some interviewees emphasize a unique aspect of the issue.

Kramer acknowledges that social acceptance is a significant issue since the rejection of the mandatory roll out by the Dutch parliament in 2009. The concerns raised then by the senate and the Dutch consumers' organization ConsumentenBond, triggered a change in the Ministry's approach to diffusing smart meters among Dutch households. In addition to change in legislation that granted consumers the right of voluntary adoption of a smart meter, the Ministry realized the importance of making consumers central, and organized round tables that mainly discussed consumer-related topics. The significance of social acceptance of smart meters was further confirmed by Edelenbos.

Kobus reports that it has already been noticed that deployment of smart meters is hindered when acceptance is not made a focal point. Kobus acknowledges that user-centric design is a starting point for innovations, and that if energy companies want to induce new behavior (energy demand reduction), they have to start with the end user and what can induce new behavior and then develop technology, instead of the other way around.

Masera states that social acceptance of smart meters is crucial mainly because only few actors understand it and its implications. Furthermore, no one can predict the implications of interconnecting consumers among themselves and the energy companies. In principle, smart meters deployment results in a new form of a social network and micro-markets at neighborhood level. However, none of the benefits that are aimed to be gained from the smart grids concept can be realized without the deployment and utilization of the smart metering infrastructure. Thus, social acceptance of smart meters is crucial for society at large and the energy companies to reap the intended benefits by both society and energy companies.

From an academic point of view, Hakvoort states that social acceptance of smart meters is indeed a key issue. However, it is important to distinguish between the development and implementation phases of the smart metering system. Acceptance is crucial during and after the implementation phase, whereas the development phase must be carried out with an eye on the future of the system, and the changes it may incur.

A slightly different viewpoint was projected by Karskens who believes that smart meters are not fundamental for smart grids, a position which contradicts that of Masera. In essence, Karskens acknowledges the importance of social acceptance of smart meters, he believes however that acceptance must remain a personal choice for members of society. Thus ConsumentenBond has exerted tremendous pressure to ensure consumers' freedom of choice. This can be observed in the rejection of the mandatory roll-out of the infrastructure in 2009 by the senate due to a report conducted by the University of Tilburg, which was commissioned by Karskens. The report states that from a legal standpoint smart meters pose a legal dilemma since the frequent readings of the meter are considered a breach of article 8 –right to respect for private and family life- from the Convention for the Protection of Human Rights and Fundamental Freedoms (Council of Europe 2003, Garcia and Jacobs 2010).

Edelenbos believes in the importance of addressing social acceptance of a technology at early stages of its development. Karskens agrees with this position and adds that this approach is a system's design fundamental that is applied by reputable IT corporates, who hire psychologists and sociologists to gain insight into the social factors of a product to increase its acceptance.

Kobus and Hakvoort believe that attending to acceptance in a timely manner is important in principle, yet difficult in practice. The ease or difficulty of achieving this depends on the level of consumers' exposure to the technology under question.

Masera believes that attending to acceptance during initial stages of systems' development presents an "egg and chicken" scenario, an outlook that is in agreement with that of Kobus and Hakvoort. Masera states that to explore public opinion regarding a technology, the technology should be deployed for individuals to have a feel for it and form an opinion. A proposed approach is to launch small pilot deployments of a technology with a gradual growth. Another proposed alternative is to apply the approach of the current work as depicted in Figure 7.3 prior to a small-scale pilot deployment.

When it comes to understanding the process of social acceptance of a technology, Kramer and Edelenbos agree on its importance since an obvious outcome of social rejection of a technology, is the failure of said technology. However, this role should not be undertaken by the Ministry (or the government in general) or NMa as a regulatory authority. Both interviewees believe that they only need a general overview of acceptance factors, rather than an in-depth knowledge to guide the energy market on what services to offer and how to design and deliver these services. Edelenbos elaborates that regulators assume the role of regulating the installation of meters according to legislation. However, ensuring social acceptance does not fall within the regulators' responsibilities. Kramer believes that this role should be assumed by companies deploying the technology, i.e. electricity grid operators.

Kobus agrees in principle with the significance of having a thorough understanding of the social acceptance process, though believes it difficult to achieve. Kobus states that there is a belief among many practitioners that educating people is the key to society's willingness to accept technology. This opinion is shared by Masera, who believes that understanding the process of social acceptance is bound to the transformation of society to deal with new technologies, and that educating people is an essential part of this process. Masera also believes that governments should be concerned with understanding the social implementations in general of introducing a new technology, including the acceptance process. Furthermore, both Hakvoort and Karskens agree with the importance of fathoming social acceptance of a new technology. Karskens reasons that it is essential to understand factors that influence or improve the level of acceptance before attempting to design solutions to overcome social rejection of the technology.

Karskens, Hakvoort, Kobus and Masera believe that acceptance determinants of a technology are dependent on both the technology and the society in which it is deployed. Kobus believes that cultural differences and motivation behind a system contribute to defining the acceptance determinants of the system. Hakvoort agrees with this position and elaborates that security and privacy risks as an acceptance determinant could be entirely inconsequential in countries where governments systemically know everything about their citizens. This contradicts with the position from this acceptance determinant in societies such as The Netherlands, where security and privacy are highly valued. In addition, Masera believes that acceptance determinants do not only vary from society to society, but also from one neighborhood to another within one society, where demographics such as level of income, education and age play a role. Furthermore, Kramer states that acceptance determinants depend on cultural and technological background differences. Kramer further states that the revised smart metering legislation that resulted from the delayed deployment was a step in the right direction of accounting for consumers and their opinions. However, Kramer also speculates about whether the overall Dutch smart metering experience would apply for other countries.

According to the cost-benefit analysis reports conducted by KEMA in 2005 and in 2010, the smart metering business case dropped from 1.3 billion euros in 2005 to 770 million euros in 2010 after the introduction of the new legislation granting voluntary adoption to consumers. When asked whether the change in the business case can be partially attributed to social rejection and the lack of accounting for social requirements in the development of the smart metering system, Kramer, Edelenbos, Kobus and Karskens agree. Kramer believes the voluntary roll-out that was introduced as a result of the social rejection of smart meters, contributed among other factors in the change of the business case. Kramer, Edelenbos and Karskens believe that freedom of choice in particular, which can be considered as a social requirement, is partially responsible for the business case drop. Kramer and Edelenbos agree that freedom of choice has a high price, however, this price is worth paying as freedom of choice is greatly valued in the Dutch society. Kramer states that a societal cost-benefit analysis is limited. However Kramer believes that the cause for the lack of such study is the difficulty in quantifying social benefits such as the freedom of choice. Kramer states that perhaps if a consumer-centric approach was adopted from the beginning the change in business case could have been avoided, and perhaps the voluntary adoption would not have been necessary. On the hand, Kramer indicates that the voluntary approach is not the only cause of a lower business case; cost of the meter among other factors listed in the KEMA 2010 report contributed to that. Furthermore, Edelenbos believes that the original business case that was based on a mandatory roll-out would have been impossible to achieve due to mass social resistance. Furthermore, Hakvoort and Masera could not attribute the reduced business case to not accounting for social requirements during the development of smart meters.

In addition, Kobus, Masera, Karskens and Hakvoort all agree on the importance of involving public opinion in defining acceptance determinants of a technology. Nevertheless, these parties had various opinions regarding whether surveys are a good way of doing so. Karskens stated that conducting large-scale surveys is difficult, and that focus groups could be an alternative to discovering public opinion. Other alternatives are consumer panels and social impact assessment, which were proposed by Hakvoort. Kobus believes that surveys are a good way of exploring public opinion as a second phase after conducting interviews with a subset of the population. Kobus also believes that this should be combined with small-scale test pilots. This position opposes that of Masera who states that surveys should be conducted as a first stage of the public opinion exploration process. However, Masera also believes that surveys can introduce the risk of overwhelming respondents with information, and forming false perceptions among respondents.

Social Requirements

Karskens, Kramer, Kobus, and Masera all believe that social requirements can be predictors of social acceptance of smart meters. Karskens believes that the inclusion of social requirements in systems' development will make public acceptance more likely to happen since the public's interests and concerns were considered in the design of the system. Kramer explains that the extent to which social requirements are able to predict acceptance depends greatly on the cultural and technological backgrounds and existing societal challenges.

Furthermore, Masera states that social requirements' predictive power of social acceptance is bound to the extent to which the elicited requirements are feasible and affordable for all actors -i.e. system owners and members of society. Otherwise, the risk is that these requirements become hurdles that hinder technology adoption rather than enable it. In principle, Masera believes in the importance of eliciting social requirements prior to development and deployment to increase the probability of yielding a socially acceptable system. Kobus believes that a good user experience can lead to social acceptance of a technology. In this work, social requirements are intended to aid in forming a good user experience in general among other goals. Thus, social requirements can predict the level of social acceptance of a technology. From Hakvoort's point of view, social requirements are necessary but not sufficient condition for social acceptance of a technology, depending on the extent to which the elicited requirements cover the various aspects of a technology. For example, attractiveness of a technology is a very important aspect for technology adoption, thus the prediction power of social requirements depends on whether this aspect among others are taken into consideration as social requirement of a technology.

A rather distinct stance on the issue is proposed by Edelenbos, who believes that a smart meter is only an enabler, thus social requirements should be bound to value added services not to the meter itself. On the other hand, Edelenbos states that the voluntary roll-out that granted freedom of choice to the Dutch population has contributed to increasing the level of social acceptance. If freedom of choice is considered as a social requirement as advocated by other interviewees, then indeed social requirements are predictors of social acceptance of technology.

All interviewees agree on the importance of the inclusion of social requirements in the development of smart metering as a socio-technical system. Kramer believes that accounting for social requirements becomes extremely important when a technology is so close to consumers, such as a smart meter which resides inside consumers' homes. Masera emphasizes that responsible actors need to realize and accept that elicitation and incorporation of social requirements is a learning process with several errors that are most likely to be committed. Karskens is of the opinion that for any technology in this age, the inclusion of social requirements is a determinant of its success. Furthermore, Karskens believes that major social requirements such as security and privacy should be mandated in the development of socio-technical systems. Though Edelenbos agrees on the importance of including social requirements in the development of smart meters as a socio-technical system, yet he believes the focus should be on the value added services offered to the consumer rather than the technology part of the system, i.e. the meter.

Kobus, Masera, Kerskens and Hakvoort all agree that accounting for social requirements in the design process of the smart metering system can significantly contribute to safeguarding important goals of the smart metering system, such as: energy efficiency and savings, and reduction of operational costs. Kobus elaborates that if the aim is to achieve EU goals, such as energy saving, then the proposed social requirements elicitation process becomes a necessity, whereas conventional systems' development life-cycles that exclude consumers would be suitable if the smart meter is intended for administration purposes only. Furthermore, Karskens believes that accounting for consumers' worries is essential for systems' development, as consumers are either the makers or breakers of a technology. Hakvoort states that if consumers do not use a technology, then none of the goals are achieved. However, Hakvoort believes that accounting for social requirements is a necessary but not a sufficient condition for safeguarding major goals of the system.

Moreover, Kramer and Edelenbos believe that it is difficult to argue that accounting for social requirements can save resources by avoiding the need for retrofits or redesigning of the system. Kramer explains that on the one hand, resources can be saved by accounting for social requirements. On the other hand, he believes that accounting for social requirements can cost a lot of time, which is valuable. Kobus, agrees that accounting for social requirements would cost more time in system development. However, Kobus believes that time should be invested into elicitation and incorporation of social requirements to save resources. Kobus gives an example of the deployment of a massive number of smart meters that lacked port P1, which required retrieving these meters and replacing them with ones that have P1.

Hakvoort offers another perspective that focuses on the lifetime of the system, rather than the length of the development cycle. By accounting for social requirements the lifetime of the system will decrease. For example, due to the high probability that communication technologies will change, a change will be triggered in the smart meter technology itself.

Karskens strongly believes that accounting for social requirements can contribute to saving resources in the order of magnitude of millions or billions of Euros. Furthermore, Masera agrees that resources can indeed be saved by avoiding retrofits to the system as a result of accounting for social requirements in systems' development. Masera elaborates that this is part of a learning process that electricity companies should embrace. Masera also states that a problem that could hinder this process is the unwillingness of the management of electricity companies to undertake this process, and that a change in their mentality is needed.

System Development Life Cycle

There is wide spectrum of opinions among the interviewees regarding whether the system development life-cycle of socio-technical systems should be altered to cater to the emergent class of requirements, i.e. social requirements. On one extreme, Edelenbos does not believe in the need for alteration in the life-cycle of systems' development. The reasoning behind this is that changes in the social requirements will have effect on the value-added services, not the meter itself. Edelenbos states that the smart meter is only a data generator, thus, changes in social acceptance and consumers' behavior towards a meter can only occur in the free market domain (i.e. commercial domain), and the current meter fully supports all these changes in the free market.

Hakvoort agrees that there is a need for the alteration in SDLC, and raises the question of how to realize this change. In a position slightly similar to Edelenbos', Hakvoort acknowledges the alteration related to the commercial part of the system should be the responsibility of the commercial market. However, Hakvoort also believes that there exists a public policy dimension of the alteration, and raises another question on how to include consumers' expectation and response in the decision making process. A comparable outlook was given by Masera, who believes in the need of altering SDLC to account for social requirements, and also raises a question this time regarding who should see this alteration through. Masera believes that the supply chain of smart meters follows a typical industrial process of power industry, where commercial suppliers lack the incentive to account for social requirements. Masera concludes that he sees a lack of an actor to undertake this task, and suggests that perhaps the government should assume such a role since none of the industrial or commercial actors of the supply chain have a direct interest.

Kramer finds it difficult to decide on the need for the alteration. He states that the Ministry has tried to hold round tables to discuss various societal demands, yet the development life-cycle remains very close to a technological process. Kramer believes that this process can be tremendously improved by including a consumers' perspective before involving governments when social issues arise. A problem with such an approach however is that there are not many consumers with an opinion, in addition to a shortage in consumers' organizations that have enough capacity to take part in this process. Thus, one question in this regard that the energy sector has yet to find an answer to is: what is the right way to involve consumers.

Furthermore, Kramer wonders about the necessity of such a change in the SDLC as society can accept a technology when it is not yet perfect. Further, Kramer states that what is necessary is a system that is able to integrate changing demands; that is designing systems in a manner to allow for changes during their lifetime. This approach is applied for the smart metering communication model, which can be replaced in the future in compliance with possible changes in communication technologies and information security demands. According to Kramer, it is very difficult to predict if such approach is in fact the right choice at the present time, or if it would incur high costs for society for flexibility that can prove later to be unneeded. Karskens and Kobus opinions fell more towards the positive end of the spectrum, where both agreed on the necessity of the alteration in the SDLC. Kobus expresses that the socio-technical systems' development process suggested in Figure 7.2 is indeed needed instead of the conventional one presented in Figure 7.1 (b). Kobus elaborates that the development of such systems must be the result of a collaboration of both technical expertise and social requirements engineers.

As an alternative is seemingly needed for conventional systems' development process to account for social requirements, the interviewees were presented with Figure 7.1, and asked if they acknowledged the difference in the development process of conventional IT systems and socio-technical systems, and whether the proposed process in Figure 7.2 would be a good alternative. Hakvoort states that he can envision a difference in the development of both types of systems, whereas Kobus believes that there is indeed a distinction between the development of IT systems and socio-technical systems due to the complexity of the latter. Kobus also confirms that the goals of consumers as systems users need to be taken into consideration.

Karskens recognizes that a difference exists between IT and socio-technical systems, which implies a difference in the development process of each type of systems. Karskens stresses that electricity grid companies need to change their attitude from dealing with electricity connections to people.

Masera and Karskens affirm that the approach proposed in Figure 7.2 is a good transition in the development of socio-technical systems, though incomplete in their opinion. Masera and Karskens each suggest amending the process in Figure 7.2 with an additional level of interaction among actors involved in systems' development as illustrated in Figure 8.1 and Figure 8.2. As shown in Figure 8.1, Masera believes that a high-level actor, e.g. the government, should be included in the process to play a monitoring role over system owners, i.e. electricity grid operators. In addition, elicited social requirements elicited should also be provided to both system owners and the government. Another modification to Figure 7.2 suggested by Karskens is shown in Figure 8.2, which illustrates an arrow from systems owners to society that denotes exploring society's reaction to the system.

Edelenbos agrees with the distinction between IT and socio-technical systems, and acknowledges the advantage of applying the process depicted in Figure 7.2. Edelenbos indicates that a distinction needs to be made whether infrastructure systems are run by governments, or by actors in the free market domain. On the other hand, Kramer believes that both types of systems are quite similar, and that in general the introduction of IT systems should be developed in a more iterative manner with societal organizations and consumers.

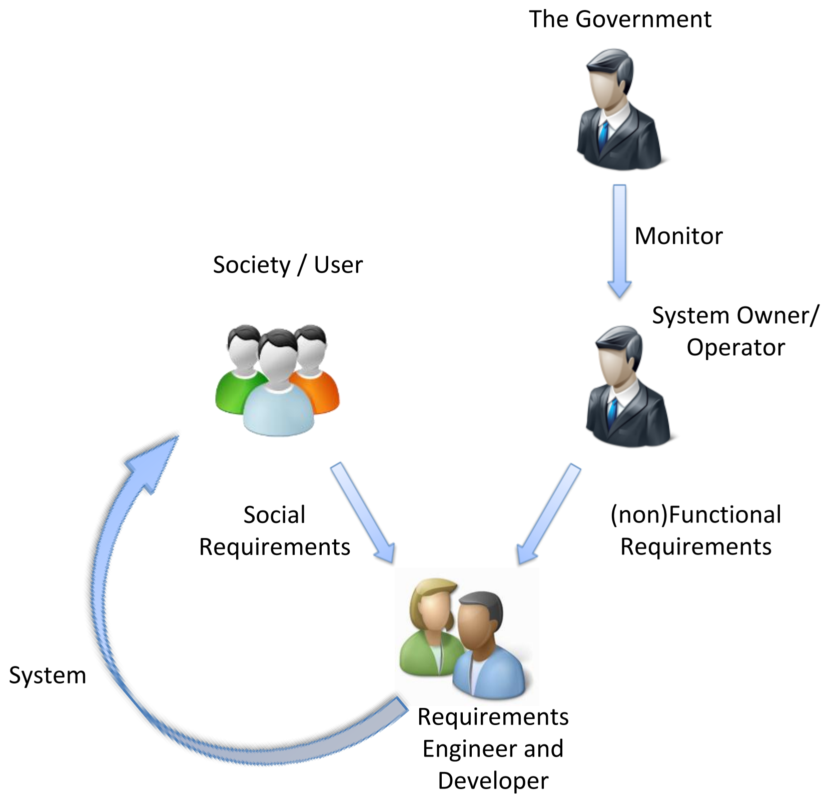

Figure 8.1: Masera's suggested addition to the proposed requirements elicitation process

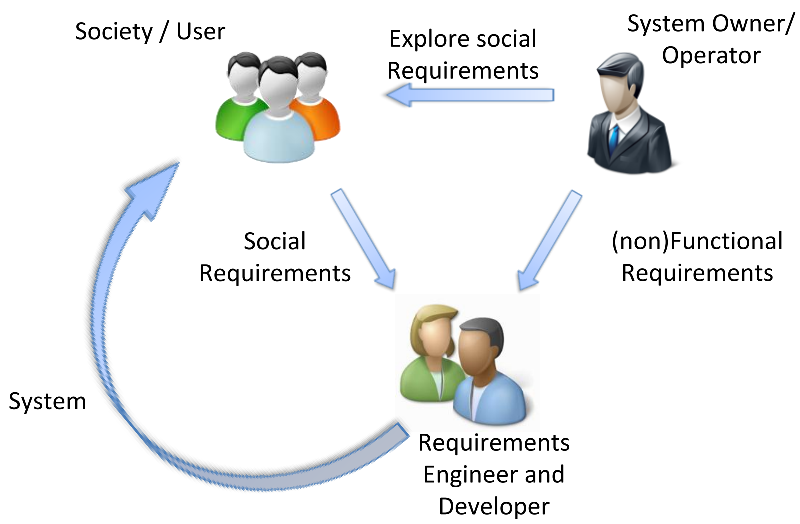

Figure 8.2: Karskens suggested modification to the proposed social requirements elicitation process

In response to the process proposed in the current work for social requirements elicitation and verification, which is depicted in Figure 7.3, most interviewees agreed on its usefulness in systems' development. Karskens asserts that the process is required for the development of socio-technical systems, otherwise patches and retro-fits to the system would be inevitable. Hakvoort states that currently there are no approaches applied for the elicitation of social requirements, thus in principle the proposed process is better than the current practices, i.e. “anything is better than nothing”.

Masera, Kobus and Edelenbos agree to the benefits to be gained from using the proposed approach. Howerver, they also agree that a feedback loop is missing due to a different reason for each interviewee. Masera believes that this is a learning process that involves errors and discoveries, thus there must be a possibility of going back in the process. In a similar position, Kobus stated the process is a good first step in development of socio-technical systems, and that it should have been used for the smart metering project. However, Kobus also states that a loop is missing as the elicited social requirements incorporated in a system must be tested to discover their usefulness. Kobus suggests using pilot roll-outs of the system for the testing of social requirements prior to large-scale deployments. Another reason for including a loop in the proposed process was offered by Edelenbos, who believes that this process is continuous and that a loop is needed to account for the inevitable change in technology, society, and consumer behavior.

Kramer could not attest to the usefulness of adopting the proposed process. However, Kramer believes that the elicitation of social requirements becomes easier when society is exposed to the technology and knows about it. That is, it is difficult to ask members of society about their expectations and demands of a technology if they are not familiar with the technology first. Further, Kramer speculates about the use of surveys as depicted in Figure 7.3 as a means of investigating society's opinion. The Ministry is expanding its ways to reach society by other means such as social media.

Mass Media

Whether or not electricity grid operators, as smart metering system owners, should invest in improving their public image and promoting their services, despite their operation in the regulated domain of the energy market triggered various reactions from the interviewees. Kobus states that electricity grid operators should indeed improve their image, mainly because when consumers do not know who their electricity grid operator is they tend to forbid technicians from entering their homes to install a smart meter. Kobus elaborates that awareness regarding the importance of company reputation is increasing within Enexis, and that the issue is being addressed by investing in media, production of informational videos on YouTube, newspaper articles, and television show appearances to give a clear view of the organization and its projects.

Another interviewee who supports the need to invest in promoting public image is Karskens, however with reservations regarding the level of promotion. Karskens believes that grid operators should launch promotional campaigns on a regional rather than national level, and recruit interactive methods. Nevertheless, Karskens warns that grid operators should not start promoting their image or services before ensuring to tackle any flaws in their systems.

Masera offers a different standpoint on the issue by wondering if electricity grid operators should make such investment to promote their image. Masera believes that this is about energy companies changing their business, and whether they see themselves only energy providers, or as information and public service providers. In the case of the former, image does not matter, whereas in the case of the latter grid operators should invest in promoting their image. Masera however doubts if grid operators are ready for such a change.

A view point on the opposite extreme is Hakvoort's, who believes that grid operators' promotional campaigns could work against the grid operators. The more operators promote their pride in their services, the more flaws of the system can be magnified by the public. Further, grid operators should refrain from spending a considerable amount of what is felt as public money on promotional campaigns to avoid public condemnation for spending such money, especially in cases of systems' failure such as electricity outages. Thus, perhaps it would be best if the promotion efforts focused on informing the public on the made exerted by grid operators, and how difficult their task is.

Furthermore, when asked whether the government should invest in promotion campaigns among the society to promote smart meters, the interviewees gave a spectrum of responses, ranging from a definite yes to a definite no. Masera states that the government should be the first in favor of the acceptance of such technologies, thus Masera strongly believes that investments should be made to prepare society for the launch of a new technology, via methods such as: the Postbus 51 that is used by the Dutch government to communicate awareness messages to society regarding various matters. Likewise, Kobus believes that it would help if a different actor than the system owners, i.e. grid operators, would recommend the use of smart meters. According to Kobus the government is a good candidate for the role since most people still believe the government, thus government's promotion of smart meters is a good idea.

Karskens projects a rather neutral argument, by binding the usefulness of such promotion to when and what the government should promote. Such campaigns will influence the social acceptance level, but the question is whether it changes reality. What is more important in Karskens' opinion is to address the problems of the system, as fixing systems flaws and advertising go hand in hand.

Edelenbos has a hesitant position on the matter, as he believes it is a risk to position smart meters as a technology promoted by the government. Edelenbos lists: electronic medical records, OV-Chipkaart, smart meters, and kilometer charger, as examples of infrastructure systems none of which was a success. The failure of the aforementioned technologies is due to their image of being problematic and consumer unfriendly. Furthermore, Edelenbos believes that instead of promoting smart meters, the government should communicate consumers' rights, e.g. their freedom of choice, and information in response to consumers' concerns such as the security and privacy of information. These communications should be at a language level that is understandable by all classes of society. In addition, grid operators should participate in the process by informing society in a clear and friendly manner about meter installation at consumers' homes, in addition to providing technical information to consumers upon their request. However, information regarding smart meter services should be communicated by actors operating in the commercial market domain.

As opposed to Kobus' position, Kramer is doubtful of the wisdom of government's involvement in promotional campaigns, and is more inclined to rejecting the concept. In Kramer's opinion, technology push can elicit social resistance. Further, governmental campaigns are not necessary in the Dutch society, where people highly value their personal freedom of choice, and do not rely on the government to dictate what members of society should do. Kramer is in favor of offering information in a passive form at a more individual level. The Ministry designed brochures and a website offering information about smart meters, which were aimed to be as objective as possible despite the Ministry's favorable position on smart meters, hence asking a consumer panel to check it. This information has been reused by parties involved in the introduction of smart meters in their own brochures. Kramer concludes that perhaps for large-scale roll-outs of smart meters mass media could help, given that only information needed from consumer perspective is offered.

On the other end of the spectrum was Hakvoort's position on the matter, that the government should not be involved in promotional campaigns of smart meters for a number of reasons. First, such campaigns cost money. Second, if the government starts to promote smart meters, there are reasons why people would be reluctant to adopt it. History has proven several times there might be some hidden agenda. Again, this position contradicts that of Kobus.

8.3 Summary of Interviews

In section 8.2 of this chapter a compilation of interviews with 6 experts in the context of the smart metering system is presented. Each interviewee is affiliated with an organization that oversees a different aspect of the smart metering system, which consequently allowed obtaining feedback with a comprehensive perspective regarding the proposed Acceptance-by-Design framework for social requirements elicitation and verification, in addition to other related concepts and hypotheses underlying the current work, such as: social acceptance of infrastructure systems, social requirements, system development lifecycle, and the utilization of mass media channels to facilitate smart metering diffusion within society.

For a number of the topics discussed, the interviewees agree in their views for the most part with minor differences either in the motivation behind their opinion, or the strength in which they believe in their opinion. Mainly, when asked whether social acceptance is a significant issue all interviewees strongly agreed that social acceptance of smart meters is a crucial and key issue that needs to be tackled. In addition, interviewees confirm the importance of understanding the process of social acceptance of infrastructure systems -such as the smart metering- and that this process must take place at the earliest stages of the system's development lifecycle prior to its development and deployment. Furthermore, there was a consensus among asked interviewees that acceptance determinants of a technology are dependent on both the technology and the society in which it is deployed, and that it is fundamental to involve public opinion in defining acceptance determinants of a technology. In addition to that, there was a unanimous agreement among interviewees that social requirements can be predictors of social acceptance of infrastructure systems such as the smart metering.

Further, most interviewees agree that infrastructures and conventional IT systems belong to two different classes of systems that are distinct in nature, which necessitates that the realization of infrastructure systems should not follow the development lifecycle of IT systems, but rather an altered lifecycle that accounts for social requirements.

In general, most interviewees positively perceive the requirements elicitation approach proposed in Figure 7.2, and envisioned advantages can be gained from its usage. The proposed approach is considered as a good transition in the development lifecycle of socio-technical systems from the conventional development lifecycle –illustrated in Figure 7.1. However, Masera and Karskens consider the approach proposed in Figure 7.2 to be incomplete, where each proposed a different amendment. Masera proposes the addition of a higher-authority that oversees the entire process, and monitors the role of the system owner, whereas Karskens suggestes the inclusion of a feedback arrow from the technology users to the technology owners to enclose social requirements from the former to the latter.

In response to the proposed social requirements elicitation and verification process in Figure 7.3, most interviewees assert its usefulness in infrastructure systems' development, and that it is considered necessary to avoid patches and retro-fits to the systems. Further, the proposed process is considered better than the current practices as currently there are no other approaches for the elicitation of social requirements. Thus, is a good start for setting the foundation for further efforts in this area. However, three interviewees suggested the addition of a loop to the process, each for a different reason. First, the process is considered as a learning experience involving errors and discoveries; hence a loop is needed to feed intermediary findings to previous steps and improve the final output. Second, the elicited social requirements incorporated in a system must be tested to discover their usefulness, thus the use of pilot roll-outs of the system was suggested for the testing of social requirements prior to large-scale deployments, the results of which should be fed back to the elicitation process to fineness the social requirements elicited. Third, the elicitation process is considered to be continuous, therefore a loop is needed to account for the inevitable changes in technology, society, and consumer behavior.

The agreement of the interviewees to the significance of a number of key concepts underlying the work presented in this thesis -such as: understanding the process of acceptance, addressing acceptance at early stages of systems development, including public opinion in defining acceptance determinants, the difference between infrastructures and ICT systems, the importance of including social requirements in systems' development, and mainly the social requirements elicitation process- confirms the valuable contribution of this work to the area of socio-technical systems development, and that the proposed Acceptance-by-Design framework sets the foundation for the emergent field of social requirements elicitation and verification, where further research efforts need to be carried out to explore alternative methods for the inclusion of public opinion in shaping ICT-intensive infrastructure systems and the services they offer.

In addition to the notions on which interviewees mostly agreed, there were a number of key concepts underlying the current work with which some interviewees disagreed. One issue of disagreement was whether the change in the business was caused by the social rejection due to the lack of accounting for social requirements in the development of the smart metering system. On the one hand, Hakvoort and Masera disagree with this position. On the other hand, Kramer, Edelenbos, Kobus and Karskens agree. Kramer believes the voluntary roll-out introduced due to rejection of smart meters contributed to the change of the business case, and that a societal cost-benefit analysis is limited due to the difficulty in quantifying social benefits such as: the freedom of choice. Edelenbos believes that the original business case would have been impossible to achieve due to social rejection that exceeded 20% at that time. Further, both interviewees agree that freedom of choice has a high price; however, this price is worth paying as freedom of choice is greatly valued in the Dutch society. Kramer, Edelenbos and Karskens believe that freedom of choice as a social requirement is partially responsible for the business case change.

Another issue that trigged interviewees conflicting outlooks was whether surveys are a good way of involving public opinion in defining acceptance determinant. Karskens believes that it is difficult and proposes the use of focus groups as an alternative. Other alternatives are consumer panels and social impact assessment, which were proposed by Hakvoort. Kobus believes that surveys can be used as a second phase after conducting interviews with a subset of the population, and in combination with small-scale test pilots. This position opposes Masera's who believes surveys should be conducted as a first stage of the public opinion exploration process. However, he also believes that surveys can risk overwhelming respondents with information, and forming false perceptions.

Furthermore, the interviewees further disagree in their views in relation to whether accounting for social requirements can safeguard chief goals of the smart metering system, or save resources by avoiding system retrofits or redesign. On one extreme, Kramer and Edelenbos believe it is difficult to argue that accounting for social requirements can help avoid costly retrofits or redesigning of the system. Kramer further argues that accounting for social requirements can be costly both financially and in terms of time. In an intermediary position, Kobus agrees that it would cost more time in system development, but she believes that this investment in time should be made to save other resources. On the other extreme, Karskens and Masera strongly believe that accounting for social requirements can contribute to saving resources.

There is wide spectrum of various opinions among interviewees regarding whether the system development lifecycle should be altered to account for social requirements. Edelenbos disagrees with this position stating that changes in the social requirements will have effect on the value-added services and not the meter. Kramer believes that the process can be tremendously improved by including a consumers' perspective, but two problems would be that there are not many consumers with an opinion, and a shortage in consumers' organizations that have enough capacity to take part in this process. Hakvoort on the other hand agrees and believes that change should take place on technical and policy levels. Masera acknowledges the need for change but he raises the concern he sees a lack of an actor to undertake this tasks. Karskens and Kobus both agree on the necessity of the alteration in the process.

Another issue which interviewees project different standpoints was the use of mass media by electricity grid operators to promote their image and services. Kobus supports the idea, while Karskens agrees to the usefulness of regional campaigns and stated it should be under the condition that grid operators will tackle flaws in their systems beforehand. Furthermore, Masera believes electricity grid operators must decide first whether they are energy providers or information and public service providers. Image does not matter for the former, whereas for the latter grid operators should invest in promoting their image. Masera however doubts if grid operators are ready for such a change in their business. A disagreeing position is stated by Hakvoort's, who believes that promotional campaigns could work against grid operators, such that he more they promote their pride in their services, the more flaws of the system can be magnified by the public, in addition to the risk of incurring public condemnation for spending what is considered as public money.

Moreover, the interviewees disagreed in their views regarding whether the government should promote smart meters via media channels. Masera strongly believes that this is necessary to prepare society for the launch of a new technology via methods such as: the Postbus 51. Kobus believes that it helps the government would promote smart meters, since most people still believe the government. Kobus' position was contradicted by Kramer and Hakvoort. Kramer believes that government campaigns are not necessary for the Dutch society who highly value its freedom of choice and does not rely on the government for making such decisions. Kramer also believes that technology push can elicit social resistance; hence the government should offer objective passive information (i.e. brochures and a website) at an individual level. In a similar stance, Hakvoort believes the government should not promote smart meters due to campaign costs, in addition to society's inclination to decline the technology if the government would promote it due to suspicions of hidden agendas. This viewpoint was close to Edelenbos' who believes it is risky to position smart meters as a technology promoted by the government, instead the government should communicate consumers' rights -e.g. their freedom of choice- and information in response to consumers' concerns related to matters such as the security and privacy of information. Karskens' stance was slightly less opposing as he believes that it is more important to fix problems of the system as it goes hand-in-hand with promoting the system.

In essence, the interviewees' opinions diverged regarding whether: administering surveys is a good way to involve public opinion in defining acceptance determinants, accounting for social requirements can save resources by avoiding systems retrofits or redesign, current system development lifecycles should be altered to account for social requirements, grid operators should recruit mass media channels to promote their image and their services, social requirements can safeguard chief goals of the system, and whether the government should launch smart metering promotional campaigns.

This disagreement in views requires conducting further investigation each of the aforementioned topics, to further improve the proposed process for social requirements elicitation and explore other alternatives. Mainly, alternative methods of including public opinion in system development need to be examined. Furthermore, there is a need to conduct cost-benefit analysis to determine the extent of resources savings, such as: money and time, which can be gained due to eliminating the need for system's patches and retrofit as a result for accounting for social requirements in systems' design. In addition, further researcher is required to determine how the development lifecycle can be altered to account for social requirements. Finally, the role that mass media can play in the process of technology diffusion within society must be carefully studied, to determine the value to be gained from recruiting the different mass media channels either by the technology owners or the government.

Chapter 9 : Conclusions, Future Research, and Recommendations

9.1 Conclusions

The motivation behind embarking on this research is the pressing need to attend to social acceptance of infrastructure systems, in combination with the evident insufficiency of current technology acceptance literature. Social acceptance is a corner stone for the success of technologies, and has to be achieved before any of the involved actors (including consumers) can reap gains from a technology. To increase social acceptance of infrastructures, sufficient effort must be put into eliciting social requirements, as acceptance of systems and their fulfillment of social requirements go hand in hand.

In this thesis, social attitudes towards ICT-intensive infrastructures are investigated, and methods to reach a better understanding of social acceptance are explored to illuminate the gap in scholarship on the social requirements engineering process; part of the infrastructure systems' development lifecycle. The social component of infrastructures has recently become critical as the adoption of information and communication technologies as backbone structures of infrastructure systems has transformed conventional and "manual" infrastructures into automated ones. Infrastructures now span beyond the physical and technical components to encompass a significant social component i.e. the consumers. Thus, new infrastructures are ICT-intensive socio-technical systems, the successful deployment and operation of which is dependent on social acceptance. However, acceptance of these new technologies by the general public has proven to be a significant obstacle to the deployment and operation of said infrastructures. Conquering this significant hurdle and achieving social acceptance of new technologies in infrastructure systems can be attained by adopting consumer-centric design approaches for these systems.

Rather than receiving services passively, consumers now must interact actively with infrastructures for their successful diffusion and operation. This active interaction ensures that infrastructure systems achieve goals determined by the system's owners. In essence, a consumer-centric design includes an exploration of public opinion and values regarding a system at an early stage of the system's development lifecycle. The public values can then be mapped into social requirements as a new class of systems' requirements. The inevitable emergence of this new class of requirements is due to the socio-technical nature of infrastructure systems. Furthermore, because direct interaction with consumers has become vital to infrastructure systems' operations, the design of such systems must be informed by social opinions to ensure society's acceptance of and willingness to utilize infrastructure systems, and subsequently the achievement of the goals driving systems development.

Social requirements' elicitation is a challenging process. The difficulty of establishing the social requirements is that they result from sociological research among society members, as opposed to functional and non-functional requirements that are determined by system owners with respect to their needs. The elicitation of social requirements requires in-depth analysis and understanding of both the new system and the society in which it will be deployed. In-depth insight into a system can be attained via a number of sources such as: systems' policies and regulatory documents, technical documents and experts interviews to name a few. However, gauging the public perception(s) of a technology requires different methods of analysis unconventional to infrastructure owners and designers. Sources of social information include television, radio, newspapers, other news media, activists' campaigns and web forums on new technologies, and, perhaps most difficult, interviews and questionnaires. This thesis sheds light on research methods that enable one to elicit social requirements, as well as how critical an understanding of factors that influence society's willingness to accept a technology, i.e. acceptance determinants, is to the success of a new system.

In this study, a new theoretical framework was devised to shed light on infrastructures acceptance. While the Unified Theory of Acceptance and Usage of Technology- UTAUT, and the Innovation Diffusion Theory- IDT are useful in many cases, they do not cater for the inherent properties or the complex nature of ICT-intensive infrastructure systems. Hence these theories proved insufficient to illuminate the issues faced in the class of systems explored here. To overcome the limitations of these two theories in investigating the acceptance of ICT-intensive systems, this work presented in Chapter 2 a hybrid model encompassing determinants from both theories. The aim of formulating the hybrid model was to combine the different points of strength and the predictive power of the UTAUT and the IDT theories. This hybrid model was extended further with additional acceptance determinants derived from inspecting the public perceptions of two ICT-intensive infrastructure systems: the smart metering and the OV-Chipkaart systems in The Netherlands. The addition of these determinants to the model presented in Chapter 5 improved the explanatory power of existing technology acceptance theories by incorporating either new inherent characteristics of infrastructure systems, such as: the feedback obtained from a system, or public values of society, such as: privacy, information security, and safety. In essence, the model proposed in Chapter 5 is a causal relationship diagram that depicts the hypothesized influences among the acceptance determinants, which was applied in the context of the smart metering system in The Netherlands.

Prior to the construction of the model, it was expected that all acceptance determinants would have a significant influence on consumers' willingness to have a smart meter installed in their homes. Furthermore, mass media were expected to influence both technology awareness and the image of energy companies. To verify these expectations and measure public opinion, the hypotheses underlying the model were tested by administering a survey among Dutch residents. Over a period of approximately two months, 450 responses were received and 315 records were used to test the model using structural equation modeling. The results led to another causal relationship diagram that depicted empirically and statistically significant acceptance determinants as well as the relationships among these determinants. This method of analysis revealed not only the determinants that significantly influenced acceptance but also the relationships between the individual acceptance determinants. While the former outcome was expected the latter was not, as many of the hypothesized influences of acceptance determinants in the original model on consumers' acceptance of smart meters were falsified, while unanticipated influences were revealed. This method gave rise to a novel approach to verify identified acceptance determinants of a technology prior to accrediting these determinants as social requirements of the technology under question, and allocating the required resources accordingly. Further, the method offers an insight into the influences among the acceptance determinants, an aspect that must be fathomed by technology stakeholders to ensure maximum utilization of the acceptance determinants in the development of the technology, to steer the public opinion towards accepting the new technology.

From the resulting model conclusions were drawn about elicited acceptance determinants. Each determinant was investigated and the questions asked were: was the predicted influence of the determinant on acceptance empirically supported? If so, was the influence positive or negative as expected? Moreover, insignificant determinants were identified and influences not anticipated among the acceptance determinants in the original model were investigated. Based on this analysis, the recommendations presented in subsequent sections of this chapter were formulated for various actors in ICT-intensive infrastructure systems.

This research yielded an Acceptance-by-Design framework –Figure 7.3 presented in Chapter 7- intended as support in the development lifecycle for successful infrastructure systems. While implemented here to investigate Dutch society's acceptance of smart meters, it can be used to analyze any ICT-intensive system in any society. Thus the Acceptance-by-Design framework can aid researchers in exploring and accounting for factors influencing the acceptance of systems at an early design stage, thereby contributing to their successful implementation. Fundamentally, when applying the Acceptance-by-Design framework for new technologies, social requirements can be elicited by analyzing existing yet similar technologies in terms of their inherent properties. Moreover, the framework can also be utilized for existing socially unacceptable systems, by retrofitting social requirements that are elicited by analyzing said systems.

Experience from the smart metering system in The Netherlands demonstrates the importance of understanding public opinion early in the design phase. The system was poorly received in its early years when consumers were ignored in the design, implementation and legislation processes. While the results presented in Chapter 6 reveal that social acceptance of smart meters is currently high, social acceptance could have been achieved years ago if system stakeholders had considered social requirements prior to implementation and thus would have saved resources, deployed meters faster, and achieved their goals sooner. Implementing the Acceptance-by-Design framework in the early stages of a system's development will help ensure social acceptance, safeguard the fulfillment of goals of the system, minimize unnecessary costs (financial or otherwise) of, for example, retrofitting the system or having to redesign and re-implement it. Working with well-understood social determinants will prevent delays in a system's deployment that impede the realization of infrastructure system goals.

The evolution of infrastructure systems as ICT-intensive dictates the need for a new way of understanding social requirements of systems in early phases of design. There is a paucity of literature that addresses this need. This thesis is one contribution to improving the overall development life-cycle of ICT-intensive infrastructure systems, so as to helps ensure a high level of social acceptance of such systems.

9.2 Future Research

This work aims to set the foundation for further research effort in the field of social requirements engineering of ICT-intensive infrastructure systems. Additional study is needed to explore the combined influences of some of the acceptance determinants on society's willingness to accept a system. In addition, it is worthy to investigate the influence of other acceptance determinants, such as: enjoyment, rewards, financial incentives, technology usage training, technology's visibility, and self-image.

Fundamentally, more research effort is needed to establish the necessary body of knowledge to support the development cycle of infrastructures and account for the evolving nature of these systems. Efforts should be exerted to investigate possible refinements to the social requirements classification scheme proposed in this work by exploring prospective further categories of the scheme. Further research is needed to develop methods to conduct social requirements cost-benefit analysis of future systems. The ability to conduct such analysis will aid systems' stakeholders to identify social requirements that are viable to be accounted for in the design of their systems. In addition, research effort should be exerted to discover means for altering the development lifecycle of infrastructures, by merging the Acceptance-by-Design framework as an integral part of the development lifecycle and exploring possibilities to improve the overall process.

The role mass media can play in the process of technology diffusion within society must be carefully studied, to determine beneficial techniques of utilizing the different mass media channels, and the value to be gained from this utilization either by the technology owners or the government, to which the latter, however, must adhere to a neutral tone that maintains an impartial stance from the technology. Another acceptance determinant the influence of which on acceptance is worth delving into is social influence. Additional investigation can be carried out to identify the concepts underlying social influence that can explain with clarify how this factor works among members of a society. Gaining a clear perspective on this matter can aid in shedding light on how to utilize this factor in accelerating the acceptance process of a technology. Investigating social influence is particularly valuable when considering that its utilization is more economical than the use of mass media.

In addition, society's misperception of a new technology in terms of aspects including: security, privacy, and health risks, is a serious matter that can jeopardize the success of said technology, even if its design safeguards these valued aspects by society. Research effort is required to devise perception gap management methods to bridge these social misperceptions.

Furthermore, systems such as the ones understudy are complex in nature. Many of the challenges that can hinder the systems' fulfillment of social requirements can ensue not only from the diversity of the technology employed by the system (e.g. hardware and software) but also from the fact that these systems reside and operate in a multi-actor context. This calls for the need to investigate possible approaches that can be applied to divide responsibilities related to the social requirements elicitation process among the different stakeholders, which in turn will aid in the standardization of the requirements elicitation process in multi-actor systems' setting.

Finally, simulation models can aid system owners in envisioning a spectrum of possible outcomes in relation to society's acceptance level of a technology. The different outcomes are triggered by various settings certain aspects (e.g. security and privacy) that are simulated in the model can assume. The models can simulate the different types of behavior consumers can assume, the various factors that can motivate consumers to adopt and use a technology, and model the influences of these factors –and others- on consumers' willingness to accept the technology.

9.3 Empirical Recommendations

In light of the work presented in this thesis, the following recommendations are proposed specifically for the smart metering system in The Netherlands, and offered per actor according to the role they play in the system.

Electricity Grid Operators

As owners of the smart metering system, electricity grid operators should adopt the Acceptance-by-Design framework to retrofit social requirements into the system. Doing so can lead to social acceptance. The acceptance determinants in the I^3S^2 model proven to be empirically significant are the social requirements that should be met in the smart metering system.

Performance expectancy proved to be the most influential acceptance determinant investigated. Improving external meter displays and electricity consumption feedback will improve social acceptance. A variety of forms of feedback on consumption should be offered promptly to consumers through various channels, such as: email, web access, and mobile phone applications. Feedback should be easy to interpret for laymen thus facilitating consumers' decision making. In addition to feedback on consumption, supplemental information should be offered such as: comparative household and neighborhood consumption patterns, forecasted scenarios based on consumers' behavior, and customized saving plans.

Because the perceived security and privacy risks ranked as the second most significant determinant of social acceptance of smart meters, electricity grid operators can address these concerns with alternative system architecture that stores data locally in the meter. In addition, a meter can be programmed to calculate bills locally in the meter rather than transmitting detailed consumption readings to a central access server for this task.

The perceived health risks of having a smart meter at consumers' homes ranked third in significance in determining acceptance of smart meters. Electricity grid operators can mitigate consumers' unease by, for example, equipping meters with wired communication protocols to reduce the level of neighborhood pollution and restricting wireless communication protocols to connecting data concentrators with the central access servers. Furthermore, meters can be physically located outside home premises, their repeater singles can be reduced, and the meter signal frequency and duration could be reconsidered.

This research revealed that a significant predictor of acceptance was the possibility for consumers to test smart meters prior to making a decision whether or not to accept the smart meter. Electricity grid operators can exploit this finding by launching large-scale pilot programs that offer consumers free meters and an external display thus providing consumers the opportunity to become familiar with the advantages of smart meters.

Consumers' often negative perception of electricity grid operators plays an influential role in consumers' (un)willingness to obtain a smart meter. Despite the fact that they do not need to compete for consumers' satisfaction, it would be prudent for electricity grid operators to invest in media campaigns to improve their public image. The media can also be used by operators to address negative misconceptions of smart meters such as the perceived security, privacy, and health risks as well as to inform consumers about their benefits.

Attention must also be paid to consumers who accept the installation of a smart meter but opt for an administrative-off setting so that grid operators cannot utilize their data for planning and forecasting purposes. Energy suppliers in collaboration with electricity grid operators could offer consumers financial incentives to share their data with these companies.

The Government

Energy sector regulators and public policy makers can contribute to the social acceptance of smart meters. For instance, the government can initiate and monitor security and privacy frameworks, to ensure interoperability and guarantee security levels. The standardization of information security and privacy-by-design practices can significantly decrease lack of social acceptance, security problems, and overhead costs due to retrofitting of security controls. Moreover, the government must ensure that the implementation, policies and legislation of the smart metering system adhere to EU Data Protection Directive 95/46/EC an integral European directive for privacy and human rights, which regulates personal data processing in the European Union.

To mitigate the concerns expressed by consumers that smart meters would lead to increased costs, the government should ensure the stability of energy prices after the roll-out of the smart metering infrastructure and maintain the affordability of smart meters and external displays.

Smart Metering Solutions Manufacturers

The smart meter and its external display are pivotal components of the infrastructure through which consumers interact with the system. Many of the smart meter acceptance determinants are related to the meter rather than to the system as a whole. To ensure a high level of performance that meets consumers' expectations, smart meter manufacturers should carefully design these devices in terms of the functions offered and the manner in which it operates. The interface of the meter and its external display should be user-friendly for all consumers regardless of their level of experience or education. Designing interfaces of high usability is possible by consulting and complying with Human Computer Interaction- HCI discipline principles.

Furthermore, in light of rising opposition to GPRS usage for smart meters communication in a number of countries including The Netherlands, smart meter manufacturers are strongly encouraged to consider other communication medium alternatives, such as: PLC, fiber optic, phone lines, or coaxial cables. It is best to account for wired and wireless communication protocols in the design of the smart metering infrastructure to avoid costly alterations or replacements.

In essence, applying the Acceptance-by-Design framework can aid manufacturers in eliciting and accounting for significant social requirements, the fulfillment of which can aid in elevating the level of social acceptance.

Government and Electricity Grid Operators

Joint efforts of government representatives and electricity grid operators to communicate reliable information will likely increase smart meter acceptance. Because consumer understanding of smart meters is a significant predictor of consumer acceptance, improving public awareness should be a priority. While smart meter information is available from the Ministry of Economic Affairs and electricity grid operators for those who seek it, a proactive approach by these institutions is needed to reach more people. Improved communication strategies can be achieved with media campaigns through newspapers, television, radio, and news websites, for example.

In addition, mass media have an indirect influence on social acceptance of smart meters via the perceived organization image, technology awareness, and performance expectancy. Therefore, the government and the electricity grid operators should proactively engage the various media channels to promote the smart meter in terms of its functionality, the services it offers to consumers, and advantages consumers can gain from using a smart meter.

9.4 Recommendations for future ICT-Intensive Infrastructure Systems

The lack of public enthusiasm for smart metering and OV-Chipkaart technologies investigated in this thesis led to deployment delays and failure of these systems to reach their goals. The costs of deploying socially unacceptable systems is enormous and requires alterations such as retrofits, patches, or in the worst case, redesign and re-implementation of the system. The social requirements elicitation framework presented in this work –i.e. Acceptance-by-Design- offers a counter measure that is based on consumer-centric design approach of systems. The framework constitutes a tool for owners and designers of future ICT-intensive infrastructure systems, which facilitates the identification of social requirements that are valued by a certain society, and expected to be fulfilled by the system. The framework encompasses a generic approach that can be applied in the context of any ICT-intensive infrastructure system, which is to be deployed in any society. The insights from this research are invaluable for stakeholders of future systems to avoid the problems seen when acceptance determinants are not properly considered.

System Owner

Prior to the design and implementation phases of the system, i.e. at the earliest stages of the system's development life-cycle, owners of future infrastructure systems must identify the social requirements of the system in the context in which it will be deployed. Post-development activities of a system should include large-scale pilot projects that offer users the chance to experiment with the technology. First-hand experience of the technology's advantages will likely contribute to increasing public acceptance. Acceptance will also increase if the owner organization has a good reputation among consumers, thus promoting the image of the organization is crucial even if it operates in a regulated monopolistic market. A positive image about both the services offered by the organization and possible negative consumer experiences in the past must be addressed. System owners should recognize that perceived security, privacy, and health risks should be addressed with public perception gap management. That is, system owners must inform society members of the measures taken to satisfy the social requirements of the system.

Perhaps most essential is that socio-technical infrastructure system owners change their attitudes especially if they are accustomed to governing their own systems. New ICT-intensive systems are no longer simply physical infrastructures—they now require active user participation. For example, electricity grid operators governing the smart metering systems must realize that they are now dealing with consumers rather than just electricity connections. If organizations are unable to make this switch of attitude, external third party entities should be considered to govern an infrastructure with a consumer-centric perspective.

Furthermore, owners of future infrastructures should avoid a sudden push of their technologies upon societies without informing society members beforehand about the technology, and what gains can be reaped from its usage. System owners should consider a gradual launch of their technology that involves familiarizing the public with its offered services and, increase their awareness about the advantages that can be gained from using the technology, which in turn can lead to an increase of public acceptance of the technology.

In essence, owners of future ICT-intensive systems should standardize the incorporation of the Acceptance-by-Design framework as an integral part of the overall system development lifecycle, to ensure a consumer-centric design of their systems, which in turn contributes to an elevated level of social acceptance of the system.

Government and System Owner

The government and systems' owners must not and cannot ignore public objection to systems. Many campaigns critical of a technology begin small and grow large ultimately interfering with the roll out of a new technology, this leads to incurring additional costs such as system retrofits. Furthermore, both the government and systems' owners must ensure that members of society are not burdened by the extra costs due to their neglect of social values. In addition, both actors must invest in increasing public awareness about new technologies. Educating society about different aspects of a technology -e.g. its services, and advantages that can be gained from its usage- eliminates public misconceptions of the technology that may hinder social acceptance.

Furthermore, the government should consider utilizing media channels to increase the public's awareness of a new system to stimulate their willingness to adopt and use the system. It is imperative however, that the government maintains an impartial tone in their technology-related educational messages communicated via the media, to uphold their unbiased position.

Manufacturers

Prior to the design and fabrication of technical components of new infrastructure systems, manufacturers should consider four crucial factors. First, the interface must be user-friendly by increasing the ease with which a user operates the system. Second, using the Acceptance-by-Design framework, the system's design will conform to information security and privacy-by-design practices, which is necessary to increase social acceptance. Third, system manufacturers should evaluate potential health risks of system components particularly for systems that are intended to operate in physical proximity to users such as homes, schools, or workplaces. Fourth, devices should be designed with flexibility for future changes. For example, wireless devices should be able to be transformed into wired means of communication thereby avoiding excessive costs of unexpected future retrofits and redesign.

Consumers' Organizations

Consumers' organizations should play a more active and prominent role in eliciting social requirements of infrastructures and in information dissemination. Thus far, these organizations have been advocating consumers' rights by voicing public concerns against certain technologies. However, the close ties of these organizations with society should be utilized to reach the public and elicit their opinion to be accounted for in systems' development.

9.5 Reflection

Social acceptance is a corner stone for the success of new technologies; hence improving social acceptance of ICT-intensive infrastructure systems motivated this research. Given the insufficiency of technology acceptance theories, the second motivating factor in this study was to contribute to the literature by developing an appropriate and productive analytical framework. Clearly, efforts must be made to understand public perceptions and opinions and thereby to increase social acceptance of new socio-technical systems.

The Acceptance-by-Design framework presented in this work is not a process of systems' development in itself, but rather an aid for social requirements engineering that supports the overall process of a system's development. Thus the framework should be aligned with the development life-cycle as an integral part, rather than be run separately or post system development.

The Acceptance-by-Design framework can be utilized for both existing and new systems that are yet to be developed. For the former, social requirements elicited are to be retrofitted into the existing system. For the latter, eliciting social requirements is feasible by analyzing existing technologies that are similar to the new technology to be developed, which possess the same or similar characteristics.

Unlike functional and nonfunctional requirements that can mostly be obtained from a system's owner, the process of social requirements identification is very different and involves many challenges. In the current work, one of the difficulties encountered in conducting the survey was the participation of individuals belonging to certain groups, such as senior citizens. This stipulates that technology owners should not push their newly-developed technology towards society without prior preparation of society members. Technology owners should adopt a phased approach of launching their systems, by utilizing possible factors, such as mass media and social influence, in increasing the levels of public familiarity with a technology, and awareness of its services and rewards to be gained by its usage.

In conclusion, it is critical that the different stakeholders of infrastructure systems recognize the changing nature of their systems due to their reliance on backbone ICT infrastructures, and fathom the implications of this transformation on society. Though the new infrastructure systems can offer enhanced services in addition to new ones that in principle can improve the daily life of society members, yet the manner in which the new systems impact –or even jeopardize- public values of society has steered society's attitude towards reluctance in accepting and utilizing the new infrastructures. The consequences of negative social perception of infrastructures are grave on different levels. Not only can the lack of social acceptance endanger reaching the intended goals of the system and reaping its sought advantages, but further it may call for costly retrofits or even redesign and implementation of the system. This scenario can be evaded by adopting user-centric design approaches of infrastructure systems, such as the Acceptance-by-Design framework presented in this work.

Appendices

Appendix A: Literature Review

Table A.1 Extensions and applications of TAM in the literature

Authors	Year	Title	Field
Davis	1989	Perceived Usefulness, Perceived Ease of Use, and User Acceptance of Information Technology	Information Technology (E-mail and File editor)
Davis	1993	User Acceptance of information technology: system characteristics user perception and behavioral impact	Information Technology (E-mail and File editor)
Malhotra et al.	1999	Extending the Technology Acceptance Model to Account for Social Influence: Theoretical Bases and Empirical Validation	Healthcare
Venkatesh and Davis	2000	A Theoretical Extension of the Technology Acceptance Model: Four Longitudinal Field Studies	Information technology systems in a manufacturing firm, a financial service firm, banking firm and an accounting services firm.
Pavlou	2001	Integrating Trust in Electronic Commerce With the Technology Acceptance Model: Model Development and Validation	E-commerce
Mathieson et al.	2001	Extending the Technology Acceptance Model: The Influence of Perceived User Resources	Business – Information Systems
Amoako-Gyampah et al.	2004	An extension of the technology acceptance model in an ERP implementation environment	ERP Systems
Wixom et al.	2005	A Theoretical Integration of User Satisfaction and Technology Acceptance	Data Warehousing Software
Luarn et Al.	2005	Toward an understanding of the behavioral intention to use mobile banking	Mobile Banking
Schepers and Wetzels	2006	A Meta-Analysis of the Technology Acceptance Model: Investigating Subjective Norm and Moderation Effects	Diverse
Kim et al.	2008	An empirical examination of the acceptance behavior of hotel front office systems: An extended technology acceptance model	Hotel information management systems

Hernandez et al.	2008	Extending the technology acceptance model to include the IT decision-maker: A study of business management software	Business – Information Systems
Hossain et al.	2008	Consumer Acceptance of RFID Technology: An Exploratory Study	FRID Technologies
Park et al.	2009	User acceptance of a digital library system in developing countries: An application of the Technology Acceptance Model	Digital Library systems
Hossain et al.	2009	Exploring user acceptance of technology using social networks	A virtual community
KU	2009	Extending the technology acceptance model using perceived user resources in higher education web-based online learning courses	Web-based learning
Turner et al.	2010	Does the technology acceptance model predict actual use? A systematic literature review	N/A
Pai et al.	2010	Applying the TAM in the Introduction of Healthcare Information Systems	Healthcare
Hsiao et al.	2010	The intellectual development of the technology acceptance model: A co-citation analysis	N/A
Djamasbi et al.	2010	Affect and acceptance: Examining the effects of positive mood on the technology acceptance model	Decision Support Systems
Lin et al.	2010	Extending technology usage models to interactive hedonic technologies: a theoretical model and empirical test	Hedonic technologies
Hauttekeete et al.	2010	Smart, smarter, smartest... the consumer meets the smart electrical grid	Smart grids
Stragier et al.	2010	Introducing Smart Grids in Residential Context: Consumers' Perception of Smart Household Appliances	Smart metering
Fung et al.	2010	A proposed study on the use of ICT and smart meters to influence consumers behavior and attitude towards renewable energy	Smart metering
Gallenkamp et	2010	Exploring the Role of Control – Smart Meter	Smart metering

al.		Acceptance of Residential Consumers	
Kranz et al.	2010	Power control to the People? Private consumers acceptance of smart meters	Smart Metering
Lin et al.	2011	Assessing citizen adoption of e-Government initiatives in Gambia: A validation of the technology acceptance model in information systems success	E-government
Lee et al.	2011	A model of organizational employees' e-learning systems acceptance	e-learning
Ortega Egea et al.	2011	Explaining physicians' acceptance of EHCR systems: An extension of TAM with trust and risk factors	Healthcare
Karaali et al.	2011	Factors affecting the intention to use a web-based learning system among blue-collar workers in the automotive industry	Web-based learning
Abbasi et. al.	2011	Social influence, voluntariness, experience and the internet acceptance An extension of technology acceptance model within a south-Asian country context	Internet technology
Jan et al.	2011	Technology acceptance model for the use of information technology in universities	Academic administrative university information system
Wu et al.	2011	User Acceptance of Wireless Technologies in Organizations: A comparison of Alternative models	Wireless technologies

Table A.2 Literature applying and extending the UTAUT model

Authors	Year	Title	Area
Cody-Allen et al.	2006	An Extension of the UTAUT model with E-Quality, Trust and Satisfaction constructs	E-business systems
Wang et al.	2006	Acceptance of E-Government Service: A Validation of the UTAUT	E-Government
Marchewka et al.	2007	An Application of the UTAUT Model for Understanding Student Perceptions Using	Course Management

		Course Management Software	software- Black Board
Chen	2007	Implementation of MS Project in a Sino-Western joint venture – A case study of user acceptance	Management Information System with emphasis on the Chinese culture
Payne et. al.	2008	Can the Unified Theory of Acceptance and Use of Technology Help Us Understand the Adoption of Computer-Aided Audit Techniques by Auditors?	Auditing
AlAwadhi et al.	2008	The Use of the UTAUT Model in the Adoption of E-government Services in Kuwait	E-Government
Cheng et al.	2008	Customer Acceptance of Internet Banking: Integrating Trust and Quality with UTAUT Model	Internet banking
Qingfei et al.	2008	Mobile Commerce User Acceptance Study in China: A Revised UTAUT Model	Mobile commerce (payments)
Shin	2009	Towards an understanding of the consumer acceptance of mobile wallet	Mobile Payments
AlQeisi	2009	Analyzing the Use of UTAUT Model in Explaining an Online Behavior: Internet Banking Adoption	Internet banking
Adell	2009	Driver Experience and Acceptance of Driver Support Systems- Case of speed adaptation	Driver Support Systems
Chan et. al.	2010	Modeling Citizen Satisfaction with Mandatory Adoption of an E-Government Technology	E-Government
Abdulwahab and Dahalin	2010	A Conceptual Model of Unified Theory of Acceptance and Use of Technology (UTAUT) Modification with Management Effectiveness and Program Effectiveness in Context of Telecentre	Shared IT facilities in remote areas
Wu et al.	2010	Acceptance of Educational Technology: Field Studies of Asynchronous Participatory Examinations	E-Learning

Or et al.	2010	Factors affecting home care patients' acceptance of a web-based interactive self-management technology	Healthcare
Thowfeek and Jaafar	2010	Integrating National Culture into Information and	Focusing on cultural aspects
Ismail	2010	International Students' Acceptance on using Social Networking Site to Support Learning Activities	Social networks as means to support education (cultural differences)
Lee et al.	2010	The influence of change agents' behavioral intention on the usage of the activity based costing/management system and firm performance: The perspective of unified theory of acceptance and use of technology	activity based costing/ management (ABC/M) system
Sundaravej	2009	Empirical Validation of Unified Theory of Acceptance and Use of Technology Model	Education- Course management software- Black Board
Verdegem and De Marez	2011	Rethinking determinants of ICT acceptance: Towards an integrated and comprehensive overview	Mobile news application, and mobile television services

Table A.3 Literature review of Rogers' Diffusion of Innovations Theory

Authors	Year	Title	Area
Tornatzky and Klein	1982	Innovation Characteristics and Innovation Adoption- Implementation: A Meta-Analysis of Findings	N/A
Moore and Benbasat	1991	Development of an Instrument to Measure the Perceptions of Adopting an Information Technology Innovation	Information technology within organization
Wright and Charlett	1995	New Product Diffusion Models in Marketing: An Assessment of Two Approaches	Marketing strategies
Jacobsen	1998	Adoption Patterns of Faculty Who Integrate Computer Technology for Teaching and Learning in Higher Education	Computer use in education
Blankenship	1998	Factors Related to Computer Use by Teachers in Classroom Instruction	Computer use in education
Walsh- Carter	1998	An Assessment of the Status of the Diffusion and Adoption of Computer-based Technology in Appalachian College Association Colleges and Universities	Computer use in education
Andreson et al.	1998	Faculty Adoption of Teaching and Learning Technologies: Contrasting Earlier Adopters and Mainstream Faculty	Computer use in education
Karahanna et al.	1999	Information Technology Adoption Across Time: A Cross-Sectional Comparison of Pre-Adoption and Post-Adoption Beliefs	Computer operating system (Windows)
Medlin	2001	The Factors that May Influence a Faculty Member's Decision to Adopt Electronic Technologies in Instruction	Computer use in education
Surendra	2001	Acceptance of Web Technology based Education by Professors and Administrators of a College of Applied Arts and Technology in Ontario	Computer use in education

Zakaria	2001	Factors Related to Information Technology Implementation in the Malaysian Ministry of Education Polytechnics	Computer use in education
Chen et al.	2002	Enticing Online Consumer: an extended Technology Acceptance Perspective	E-commerce
Isleem	2003	Relationships of selected factors and the level of computer use for instructional purposes by technology education teachers in Ohio public schools: a statewide survey	Computer use in education
Less	2003	Faculty Adoption of Computer Technology for Instruction in the North Carolina Community College System	Computer use in education
Lee	2004	Nurses' Adoption of Technology: Application of Rogers' Innovation-Diffusion Model	Healthcare
Wonglimpiyar at and Yuberk	2005	In support of innovation management and Roger's Innovation Diffusion theory	Research and Development systems
Wu et al.	2005	What drives mobile commerce? An empirical evaluation of the revised technology acceptance model	Moible Commerce
Mallat	2007	Exploring consumer adoption of mobile payments	Mobile Payment
Lo pez-Nicola et al.	2008	An assessment of advanced mobile services acceptance: Contributions from TAM and diffusion theory models	Mobile services
Tung et. al.	2008	An extension of trust and TAM model with IDT in the adoption of the electronic logistics information system in HIS in the medical industry	Healthcare
Nan et. al.	2008	IDT-TAM Integrated Model for IT Adoption	Email
Chen et. al.	2009	The acceptance and diffusion of the innovative smart phone use: A case study of a delivery service company in logistics	Smart phones

Zhang et. al.	2010	E-learning adoption intention and its key influence factors based on innovation adoption theory	E-learning
.Gerpott	2011	Attribute perceptions as factors explaining Mobile Internet acceptance of cellular customers in Germany – An empirical study comparing actual and potential adopters with distinct categories of access appliances	Mobile Internet
Al-maghrabi et. al.	2011	Antecedents of Intentions Towards e-shopping: Continuance the Case of Saudi Arabia	E-shopping
Swingler and Lee	2006	The Diffusion of Legal Music Download Services	Digital music technologies

Appendix B: Survey Development and Design

Survey Design

In Chapter 5, the I^3S^2 Model was presented within the arena of the smart metering system. The model encompasses a number of technology acceptance determinants that are assumed to be predictors on consumers acceptance of smart meters. To estimate the I^3S^2 Model and investigate the significance of the hypothesized influences a survey was developed as measurement instrument, which captures consumers perceptions of the notions included in the model. The process of designing and developing the survey used for the current work is described next.

Survey Translation to the Dutch Language

The survey was made available to respondents in two versions: in Dutch and in English languages. The latter was necessary to cater for the substantial number of non-Dutch speaking foreign nationals whom are residing in The Netherlands. The survey was first developed in the English language by the author of this book. It was then translated into the Dutch language by a native Dutch speaker. The translation was later scrutinized and slightly amended by another native Dutch speaker.

Survey Layout

The survey in both its Dutch and English language versions was made available online for respondents using the NetQuestionnaire software. The survey consists of several sections, each serving a different purpose. The first page of the survey is a welcome page that gives a brief introduction of the survey, the purpose of the research it is employed for, and how the survey can help serve this purpose. The page also included the contact information of the researcher in case respondents had any questions relating to the survey that required clarification. Next, respondents are presented with a brief description of the smart metering system accompanied with a figure illustrating the main components of the system. This was followed by 68 items (questions) related to the acceptance determinants in the I^3S^2 model. The last section of the survey consists of questions related to respondents demographics. Finally, the survey concludes with a thank you note for respondents for taking the time to fill out the survey, and again the contact information of the researcher. The survey used for this research is shown in Appendix A in both versions: Dutch and English.

Survey Pre-Test

Upon the completion of the first draft of the survey, a pilot administration was conducted to ensure the soundness of the survey as a measurement tool. The pilot administration took place in December 2011 within the Technology Policy and Management Faculty, at Delft University of Technology in The Netherlands. The target population for this pilot administration was employees within the faculty, both academic and administrate staff. The survey was delivered to respondents via an email invitation that was sent to all employees within the faculty of TPM. The invitation requested respondents' participation in filling out the survey by following a hyper link that was embedded in the email message.

Acquiring a representative sample was not a concern nor the aim at that point of the study. The reason for this is that the purpose of conducting the pilot administration was to verify the suitability of the items included in the survey to measure the latent variables that they are hypothesized to be associated with. The pilot dataset consists of 58 responses, which was deemed a suitable sample size for the intended purpose. In general, the pilot survey consisted of the same sections as in the actual survey used for the large-scale administration, however, it differed by the inclusion of one additional section at the end of the survey. The additional section consisted of one optional question that requested respondents to give any comments or remarks, which they may have, regarding the survey in general including aspects such as layout, choice of words or phrasing of survey items. This field proved rather beneficial as it offered an insight into respondents' perception of the survey, what flaws it may have, and what possible improvements can be made to the survey prior to the large-scale administration. Relevant and constructive comments were taken into consideration and some changes were applied to the survey accordingly.

Confirmatory factor analysis statistical methods –described in further detail in Chapter 7- were used to analyze the pilot dataset, in order to help establish the suitability of each construct's set of items to be used as observed variables to measure the said construct. The results of this stage proved the suitability of most constructs except some such as: Trialability, Perceived Financial Costs, and Technology Awareness. To overcome this problem, the items representing these constructs were revised and some were replaced in the final version of the survey used for the larger-scale administration.

In addition to testing the survey, it was presented to experts from academia and industry for review. From the industry side, the survey was scrutinized by experts from both a market research company, and the department of consumer research in an energy company. The input obtained from all experts helped in shaping the survey in its final form.

Data Collection

In order to obtain the required dataset, the on-line survey in both of its versions, i.e. Dutch and English, was circulated among members of the Dutch society. One limitation of the current work related to the conduction of the survey is the lack of resources to delegate the data collection task to a survey research companies. Delegation of such task to specialized companies ensures acquiring a sample of the required size, which is representative of the population.

Collecting the data was accomplished by circulating the survey via e-mail to social and professional contacts, and asking recipient to propagate the survey further within their own social circles. Furthermore, efforts were made to approach in person individuals that showed lack of interest in receiving the survey by email, such as senior citizens.

In addition, to ensure diversity of respondents a number of auxiliary departments were contacted in Delft University of Technology that offer supporting services, such as: catering, human resources, service points and security staff. Representatives of each department were asked to circulate the survey among their staff.

Moreover, both national and international corporates operating in The Netherlands were contacted requesting the survey be dispensed among their staff. The initiative was motivated by the fact that these companies operate within the different regions within The Netherlands, and employ diverse members of society in terms of age, gender and level of education. The companies contacted were Albert Heijn supermarket chain, DHL shipping company, Rots-Vast real estate agency, and ROC Mondriaan institute for vocational education.

The reason for collecting the dataset used for this work was following the manner described above, rather than commissioning the process to specialized consumer-research companies was solely due to financial reasons.

Respondents Overview

The data gathering process described above lasted for a period of a little over two months between April 2012 and June 2012. The process resulted initially with a dataset of 450 responses, which was later reduced to 315 responses after eliminating records with missing data, i.e. incomplete response sets due to respondent's failure or lack of willingness to complete the entire survey. The dataset minimum size requirements differs throughout the literature. Some researchers bind the size of the dataset to a model's complexity -i.e. the number of constructs included- in combination with other factors such as: the number of items used per constructs. Other researchers focus mainly on the number of items used per construct as a guideline for the minimum number of responses needed in a dataset to estimate a model. In general, a lower bound of acceptable dataset size is a ratio of at least 5 times as many responses as the number of items used for the analysis. Furthermore, a ratio of 10:1 is considered a more acceptance threshold, whereas an extreme guideline proposed by some researchers is 20:1 (Hair, Black et al. 2010). In the current work, a ratio of at least five responses per item is adopted, which is satisfied by the acquired data set of 315 responses.

The efforts exerted to obtain a representative sample were not all successful. In fact, only two companies positively responded indicating their willingness to circulate the survey among their employees. However, significant increase in sample size was not logged afterwards. This scenario was repeated with auxiliary departments within TU Delft. Furthermore, personally approaching janitors in the Faculty of Technology Policy and Management resulted in failure, as the cleaning staff refused to fill in the survey whether at the university or at home. Again, this scenario was repeated for many senior citizens personally approached to fill in the survey. The difficulty of reaching individuals on a larger scale, in addition to the refusal of certain groups of society to fill in the survey meant that the desired level of sample representativeness could not be entirely achieved. The representativeness of the sample is discussed along three dimensions: gender, age and education, as described next.

Gender

The gender distribution of survey respondents was compared to statistics released by Statistics Netherlands- SN (Centraal Bureau voor de Statistiek 2012). The comparison is showed in Table B.1, where the column labeled "SN Percentage" contains the ratio of women to men in The Netherlands in the year 2012 (Centraal Bureau voor de Statistiek-B 2012).

Table B.1 Comparison of gender distribution

Gender	Percentage of survey Respondents	SN Percentage
Women	36.50%	50.49%
Men	61.60%	49.51%
Missing	1.95%	---
Total	100%	100%

Table B.1 reveals a discrepancy between gender distribution of survey respondents and that released by SN. However, since the influence of gender on social acceptance of smart meters is not investigated in the current work, in addition to missing data in this field that influence the accuracy of the respondent's gender distribution, the dataset is considered satisfactory to carry out the statistical analysis process and draw conclusions.

Age

The distribution of age categories of survey respondents was compared to the distribution of age of the Dutch population as released by SN (Centraal Bureau voor de Statistiek- C 2012). The comparison is depicted in Table B.2.

Table B.2: Comparison of respondents' age distribution

Age Categories	Percentage of survey Respondents	SN Percentage
15 – 24	3.17%	12.24%
25 – 34	30.16%	12.08%
35 – 44	19.05%	14.11%
45 – 54	17.78%	15.03%
55 – 64	14.92%	13.00%
65 – 74	10.48%	9.11%
75 – 84	14.92%	5.23%
85 – 90	0.63%	1.45%
Missing	1.90%	---
Total	100%	100%

As shown in Table B.2, age categories 15-24 and 85- 90 were underrepresented by survey respondents, whereas age categories 25-34 and 75-84 were considerably overrepresented by survey respondents. Age categories 35- 44, 45-54, 55-64, and 65-74 were fairly well represented as the numbers reported by SN and the survey were fairly close.

In general, the age distribution across the different age categories showed a reasonable number of respondents per category, which implies that the survey respondents represent the different age categories within society. Further, due to the inaccuracy of the age distribution of survey respondents due to missing data, in addition to the fact that the influence of age on social acceptance of smart meters is not to be investigated in the current work, the age distribution was deemed acceptable to proceed with analyzing the dataset.

Education

Comparing the distribution of respondents' level of education to that of the Dutch society released by SN was not a straight forward task. This was due to the difference between the levels of education used in the survey, and the classification used by SN. Furthermore, SN does not account for individuals with no education, whereas one respondent to the survey indicated not having any education. Though there is a chance this entry is faulty, yet this in addition to the different classification of education and missing data contribute to uncertainty of the distribution of respondents' level of education. Table B.3 presents the comparison between SN's (Centraal Bureau voor de Statistiek-D 2012) and respondents' distributions.

Table B.3 Level of education distribution

Level of Education	Percentage of survey Respondents	SN Percentage
None	0.32%	--
Primary School	0.00%	8.50%
Vocational Education	5.08%	20.80%
High School	5.08%	42.90%
Bachelor's	28.57%	18.40%
Masters and Doctorate	59.05%	9.50%
Missing/ Undefined	1.90%	--
Total	100.00%	100.00%

From the table above it is clear that distribution of the level of education of survey respondents does not tally with that released by SN. This discrepancy can be attributed to several factors, such as: the different levels of classification used by the survey and SN, and missing data. Furthermore, a main cause for this bias towards higher levels of education is refusal of individuals with lower levels of education to fill out the survey. This has been personally experienced by the researcher upon attempting to approach such individuals in person.

To overcome the limitations listed above, the possible influence of the level of education on respondents' acceptance of a smart meter was investigated. This was accomplished by applying the mean difference statistical test to examine whether a significant difference exists between two groups of respondents: highly educated group that included respondents with a Bachelors degree or higher, and a second group that included the rest of respondents. The results of the test revealed that people with higher levels of education have a mean of 3.28 versus a mean of 3.52 for those with lower levels of education, i.e. an insignificant difference between the two means. Furthermore, the tests also proved that the significance value that indicates whether the difference between the two means is significant was at a level of 0.144, which confirms that the difference of the two means is insignificant. The insignificant difference between the two groups of respondents, in addition to the fact that level of education will not be investigated in the current study as a possible factor impacting social acceptance of smart meters, yielded the dataset acceptable to be analyzed for the estimation for the I^3S^2 model.

Appendix C: List of Variables Used for Identification of the I^3S^2 model

Construct	Item Name	Item Description	Scale
Performance Expectancy	PE2	I would find a smart meter useful in managing my electricity consumption	5-point likert scale (strongly agree – strongly disagree)
	PE3	I believe that using a smart meter would enable me to contribute in saving the environment	
	PE4	I believe that using a smart meter would enable me to reduce the amount of electricity used significantly	
	PE5	I believe that using a smart meter would enable me to reduce my electricity bill	
Social Influence	SI2	People in my community (family, friends, neighbors, coworkers....etc) who use a smart meter have high status and prestige	5-point likert scale (strongly agree – strongly disagree)
	SI3	Given that a smart meter would be available to me, I would it use it if people who are important to me (friends/ family) would use it	
	SI4	Given that a smart meter would be available to me, I would it use it if my idol (such as a favorite politician/ actor) supports its use	
Effort Expectancy	EE1	I believe that I would become experienced in using a smart meter in a short time (less than 1 month)	5-point likert scale (strongly agree – strongly disagree)
	EE2	I believe that I would find a smart meter easy to use	
	EE3	I believe that learning to use a smart meter would be easy for me	
	EE4	I believe that the steps involved in	

		using a smart meter would be clear	
Trialability	TR1	I have had the chance to try out a smart meter	Never, Once, Many Times
	TR2	I have participated in a trial roll-out of smart meter	
	TR3	It was possible for me to use a smart meter on trial basis to see what it can do	
Compatibility	CM1	I find it acceptable to receive an electricity bill that better reflects my electricity consumption	5-point likert scale (strongly agree – strongly disagree)
	CM2	I believe that a smart meter would be as good as my current mechanical meter in tracking my electricity consumption	
	CM3	I find it acceptable to receive an electricity bill every 2 months instead of every month	
Perceived Organization Image	OI1	The services provided by the electricity grid operator in my region are known to me	5-point likert scale (strongly agree – strongly disagree)
	OI2	I know the electricity grid operator in my region	
	OI3	I am able to recognize the logo of the electricity grid operator in my region	
	OI4	I know whom to contact in my region in case I had inquiries about smart meters	
	OI5	I am familiar with the website of the electricity grid operator in my region	
Technology Awareness	TA1	Installation of a smart meter is mandatory	True, False, I do not know
	TA2	Obtaining a smart meter is free of charge	

	TA3	Electricity supply can be remotely activated/ deactivated by electricity companies via a smart meter	
	TA4	A smart meter can send meter readings to electricity companies at a 15 minute interval	
	TA5	A smart meter can use wireless communication to send meter readings to electricity companies	
	TA6	Meter readings recorded by a smart meter are sent electronically to electricity companies and stored	
	TA7	In addition to measuring electricity consumption, a smart meter can also be used to measure gas consumption	
	TA8	A smart meter makes it possible to charge consumers based on the time at which electricity was used	
	TA9	The use of a smart meter can help reduce the amount of electricity consumed	
Mass Media	MM1	I know of the functionality of a smart meter through media channels (newspaper/tv/ radio/internet)	5-point likert scale (strongly agree – strongly disagree)
	MM2	The advantages of using a smart meter are communicated via media channels (newspapers/TV/radio/Internet)	
	MM3	The adverse effects of using a smart meter are mentioned in media channels	
Perceived Security and Privacy Risks	SP1	I believe that intruders cannot access my information when stored in the remote system managed by electricity companies	5-point likert scale (strongly agree – strongly disagree)

	SP2	I believe that intruders cannot access my information during transmission	
	SP3	I believe that the privacy of my information will remain protected when using a smart meter	
	SP4	I believe that electricity companies would not disclose my information to unauthorized parties	
	SP5	I believe that the smart metering system applies strong security measures to protect the security of my information	
Perceived Financial Costs	FC1	I find it acceptable to pay 60 Euros for a smart meter	5-point likert scale (strongly agree – strongly disagree)
	FC2	I find it acceptable to pay 60 Euros for a meter display	
	FC3	I believe that the electricity used by a smart meter would not increase my electricity bill	
	FC4	I believe that my electricity bill will not increase after the installation of a smart meter	
Perceived Health Risks	HR1	I believe that the occurrence of adverse effects of a smart meter on health are..(likely/unlikely)	5-point likert scale (highly unlikely – highly likely)
	HR2	I believe that it is acceptable for electricity companies to install smart meters that use wireless communication	5-point likert scale (strongly agree – strongly disagree)
	HR3	I believe that it is acceptable to have at home a smart meter that uses wireless communication	
	HR4	I believe that having a smart meter that uses wireless communication at home is safe for my health	

Perceived Loss of Control	In the event of not paying my electricity bill for any reason, I find it acceptable that electricity companies can disconnect my electricity connection…		
	CL1	… remotely	5-point likert scale (strongly agree – strongly disagree)
	CL2	… instantly	
System Data Architecture	I believe that storing meter readings on the meter at my home instead of the remote system managed by electricity companies…		
	DA1	…protects the privacy of my data better	5-point likert scale (strongly agree – strongly disagree)
	DA2	…ensures the security to my data	
	DA3	…makes me feel more comfortable	
Acceptance of a Smart Meter	ACC2	I want to have a situation C or D smart meter	5-point likert scale (strongly agree – strongly disagree)
	ACC3	I will allow the installation of a situation C or D smart meter at my home	
	ACC4	I intend to get a situation C or D smart meter	
	ACC5	It is important for me to have a situation C or D smart meter	
	ACC6	I intend to use a smart meter when it becomes available to me	
Effective Feedback	EF1	I believe that effective feedback would suit the need of consumers to manage their electricity consumption	5-point likert scale (strongly agree – strongly disagree)
	On a scale from 1 (not important) to 5 (very important) how important is it to you:		
	EF2	Receive effective feedback	5-point likert scale (not important – very important)
	EF3	Use effective feedback to keep electricity consumption under control	
Observability	By using a smart meter the following would be evident to me:		
	OB1	…decrease in my electricity bill	5-point likert scale (strongly agree

	OB2	…easier switching between the different electricity suppliers	– strongly disagree)
	OB3	…my active contribution in saving the environment by keeping my electricity consumption under control	

Appendix D: Statistical Analysis

Performance Expectancy

Correlations

		PE2	PE3	PE4	PE5
PE2	Pearson Correlation	1	,457**	,510**	,672**
	Sig. (2-tailed)		,000	,000	,000
	N	315	315	315	315
PE3	Pearson Correlation	,457**	1	,582**	,488**
	Sig. (2-tailed)	,000		,000	,000
	N	315	315	315	315
PE4	Pearson Correlation	,510**	,582**	1	,551**
	Sig. (2-tailed)	,000	,000		,000
	N	315	315	315	315
PE5	Pearson Correlation	,672**	,488**	,551**	1
	Sig. (2-tailed)	,000	,000	,000	
	N	315	315	315	315

**. Correlation is significant at the 0.01 level (2-tailed).

Communalities

	Initial	Extraction
PE2	,487	,562
PE3	,388	,446
PE4	,447	,543
PE5	,522	,635

Extraction Method: Principal Axis Factoring.

Factor Matrix[a]

	Factor
	1
PE2	,749
PE3	,668
PE4	,737
PE5	,797

Extraction Method: Principal Axis Factoring.

a. 1 factors extracted. 6 iterations required.

Effort Expectancy

Correlations

		EE1	EE2	EE3	EE4
EE1	Pearson Correlation	1	,395**	,538**	,478**
	Sig. (2-tailed)		,000	,000	,000
	N	315	315	315	315
EE2	Pearson Correlation	,395**	1	,517**	,438**
	Sig. (2-tailed)	,000		,000	,000
	N	315	315	315	315
EE3	Pearson Correlation	,538**	,517**	1	,622**
	Sig. (2-tailed)	,000	,000		,000
	N	315	315	315	315
EE4	Pearson Correlation	,478**	,438**	,622**	1
	Sig. (2-tailed)	,000	,000	,000	
	N	315	315	315	315

**. Correlation is significant at the 0.01 level (2-tailed).

Communalities

	Initial	Extraction
EE1	,334	,416
EE2	,301	,369
EE3	,507	,711
EE4	,427	,539

Extraction Method: Principal Axis Factoring.

Factor Matrix[a]

	Factor
	1
EE3	,843
EE4	,734
EE1	,645
EE2	,608

Extraction Method: Principal Axis Factoring.

a. 1 factors extracted. 9 iterations required.

Social Influence

Correlations

		SI2	SI3	SI4
SI2	Pearson Correlation	1	,454**	,418**
	Sig. (2-tailed)		,000	,000
	N	315	315	315
SI3	Pearson Correlation	,454**	1	,678**
	Sig. (2-tailed)	,000		,000
	N	315	315	315
SI4	Pearson Correlation	,418**	,678**	1
	Sig. (2-tailed)	,000	,000	
	N	315	315	315

**. Correlation is significant at the 0.01 level (2-tailed).

Communalities

	Initial	Extraction
SI2	,229	,280
SI3	,495	,733
SI4	,475	,627

Extraction Method: Principal Axis Factoring.

Factor Matrix[a]

	Factor
	1
SI3	,856
SI4	,792
SI2	,529

Extraction Method: Principal Axis Factoring.

a. 1 factors extracted. 14 iterations required.

Trialability

Correlations

		TR1	TR2	TR3
TR1	Pearson Correlation	1	,502**	,692**
	Sig. (2-tailed)		,000	,000
	N	315	315	315
TR2	Pearson Correlation	,502**	1	,545**
	Sig. (2-tailed)	,000		,000
	N	315	315	315
TR3	Pearson Correlation	,692**	,545**	1

	Sig. (2-tailed)	,000	,000	
	N	315	315	315

**. Correlation is significant at the 0.01 level (2-tailed).

Communalities

	Initial	Extraction
TR1	,500	,639
TR2	,327	,396
TR3	,531	,748

Extraction Method: Principal Axis Factoring.

Factor Matrix[a]

	Factor
	1
TR3	,865
TR1	,799
TR2	,629

Extraction Method: Principal Axis Factoring.

a. 1 factors extracted. 12 iterations required.

Observability

Correlations

		OB1	OB2	OB3
OB1	Pearson Correlation	1	,498**	,611**
	Sig. (2-tailed)		,000	,000
	N	315	315	315
OB2	Pearson Correlation	,498**	1	,439**
	Sig. (2-tailed)	,000		,000
	N	315	315	315
OB3	Pearson Correlation	,611**	,439**	1
	Sig. (2-tailed)	,000	,000	
	N	315	315	315

**. Correlation is significant at the 0.01 level (2-tailed).

Communalities

	Initial	Extraction
OB1	,438	,690
OB2	,277	,358
OB3	,397	,540

Correlations

		OB1	OB2	OB3
OB1	Pearson Correlation	1	,498**	,611**
	Sig. (2-tailed)		,000	,000
	N	315	315	315
OB2	Pearson Correlation	,498**	1	,439**
	Sig. (2-tailed)	,000		,000
	N	315	315	315
OB3	Pearson Correlation	,611**	,439**	1
	Sig. (2-tailed)	,000	,000	
	N	315	315	315

Extraction Method: Principal Axis Factoring.

Factor Matrix[a]

	Factor
	1
OB1	,831
OB3	,735
OB2	,598

Extraction Method: Principal Axis Factoring.

a. 1 factors extracted. 14 iterations required.

Compatibility

Correlations

		CM1	CM2	CM3
CM1	Pearson Correlation	1	,022	,147**
	Sig. (2-tailed)		,699	,009
	N	315	315	315
CM2	Pearson Correlation	,022	1	,008
	Sig. (2-tailed)	,699		,893
	N	315	315	315
CM3	Pearson Correlation	,147**	,008	1
	Sig. (2-tailed)	,009	,893	
	N	315	315	315

**. Correlation is significant at the 0.01 level (2-tailed).

Communalities

	Initial	Extraction
CM1	,022	,153
CM2	,000	,001
CM3	,022	,141

Extraction Method: Principal Axis Factoring.

Factor Matrix[a]

	Factor
	1
CM1	,391
CM3	,376
CM2	

Extraction Method: Principal Axis Factoring.
a. 1 factors extracted. 9 iterations required.

Perceived Organization Image

Correlations

		OI1	OI2	OI3	OI4	OI5
OI1	Pearson Correlation	1	,431**	,559**	,559**	,504**
	Sig. (2-tailed)		,000	,000	,000	,000
	N	315	315	315	315	315
OI2	Pearson Correlation	,431**	1	,565**	,461**	,428**
	Sig. (2-tailed)	,000		,000	,000	,000
	N	315	315	315	315	315
OI3	Pearson Correlation	,559**	,565**	1	,430**	,526**
	Sig. (2-tailed)	,000	,000		,000	,000
	N	315	315	315	315	315
OI4	Pearson Correlation	,559**	,461**	,430**	1	,523**
	Sig. (2-tailed)	,000	,000	,000		,000
	N	315	315	315	315	315
OI5	Pearson Correlation	,504**	,428**	,526**	,523**	1
	Sig. (2-tailed)	,000	,000	,000	,000	
	N	315	315	315	315	315

**. Correlation is significant at the 0.01 level (2-tailed).

Communalities

	Initial	Extraction
OI1	,452	,540
OI2	,383	,431
OI3	,479	,555
OI4	,421	,482
OI5	,404	,491

Extraction Method: Principal Axis Factoring.

Factor Matrix[a]

	Factor
	1
OI3	,745
OI1	,735
OI5	,700
OI4	,694
OI2	,657

Extraction Method: Principal Axis Factoring.

a. 1 factors extracted. 5 iterations required.

Mass Media

Correlations

		MM1	MM2	MM3
MM1	Pearson Correlation	1	,498**	,255**
	Sig. (2-tailed)		,000	,000
	N	315	315	315
MM2	Pearson Correlation	,498**	1	,376**
	Sig. (2-tailed)	,000		,000
	N	315	315	315
MM3	Pearson Correlation	,255**	,376**	1
	Sig. (2-tailed)	,000	,000	
	N	315	315	315

**. Correlation is significant at the 0.01 level (2-tailed).

Communalities

	Initial	Extraction
MM1	,254	,342
MM2	,314	,724
MM3	,147	,193

Factor Matrix[a]

	Factor
	1
MM2	,851
MM1	,585
MM3	,440

Perceived Financial Costs

Including all four variables:

Correlations

		FC1	FC2	FC3	FC4
FC1	Pearson Correlation	1	,625**	,386**	,290**
	Sig. (2-tailed)		,000	,000	,000
	N	315	315	315	315
FC2	Pearson Correlation	,625**	1	,328**	,237**
	Sig. (2-tailed)	,000		,000	,000
	N	315	315	315	315
FC3	Pearson Correlation	,386**	,328**	1	,504**
	Sig. (2-tailed)	,000	,000		,000
	N	315	315	315	315
FC4	Pearson Correlation	,290**	,237**	,504**	1
	Sig. (2-tailed)	,000	,000	,000	
	N	315	315	315	315

**. Correlation is significant at the 0.01 level (2-tailed).

Communalities

	Initial	Extraction
FC1	,432	,564
FC2	,400	,447
FC3	,324	,365
FC4	,265	,245

Factor Matrix

	Factor
	1
FC1	,751
FC2	,669
FC3	,604
FC4	,495

Excluding FC4:

Communalities

	Initial	Extraction
FC1	,427	,729
FC2	,400	,536
FC3	,161	,203

Factor Matrix

	Factor
	1
FC1	,854
FC2	,732
FC3	,450

Splitting the construct into two sub-constructs:

Perceived Financial Costs 1

Communalities

	Initial	Extraction
FC1	,391	,624
FC2	,391	,624

Factor Matrix[a]

	Factor
	1
FC2	,790
FC1	,790

Perceived Financial Costs 2:

Communalities

	Initial	Extraction
FC3	,254	,503
FC4	,254	,503

Factor Matrix[a]

	Factor
	1
FC4	,709
FC3	,709

Effective Feedback

Correlations

		EF1	EF2	EF3
EF1	Pearson Correlation	1	,613**	,583**
	Sig. (2-tailed)		,000	,000
	N	315	315	315
EF2	Pearson Correlation	,613**	1	,820**
	Sig. (2-tailed)	,000		,000
	N	315	315	315
EF3	Pearson Correlation	,583**	,820**	1
	Sig. (2-tailed)	,000	,000	
	N	315	315	315

**. Correlation is significant at the 0.01 level (2-tailed).

Communalities

	Initial	Extraction
EF1	,395	,436
EF2	,701	,860
EF3	,683	,782

Extraction Method: Principal Axis Factoring.

Factor Matrix[a]

	Factor
	1
EF2	,928
EF3	,884
EF1	,660

Extraction Method: Principal Axis Factoring.

a. 1 factors extracted. 11 iterations required.

Perceived Health Risks

Correlations

		HR1	HR2	HR3	HR4
HR1	Pearson Correlation	1	,525**	,542**	,608**
	Sig. (2-tailed)		,000	,000	,000
	N	315	315	315	315
HR2	Pearson Correlation	,525**	1	,887**	,722**
	Sig. (2-tailed)	,000		,000	,000

	N	315	315	315	315
HR3	Pearson Correlation	,542**	,887**	1	,675**
	Sig. (2-tailed)	,000	,000		,000
	N	315	315	315	315
HR4	Pearson Correlation	,608**	,722**	,675**	1
	Sig. (2-tailed)	,000	,000	,000	
	N	315	315	315	315

**. Correlation is significant at the 0.01 level (2-tailed).

Communalities

	Initial	Extraction
HR1	,402	,402
HR2	,815	,848
HR3	,795	,806
HR4	,594	,648

Extraction Method: Principal Axis Factoring.

Factor Matrix[a]

	Factor
	1
HR2	,921
HR3	,898
HR4	,805
HR1	,634

Extraction Method:
Principal Axis
Factoring.
a. 1 factors extracted. 5
iterations required.

Perceived Control Loss

Correlations

		CL1	CL2
CL1	Pearson Correlation	1	,690**
	Sig. (2-tailed)		,000
	N	315	315
CL2	Pearson Correlation	,690**	1
	Sig. (2-tailed)	,000	
	N	315	315

**. Correlation is significant at the 0.01 level (2-tailed).

Communalities

	Initial	Extraction

CL1	,477	,690
CL2	,477	,690

Extraction Method: Principal Axis Factoring.

Factor Matrix[a]

	Factor
	1
CL1	,830
CL2	,830

Extraction Method: Principal Axis Factoring.

a. 1 factors extracted. 8 iterations required.

Data Architecture

Correlations

		DA1	DA2	DA3
DA1	Pearson Correlation	1	,832**	,749**
	Sig. (2-tailed)		,000	,000
	N	315	315	315
DA2	Pearson Correlation	,832**	1	,684**
	Sig. (2-tailed)	,000		,000
	N	315	315	315
DA3	Pearson Correlation	,749**	,684**	1
	Sig. (2-tailed)	,000	,000	
	N	315	315	315

**. Correlation is significant at the 0.01 level (2-tailed).

Communalities

	Initial	Extraction
DA1	,753	,909
DA2	,701	,761
DA3	,573	,616

Extraction Method: Principal Axis Factoring.

Factor Matrix[a]

	Factor
	1
DA1	,953
DA2	,872

DA3	,785

Extraction Method:
Principal Axis
Factoring.
a. 1 factors extracted.
11 iterations required.

Smart Meter Acceptance

Correlations

		ACC2	ACC3	ACC4	ACC5	ACC6
ACC2	Pearson Correlation	1	,932**	,641**	,692**	,645**
	Sig. (2-tailed)		,000	,000	,000	,000
	N	315	315	315	315	315
ACC3	Pearson Correlation	,932**	1	,607**	,669**	,632**
	Sig. (2-tailed)	,000		,000	,000	,000
	N	315	315	315	315	315
ACC4	Pearson Correlation	,641**	,607**	1	,739**	,627**
	Sig. (2-tailed)	,000	,000		,000	,000
	N	315	315	315	315	315
ACC5	Pearson Correlation	,692**	,669**	,739**	1	,622**
	Sig. (2-tailed)	,000	,000	,000		,000
	N	315	315	315	315	315
ACC6	Pearson Correlation	,645**	,632**	,627**	,622**	1
	Sig. (2-tailed)	,000	,000	,000	,000	
	N	315	315	315	315	315

**. Correlation is significant at the 0.01 level (2-tailed).

Communalities

	Initial	Extraction
ACC2	,881	,827
ACC3	,871	,777
ACC4	,604	,600
ACC5	,638	,668
ACC6	,510	,554

Factor Matrix[a]

	Factor
	1
ACC2	,910
ACC3	,881
ACC4	,774
ACC5	,817
ACC6	,744

Appendix E: Experts’ Interviews Transcription

Interviewee: Marcelo Masera

Affiliation: Energy Security Unit, Institute for Energy of the Joint Research Center (JRC), European Commission

Title: Head of Unit “Energy Security”

Date of interview: 30-08- 2012

Question	Interviewee Answer
Is public acceptance of smart metering a crucial matter?	Yes, crucial but mainly because few people understand what it is about. And nobody really knows which could be the implications of interconnecting people among themselves and services providers. By deploying smart grids we are deploying new types of social networks and micro markets at neighborhood level. All the benefits that are aimed to be gained from smart grids concepts cannot be gained without the smart metering infrastructure. Acceptance is important for society at large and the utilities companies.
Is addressing acceptance during early stages of systems' development (before implementation) important?	Its chicken and egg scenario, you need something to show simple and professional users. System needs to be deployed, people can have a feel for it and an opinion then the public opinion can be explored. It’s difficult to predict the interaction. It has to start with a small scale pilot project. It is also important to monitor the scaling of these rollouts, because changes due to the size of the rollout are unpredictable. Small scale pilot with gradual growth is a better approach. Another alternative would be applying the proposed social requirements elicitation framework before the small pilot.
Would acceptance determinants be different per system/ per society? Would common determinants have different influence based on system and society?	Yes, even from neighborhood to neighborhood. Demographics play a role: age, education. Ex: Almere pilot in area inhabited by pensioners.
Do you think it is important to understand the process of acceptance?(i.e. how factors influence acceptance and incur change in consumer behavior)	This goes back to the point of transformation of society to deal with new technology, governments should be worried and concerned about social implications. Educating people is important.

Is acceptance partially responsible for the drop of the business case from 1.3 B euros in 2005 to 770 M euros in 2010? (According to KEMA cost-benefit analysis reports 2005 and 2010)	I cannot argue that.
Would including public opinion in defining acceptance determinants important? Would surveys be a good way of doing so?	Yes, surveys worked in the past, but it perhaps should be part of it as an initial stage. This has the risk of overwhelming people with information and forming false perception.
Are social requirements predictors of smart metering acceptance?	If elicited 1st set of requirements is something that is technically feasible and affordable for actors then yes, but if the requirements would put stiff price for some actors this can be a hurdle, because it is about money.
Is it necessary to include social requirements (e.g. security and privacy, health, perceived financial costs..etc) in smart metering development?	We need to incorporate the new trends of energy in education systems, just as traffic safety is incorporated in traffic schools. Awareness at early age.
Can accounting for social requirements in systems' development save resources by avoiding the need for retrofits or redesigning of the system? (e.g. wired/ wireless HW)	Yes, absolutely, this is part of the learning process. Companies should be aware of this but their first reaction is purely technical, if I were a manager I would say I have been in this business for 30 years, ... Why should I care for something that could perhaps be of benefit in 20 years' time for society, there's nothing for him, and my approach is asking him to change mentality for nothing.
Does accounting for social requirements in the design process of the smart metering system significantly contribute in safeguarding important goals of the smart metering system such as: energy efficiency	Yea, definitely.

and savings, and reduction of operational costs?	
Is the inclusion of social requirements important for socio-technical systems (e.g. smart meters)?	The question is how to arrive to this elicitation? You can propose some techniques but it's going to be a learning process with several errors, and this is not apparent what talking with utilities they want to have perfect solutions from the beginning but if you are not ready for trial and error then you will not learn. Effort counts but we must accept mistake and faults.
Do you agree that the government should invest in promotion campaigns among the society to promote smart meters?	Definitely. The government should be the 1st in favor of the acceptance of these technologies. Investments should be made to prepare society. 51 messages: To have a visual from TV and the street to remind people with it.
Would infrastructure systems' development lifecycle need to be altered to account for the emergent class of social requirements, such as avoiding adverse effects on health, security and privacy…etc?	Yes But who should see this through? Supply chain of smart metering follows typical industrial process of power industry, so you have most popular vendors making [metering devices] Why would most popular vendors worry about this? I see the lack of actor, perhaps the government, because none of the industrial actors of the supply chain might have a direct interest.
Is the method shown in figure 7.3 beneficial for the inclusion of social requirements in infrastructures systems' development?	I would like to see some feedback. You have to come back, if you accept this as a learning process, there are going to be errors and discoveries, so there has got to be the possibility of coming back.
Is the system development lifecycle of ICT-Intensive critical infrastructure systems (e.g. smart meters) the same as that of IT systems? Do you see the need to rethink it? (Figures 7.1	7.2 needs an arrow from the system owner to a higher level to monitor the grid operator [as an owner]. Social requirements should go back to the owner and government (monitor). It is a good transition but 7.2 is incomplete.

and 7.2)	
Should grid operators address the issue of the public perception of their image to familiarize the public with the organization and increase the awareness regarding their offered services, despite the non-competence nature among them?	No known efforts of grid operators to promote their image. Should they? This is about changing their business, if they see themselves only as sellers of electricity then it does not matter, if [they see themselves] as information and service providers then they should. Not sure if utilities are ready for this change.

Interviewee: Edwin Edelenbos

Affiliation: National Competition Authority- NMa

Title: Program Manager Metering

Date of interview: 13-09- 2012

Question	Interviewee Answer
Is public acceptance of smart meters a crucial matter?	Yes, of course.
Is addressing acceptance at early stages of systems' development (before implementation) important?	Yes, of course. Because roll out is a combination of technology push and demand driven and its starts with technology push.
Do you think it is important to understand the process of acceptance? (i.e. how different factors influence acceptance and incur change in consumer behavior)	Yes, but for who is it important? As a regulator I'm interested in this, because I understand when a consumer does not accept a technology then it won't be success, but it is not my role to understand the consumer and to give guidance to the market on what services should be there. This is also not the role of the ministry or the government in general. So it is important in the general sense, but not to regulators because regulators to not have a task regarding social acceptance other than regulating if meters are offered and installed according legislation.
Is acceptance partially responsible for the drop of the smart metering business case from 1.3 billion euros in 2005 to 770 million euros in 2010 (according to KEMA cost-benefit analysis reports in 2005 and 2010)?	Yes, of course. Price for good privacy framework for smart metering is very high. Based on the cost benefit analyses that are conducted by KEMA You might say that cost of privacy framework 0.5 billion euros. But the other ('old') model, that was based on a mandatory roll out with no possibility for a consumer to refuse would probably have resulted in mass resistance against the roll out. So yes there's a price for consumer freedom of choice, it is quantified at around 0.5 billion. In the current model consumers have the right to refuse, but as long as that percentage is lower than 20 the overall business case will be positive.

Are social requirements predictors of smart metering acceptance?	Security and privacy is not a requirement it is more a condition. Security and privacy discussion differs from functionality discussion because Security and Privacy is something that must be in place, and when not then other discussions might be irrelevant because the roll out will not become a success as consumers are likely to refuse the meter. Difficult question, I am not convinced they are predictors we saw so many technologies rolled out in the last decades which we thought it was going to work like this or that but actually they turn out to be slight or totally different or not working at all even. The way I look at introduction of smart meters: A smart meter is not an objective but a tool to reach an objective, and the real question comes in. I consider a smart meter a natural upgrade from the analog meter, because we are in the decade of digitalization, consumers see it as a sort of natural thing that they can control all kinds of things in their lives, they can control private banking, bills. They also expect to be able to control their energy environment and currently that is not possible and for that you need an enabler like a smart meter. But a smart meter on its own is not enough. So when you talk about social acceptance I am curious on how it will go with the added value services: is switching the driver for example? Or is it money? And how are people going to change their behavior in a slightly different way or fundamental way? But a smart meter is an enabler and I think the privacy discussion in 2009 is only 3 years ago but also centuries ago as it changed the paradigm and now consumer freedom is part of the legislation and that is central and I think maybe it took us too long and there was a clash in parliament but now we can be proud in The Netherlands to have consumer choice as a fundamental roll out regulation. Acceptance increased a lot partly due to the step back of ConsumentenBond and Vrijbit, energy industry changed the communication towards the consumer they are less pushing but now introducing it as a natural upgrade from analog to digital. Rejection decreased due to voluntary roll out.
Can accounting for social requirements in systems development save resources by avoiding the need for retrofits or redesigning of a system? (e.g. wired/ wireless hardware)	Difficult question, no clear answer. Acceptance 100% influencing and influenced by services and that influence the technical requirements.

Is the inclusion of social requirements important for socio-technical systems (e.g. smart metering)?	Yes, but for the value added service not the meter. My concern is in the role definition. Acceptance is related to consumer services provided in the free market. Service providers that is the model that is a free market because we really expect that free market will develop services around smart metering technology that are most wanted, needed etc. by consumers, so it’s not the role of grid operators to develop VAS currently we're in the first year of the roll out so it’s all new for the grid operator's so in this phase it is still very immature market cause there aren't enough meters out there yet, so there’s no way to make a positive business plan this year. So why grid operators are picking up that role, there is some tension. Chicken and egg situation for smart meters and services. Acceptance not technological part but in the services part. We should discuss social requirements of the services that the consumers will use. So not in the technology part but in the services part.
Do you agree that the government should invest in promotion campaigns among the society to promote smart meters?	Not sure about that, it’s a risk to position the smart meter as something that is promoted by government, so consider the following technologies: electronic medical records, OV-Chipkaart, smart meter, kilometer charger..etc. All in the same categories: socio-technical IT-intensive, and none of them was a success, it has the image of problems and not working, and has the image of very consumer unfriendly. I think if we should communicate not promote the rights of consumers. E.g. When people are concerned about security and privacy then we have professional communication about that. B1 Language level can explain what the choice of freedom means relating to smart metering, the grid operator should communicate in a friendly way information about the installation of the meter, some technical information for people interested, and the rest of smart metering services and what the consumer is going to do with the meter is up to the market. This is the market model.

Would systems' development lifecycle need to be altered to account for the emergent class of social requirements, such as avoiding adverse effects on health, security and privacy…etc?	No, I do not think so. Because I think changes in the social requirements will affect the services not the meter. When we think from the 5.0 meter there is a lot in it. In 3 years from now there will be new developments, it's a continuous process but everything we currently think of is in the current design. The meter is only a data generator, meaning that it should be future proof as the development should be in the services part and not in the meter part. So changes in social acceptance, and changes of what people are doing with a smart meter is in the free market area, and the current meter fully supports all these changes in the free market
Is the method shown in figure 7.3 beneficial for the inclusion of social requirements in system's development?	Yes, but if it is a continuous process. The technology is changing, society, consumer behavior is changing. A loop is missing.
Is the system development lifecycle of ICT-Intensive critical infrastructure systems (e.g. smart metering) the same as that of IT systems? Do you see the need to rethink it? (Figures 7.1 and 7.2)	I agree. Infrastructure systems are they government run or systems running in the free market domain? I see the sense in the proposed approach.

Interviewee: Michiel Karskens

Affiliation: Consumentenbond
Title: Head of Public Affairs
Date of interview: 31-08- 2012

Question	Interviewee Answer
Is public acceptance of smart metering a crucial matter?	I don't believe that smart meters are fundamental for smart grids Of course public acceptance is crucial, but for us acceptance of smart meters has to be individual by a consumer so we have made sure in The Netherlands that consumers have the right to choose, if my neighbor accepts it that's his individual right. Social acceptance is important but that's the case for any technology, such as wind mills.
Is addressing acceptance during early stages of systems' development (before implementation) important?	These are system design fundamentals: acceptance shows that you've done your homework before hand. Big IT corporate like Google hires psychologists and sociologists to gain an insight on the social factors of a product to increase acceptance.
Would acceptance determinants be different per system/ per society? Would common determinants have different influence based on system and society?	Yes, systems are transparent in their fulfillment of social requirements, in terms of security and privacy for example. Transparency means the public are aware
Do you think it is important to understand the process of acceptance?(i.e. how factors influence acceptance and incur change in consumer behavior)	Of course it is important to have knowledge about it because how you think about it and conceptualize it, determines what solutions you will offer. To know how to influence and improve acceptance.

Is acceptance partially responsible for the drop of the business case from 1.3 B euros in 2005 to 770 M euros in 2010? (According to KEMA cost-benefit analysis reports 2005 and 2010)	Yes to an extent such that freedom of choice is a social requirement, which was the cause for the drop.
Would including public opinion in defining acceptance determinants important? Would surveys be a good way of doing so?	Public opinion is the result of a lot of different things and it's very difficult to capture. If it were easy it would have been done more often. It is important to include the public, but its difficult thing to do, and surveys may not be the best way to do so. People definitely need to be included. Focus groups might be a better way, as opposed to general perception captured by a survey.
Are social requirements predictors of smart metering acceptance?	Yes. Cost, sustainability, security and privacy, are social requirements that were not accounted for in smart metering in early years 2007. These are important and they are predictors of acceptance. These social requirements were not included in the cost-benefit analysis.
Is it necessary to include social requirements (e.g. security and privacy, health, perceived financial costs..etc) in smart metering development?	Yes, should be mandatory for security, so at least mandate major ones.
Can accounting for social requirements in systems' development save resources by avoiding the need for retrofits or redesigning of the system? (e.g. wired/ wireless HW)	Yes, save millions or billions. Retrofits are expensive. Smart metering was rushed, not taking the time that is needed for developing it to the minimal maturity that is required for a large scale role out.

Does accounting for social requirements in the design process of the smart metering system significantly contribute in safeguarding important goals of the smart metering system such as: energy efficiency and savings, and reduction of operational costs?	Yes, you have to take consumers worries into account because the consumer is the maker or breaker of the technology.
Is the inclusion of social requirements important for socio-technical systems (e.g. smart meters)?	For any technology these days, its determinator of their success. Most of the success of consumer technology is their ability to design a system in a way that meets social requirements and give individuals [the chance] to increase their social presence, help them fulfill their social obligation. Apple is a success due to social aspect research, the design of their product is in a way that connection to consumer is intuitive. These are system design fundamentals: acceptance shows that you have done your homework before hand. Big IT corporate like Google hires psychologists and sociologists to gain an insight on the social factors of a product to increase acceptance.
Do you agree that the government should invest in promotion campaigns among the society to promote smart meters?	Depends on when what to promote? It will influence acceptance, but does it change reality? What's more important is to address problems of the system. Fixing problems and advertising go hand in hand.
Would infrastructure systems' development lifecycle need to be altered to account for the emergent class of social requirements, such as avoiding adverse effects on health, security and privacy…etc?	Yes.

Is the method shown in figure 7.3 beneficial for the inclusion of social requirements in infrastructures systems' development?	The process is required for socio-technical systems development, otherwise fixing at the end.
Is the system development lifecycle of ICT-Intensive critical infrastructure systems (e.g. smart meters) the same as that of IT systems? Do you see the need to rethink it? (Figures 7.1 and 7.2)	Grid operators should change their attitude from dealing with connections to people. Compassion -as in a “non autistic stance” the recognition you (know you) deal with people- on grid operators’ side is (desperately) needed. There is a difference between IT and Infrastructure systems development. 7.2 is useful with some modification: an arrow from owner to user labeled: explore reaction, which denotes what is their perception of society?
Should grid operators address the issue of the public perception of their image to familiarize the public with the organization and increase the awareness regarding their offered services, despite the non-competence nature among them?	No, not to national level, but yes to regional. Use interactive method. Before campaigning put your house in order.

Interviewee: Rudi Hakvoort

Affiliation: Delft University of Technology
Title: Associate Professor
Date of interview: 31-08- 2012

Question	Interviewee's Answer
Is public acceptance of smart metering a crucial matter?	I think so yes. One thing though maybe we should distinguish between the development and implementation phases. Acceptance is crucial during and after implementation phase. And for the development you need to develop a technology with an eye on the future**.**
Is addressing acceptance during early stages of systems' development (before implementation) important?	I think it's difficult to. The polite answer is yes, but the question is how to do this? Because before implementation consumers don't know what we're talking about. We are talking about the acceptance of something that is invisible for them. Yes but in reality bit difficult to do. Especially because why do you need a smart meter (conservatism)? Unless you have something very attractive and appealing like an iPhone then life changes. 10 years we worked without tablets. It's not about social acceptance but it has something that interests people.
Would acceptance determinants be different per system/ per society? Would common determinants have different influence based on system and society?	Yes, I think so. I think determinants can be significant in different ways depending on the context. It's e.g. very easy in North Korea, where everything is known already of every person. So why bother about security? But again these things can be compensated on the positive side; research should not focus on the negative aspects only.
Do you think it is important to understand the process of acceptance?(i.e. how factors influence acceptance and incur change in consumer behavior)	Yes.

Is acceptance partially responsible for the drop of the business case from 1.3 B euros in 2005 to 770 M euros in 2010? (According to KEMA cost-benefit analysis reports 2005 and 2010)	No, I don't think so.
Would including public opinion in defining acceptance determinants important? Would surveys be a good way of doing so?	On the condition of knowing what is "public opinion" and how to measure it. I think there's a difference between technology which is just purchased by people on their own, then it's up to the consumer. But if it's a technology which the government obliges people to invest in then in this case yes it would help to have consumers' panels. But I'm not sure that they exist, the questions is what role do they have in the decision making procedure? Do they really assist in getting the best design which has the highest probability to come as a success? Survey: from the environmental perspective an environmental impact assessment is made. Which is a standard approach. Maybe you can define a framework for social impact in a similar manner. Giving a standardized list of issues that need to be addressed and whenever any technology is to be implemented in a public setting then the people in charge are forced to run the social impact assessment.
Are social requirements predictors of smart metering acceptance?	Difficult to say. I think they are requirements in the sense as a necessary not a sufficient condition. Meeting these criteria is not enough for acceptance. Attractiveness of technology is probably very important for the adoption of technology and the social characteristics are very important for consumers not to block the technology.
Is it necessary to include social requirements (e.g. security and privacy, health, perceived financial costs..etc) in smart metering development?	Of course, but at the same time how to quantify? Health: cell phones emit low dose radiation for which it is scientifically difficult to prove any adverse effect. Same for the smart meter. One thing is to state in principle this should be done but in practice it's not that easy. Same with the privacy issues, how to measure privacy? How to prove that the system cannot be hacked? It's more or less impossible. I think we lack metrics, how to measure.

Can accounting for social requirements in systems' development save resources by avoiding the need for retrofits or redesigning of the system? (e.g. wired/ wireless HW)	Yes, the life time of the technology is going to decrease. Electricity meters had longer life span; this is not the case with the smart meter. Communication technologies for example most probably will change, which will trigger changes in the smart meter technology itself.
Does accounting for social requirements in the design process of the smart metering system significantly contribute in safeguarding important goals of the smart metering system such as: energy efficiency and savings, and reduction of operational costs?	Of course. If consumers do not use a technology, nothing is achieved. It is a necessary condition but not sufficient.
Is the inclusion of social requirements important for socio-technical systems (e.g. smart meters)?	Yes, it is necessary.
Do you agree that the government should invest in promotion campaigns among the society to promote smart meters?	No, it costs money. As soon as the government is going to promote a technology I tend to not want it. If the government starts to promote it, there are reasons why people are reluctant to adopt it. History has proven several times there might be some hidden agenda…

Would infrastructure systems' development lifecycle need to be altered to account for the emergent class of social requirements, such as avoiding adverse effects on health, security and privacy…etc?	From a public perspective: I think the balance between the risks and the benefits is something to be done in the policy debate and of course you need to do analysis..etc. I think it's the duty of the technology providers to come up with stuff that appeal to consumers and where the benefits are greater than the drawbacks. So from a commercial perspective I would say ok, just like Steve jobs, all the new technology passed his desk, he looked at it and what he did not like was sent back to be changed. Design of these technologies is not only an engineering process, but marketers are also involved and need to have their role in the process. So the social requirements process will play a role. Difficult to answer but I think from a risk perspective the waste when you invest in the process of a new technology that is not implemented in the end is so high that of course you need to include it in the design of these systems. From a social prospect it is very difficult to do because you do not know the technology and its details and you do not know how the public will respond. You need tools to estimate and predict how people will use it or react on it. Yes, but there is no clearway how to do it. I think the commercial part is the commercial market responsibility. From the public policy perspective how to include user expectation and consumer response in the decision making process?
Is the method shown in figure 7.3 beneficial for the inclusion of social requirements in infrastructures systems' development?	Now we have nothing, so anything is better than nothing. Better than what we have now Doesn't look terrible.
Is the system development lifecycle of ICT-Intensive critical infrastructure systems (e.g. smart meters) the same as that of IT systems? Do you see the need to rethink it? (Figures 7.1 and 7.2)	I can envision there is a difference.

Should grid operators address the issue of the public perception of their image to familiarize the public with the organization and increase the awareness regarding their offered services, despite the non-competence nature among them?	It may go against their image, such that the more they promote and show how proud they are of their services, flaws of the system will fire back at them. Maybe they can find a way to inform people with the work they do and how difficult their job is. But not in the sense look at us and spend a lot of money which is felt as public money and then there is a major outage somewhere and all people blame the utility for spending money on campaigns.

Interviewee: Charlotte Kobus

Affiliation: ENEXIS
Title: Innovator
Date of interview: 28-08-2012

Question	Interviewee Answer
Is public acceptance of smart metering a crucial matter?	Yes, I do but I am biased. User-centric design is a starting point for every innovation in my point of view. People need a product that they love to use. In my opinion, the smart meter is a translation of the old meter, but needs to meet new goals. This is a very difficult starting point. If you want to induce new behavior (energy demand reduction), you have to start with the end user and what can induce new behavior and then develop technology, instead of the other way around. We have already noticed that it goes wrong when acceptance is not made a focal point.
Is addressing acceptance during early stages of systems' development (before implementation) important?	Yes, I think so, only it's a bit difficult because you only notice a barrier of social acceptance if it happens. So, in theory yes, in practice very difficult. The ease depends on people's exposure to the technology.
Would acceptance determinants be different per system/ per society? Would common determinants have different influence based on system and society?	Society: yes, people have different believes, values per culture. System: yes, Sweden, Italy, The Netherlands all different systems with different goals. Different motivation behind the system would affect acceptance determinants. In Italy people are sensitive to hierarchy so there's no refusal of a meter. Common determinants: yes, a determinant with the same label could take different definition and behave differently.
Do you think it is important to understand the process of acceptance?(i.e. how factors influence acceptance and incur change in consumer behavior)	Yes, but difficult. A lot of people believe in the model of knowledge attitude behavior, linear model, give information to people and educate them and they will want your product. I think it is more complex than that.

Is acceptance partially responsible for the drop of the business case from 1.3 B euros in 2005 to 770 M euros in 2010? (According to KEMA cost-benefit analysis reports 2005 and 2010)	Not sure, main element of business case is reduction of consumption [leading to] energy savings and efficiency. It's also in debate because sample sizes are increasing and show that with feedback systems we get effects of 3-5 % instead of 10-15% as expected. It is partially responsible. More expensive development but roll out phase will be more stable.
Would including public opinion in defining acceptance determinants important? Would surveys be a good way of doing so?	Yes, but not solely, but it's important to include them. Start with interviews with a selection of people. Surveys come second. Prototype and testing on smaller scale.
Are social requirements predictors of smart metering acceptance?	Yes, it's difficult to ask people what they want. But it's easier when you have a product to evaluate the product experience and develop the product even more so it becomes what people really need. A good user experience can lead to acceptance.
Is it necessary to include social requirements (e.g. security and privacy, health, perceived financial costs..etc) in smart metering development?	Yes, example of Alliander is illustrating this: if you put some effort, people discovered that risk perception can be reduced. Bridging the gap is important. Talking to people and listening is important. Don't only send information to audience but listen to what they have to say and ask questions, why don't you want a meter? Surveys are a good way in the 2nd stage. Electricity grid operator is responsible for acceptance and not only the rollout. Because roll out is only possible when you have acceptance.
Can accounting for social requirements in systems' development save resources by avoiding the need for retrofits or redesigning of the system? (e.g. wired/ wireless HW)	Yes, it costs more time to develop the system. Your development stage will be longer. It would be difficult due to EU down your neck stating roll-out requirements. I think it's not good for the quality of the product. And I believe that the requirements should be about energy savings (the goals), not about the roll-out of a specific technology (the means). It costs more time but it should be done this way to save resources. Ex: we deployed a lot of meters that we need to take back due to lack of P1.

Does accounting for social requirements in the design process of the smart metering system significantly contribute in safeguarding important goals of the smart metering system such as: energy efficiency and savings, and reduction of operational costs?	Yes, I agree.
Is the inclusion of social requirements important for socio-technical systems (e.g. smart meters)?	Yes, if you see it as a socio-technical development as most grid operators do then it's interesting to understand what the end user needs. (Referring to figure 7.1(b)) is a function approach and the old meter is a bit like this. 7.2 is a good approach to develop Socio-technical systems. If you have the goals described by the EU: energy reduction..etc, then you need 7.2. If you need the meter for administration then 7.1 b is fine. But to comply with EU goals 7.2 is needed. 7.1 b demonstrates how a lot of grid operators think.
Do you agree that the government should invest in promotion campaigns among the society to promote smart meters?	It would help if somebody else other than a grid operator would recommend a smart meter, and the government is a good example because most people believe the government still, so I think it is a good idea.
Would infrastructure systems' development lifecycle need to be altered to account for the emergent class of social requirements, such as avoiding adverse effects on health, security and privacy…etc?	Yes, 7.2 instead of 7.1 (b) let people experience the benefit of the system. You need to work with different people for the development of the system: e.g. technical people and specialists on human factors need to work together. So system development life cycle requires alteration at least for socio-technical system.
Is the method shown in figure 7.3 beneficial for the inclusion of social requirements in infrastructures systems' development?	Yes, but a loop is missing. You have social requirements you build in then you have to test to find out if this is what they really wanted. The 4-stage is a good 1st step; we should have started with this step that you are proposing. But pilots for verification are a good idea before the roll out.

Is the system development lifecycle of ICT-Intensive critical infrastructure systems (e.g. smart meters) the same as that of IT systems? Do you see the need to rethink it? (Figures 7.1 and 7.2)	There is a difference, because socio-technical systems are complex systems. With major goals that have to be solved with the same product. Usual IT development is about making PC faster, lighter and cheaper and user friendly. The real goals of the system owner need to be incorporated in the system development. Goals of system user need to be taken into consideration. There is a distinction between the developments of the two types of systems.
Should grid operators address the issue of the public perception of their image to familiarize the public with the organization and increase the awareness regarding their offered services, despite the non-competence nature among them?	Enexis is working on it. They should of course. Based on the fact that when people do not know you they won't let you in their homes. We are working on reputation; it is difficult for the marketing department to make clear what the added value of the marketing department is within Enexis. The awareness is increasing within the organization because it is necessary. They are investing in the media to sell their image. Making movies for information on YouTube, to explain the companies and their projects. No TV commercial. Newspapers yes, TV programs exposure.

Interviewee: David Kramer

Affiliation: Ministry of Economic Affairs
Title: Senior Policy Advisor, Project Leader Smart Metering The Netherlands
Date of interview: 28-08-2012

Question	Interviewee's Answer
Is public acceptance of smart meters a crucial matter?	In The Netherlands it is important. 2008 -2009 witnessed more a market driven approach. Consumentenbond, Eerste Kamer raised consumer concerns. We realized we needed to make consumers central in our following approach. After the delay we changed to voluntary approach, introduce the meters and it's working out well. It took 2 years to get everyone on board to rebuild trust and embed the principle of thinking from consumer perspective in a proper way. We organized round tables mainly around consumers' topics. It has influenced our approach towards smart meters in The Netherlands.
Is addressing acceptance during early stages of systems' development (Before implementation) important?	During early stages I think that 2 steps are important: there needs to be societal acceptance mainly by media and societal debate. 2nd, acceptance by consumers as individuals and that is something different, because when a consumer finally decides it is not at the moment of the political decision making but at the moment when he has to make a choice at the moment that the meter is offered.
Would acceptance determinants be different per system/ per society? Would common determinants have different influence based on system and society?	Yes. That is very interesting for me from a government perspective. After the delay, it seems that we handled it quite well, but would it be good for other countries? No idea.
Do you think it is important to understand the process of acceptance? (i.e. how factors influence acceptance and incur change in consumer behavior)	Important for companies deploying the system. Government needs general overview of acceptance factors. There is research but companies differ in their approach. Some companies undertook simple research, but doesn't give a comprehensive view.

Is acceptance partially responsible for the drop of the business case from 1.33 B euros in 2005 to 770 M euros in 2010? (according to KEMA cost-benefit analysis reports in 2005 and 2010)	The difference is that rollout was introduced on voluntary basis, voluntary basis is the cause. What is limited in the societal cost-benefit analysis are the factors that are difficult to quantify. How do you quantify freedom of choice as social benefit? You say that the business case has dropped, but has it? I think freedom of choice is worth a lot, so we value it very greatly. But there are other aspects not considered, which are very hard to quantify. The cost side is much more easy to quantify than the benefits. Not putting consumers as a focal point is partially the reason for the change, maybe it could have been avoided. We learnt and made a big change: from compulsory to voluntary. We shall never know it but if we would have developed the system much more together with consumers maybe it would have not been necessary to choose for voluntary approach. Or maybe for partly voluntary. But Voluntary approach is not the only cause of a lower business case, cost of the meter and other price index....and others. There are positive and negative factors. Details are listed in the KEMA 2010 report.
Are social requirements predictors of smart metering acceptance?	It depends greatly on cultural and technological backgrounds and existing societal challenges whether they are predictors. Health effects in the US are much more sensitive in the society than The Netherlands, it does not mean it is not an issue in The Netherlands but it is relatively a smaller issue in The Netherlands than privacy and security. It does not mean we do not do anything about health but in other society privacy is not an issue, in Italy people are happy to have a smart meter because it prevents fraud. I think to a certain extent they can be predictors but also take into account societal factors. The way these acceptance determinants would behave is dependent on society and system. It might be quite difficult to find out all social requirements that have a certain impact.
Is the inclusion of social requirements important for socio-technical systems (e.g. smart meters)?	Yes, when technologies are so close to consumers, social requirements are important. A smart meter is a very close technology to consumers as it resides inside their homes. For example: medical records project was paused. We have to learn from other projects but we have to understand that it’s hard to avoid making mistakes. To a certain extent we need to accept risks.
Can accounting for social requirements in systems’ development save resources by avoiding the need for retrofits or	Yes and no. Yes, it can save resources. No, it can cost a lot of time, and time is valuable. Hard to give a general answer

redesigning of the system? (e.g. wired/ wireless HW	
Do you agree that the government should invest in promotion campaigns among the society to promote smart meters?	No, with a very small maybe. Technology push can call resistance. I don't think it is necessary in the Dutch society, people care very much about their personal freedom of choice. They do not need the government to tell them what to do. But campaign is just for letting people know. I do not think it is needed as broad campaign, information has to be there and available, as objective as possible and at a more individual level, so what we did was design a brochure and a website www.watisdeslimmemeter.nl, this is a passive and not an active promotion. What we see is that parties introducing smart meter are making use of this information by copying it for example in their own brochures. We tried to write it as impartially as possible, it’s very difficult because of course we have preference, that’s why we asked a consumer panel to check it. Maybe for a large scale out roll small forms of mass media could help but really a small maybe and only with information needed from consumer perspective.
Would system development lifecycle need to be altered to account for the emergent class of social requirements, such as avoiding adverse effects on health, security and privacy…etc?	Difficult question. We tried to do it, but is it necessary? You cannot foresee all risks, so what’s necessary is a system that is able to integrate changing demands. Usually society can accept it when something is not completely good. Society acknowledges that it is not a perfect solution. [Example] When government found out that some materials of buildings can cause cancer, there's a program to replace it. It’s being replaced slowly with care and society accepts that. You can also try to make a system that can be changed during its lifetime, we try to do that with smart meters we have the communication module that is planned to have the ability to have it replaced because we think within time communication technology will change and security demands will become higher and if you can change the communication module, it has higher flexibility. It’s very difficult to predict if this is the right choice to do right now, maybe it’s an extra cost for society and we are never going to use this flexibility. Yes, what is done now as a result of privacy debate, that we have round tables with all kinds of societal demands being discussed. It is still very close to technological process; from my perspective it could be much better if you include consumer perspective much more in this process. There is a problem there: there are not many consumers with an opinion, and there are not so many consumer organizations

	that have enough capacity to be involved in this process and have a balanced, thorough opinion, so there is a problem in how to involve consumers in the right way. There’s not one simple method to involve them.
Is the method shown in figure 7.3 beneficial for the inclusion of social requirements in infrastructure systems’ development?	Hard to react now. I can only name a few aspects that come to mind when I see it: It is much easier to ask society what it wants when the subject is discussed already. For smart meters of course the first approach was not the best, but the 2nd approach was easier because people already have had exposure to the topic. If people do not know what something is it’s difficult to ask them whether they want it or not, or what demands they have from this product or service. As for the use of a survey that's not easy to say because in the ministry we are expanding our ways to reach society, we do that in steps, maybe also social media or other ways of reaching society could help, but we're in early stages of exploring social media.
Is the system development lifecycle of ICT-Intensive critical infrastructure systems (e.g. smart meters) the same as that of IT systems? Do you see the need to rethink it? (Figures 7.1 and 7.2)	I think they are quite similar. The introduction of IT-systems in general should be developed in a more iterative way with societal organizations and consumers.

Summary

Critical infrastructures are a class of systems that deliver a spectrum of essential services to members of society across different vital sectors, such as energy and transportation. Infrastructure systems reside and operate within a multi-actor context, which contributes to their complexity and brands this class of systems as socio-technical. In addition to that, there has been a massive and on-going development in information and communication technologies over the past decades, which led to the emergence of state-of-the-art ICT infrastructures facilitating the manipulation, storage and transportation of enormous volumes of data and information. Ensuing from this, was an evolution of infrastructure systems as they incorporated novel ICT infrastructures as a backbone supporting the operation and services infrastructure systems deliver to society. This brought many advantages, such as a wider range of services offered to society with higher efficiency and more interaction with consumers. The latter feature, however, greatly added to the overall complexity of these systems. Examples of ICT-intensive infrastructures are the electronic medical records system in the health-care sector, smart metering in the energy sector - which aims to increase consumers awareness of their energy consumption - and the OV-Chipkaart system in the transport sector, which is the Dutch public transport electronic card, allowing travelers to check-in and out of public transport vehicles using their electronic cards, thus eliminating the need for paper tickets.

In the Netherlands, the initial attempts to introduce a number of ICT-intensive infrastructure systems – such as the smart metering and OV-Chipkaart - failed, raising a substantial amount of negative attention in the media. The deployment of both systems has been delayed due to two major problems with both systems: the privacy and security of the information generated and maintained by both systems. There was a lot of concern that the privacy of the smart-meters users as well as travelers can be at risk. In principle, it was possible in the first stage of the system introduction to get access to data of smart meters and on cards of passengers checking in or out. It was also possible to break the security systems to tamper with the amounts of payment due. It should be stressed that such vulnerability - among others - was caused by the design and development of such systems in isolation of esteemed public values of society and consumers as primary users of these systems despite the fact that consumers' utilization of these technologies is a cornerstone for their success. Ultimately, this resulted in the lack of social acceptance of these innovative systems, which in turn hindered their deployment and obstructed the fulfillment of their goals.

To overcome the aforementioned limitations and ensure a higher level of social acceptance of ICT-intensive infrastructure systems and services, a consumer-centric design is of the essence. This approach can be achieved by exploring public opinion and values of a society, and translating the findings into a new class of system requirements, i.e. social requirements, which accounts for criteria that society deems necessary to be satisfied. Social requirements must be addressed from the early stages of system design alongside functional and non-functional system requirements. The elicitation of social requirements is not a straightforward process, and is more challenging than the elicitation of functional and non-functional

requirements. The cause of the difficulty in social requirements elicitation is that they are obtained from the society, as opposed to functional and non-functional requirements that are normally provided by technology developers, system owners and operators.

In this thesis, the Acceptance-by-Design framework is presented, which encompasses a novel process of social requirements elicitation and verification. The framework supports a consumer-centric design approach of ICT-intensive infrastructures, to yield systems with a high level of social acceptance. The elicitation of social requirements begins with investigating acceptance determinants, i.e. factors that could influence society's willingness to accept a technology. Detailed investigation of the smart metering and OV-Chipkaart systems as two case studies of this work in light of existing theories and models throughout the technology acceptance literature, proved such theories to be insufficient for ICT-intensive infrastructure systems, as they fail to address unique properties that distinguish infrastructure systems from conventional IT systems. For example, as these infrastructures are part of the daily lives of society members, they are perceived as invasive in individuals' private lives. This also implies prolonged periods of exposure to these technologies throughout the day as opposed to IT systems that exist in a work place, for example. Thus, to investigate social acceptance of ICT-intensive infrastructures, a hybrid model was devised from two well-known theories in the technology acceptance literature: the Unified Theory of Acceptance and Usage of Technology (UTAUT) and the Innovation Diffusion Theory (IDT). The hybrid model was further extended into the novel ICT-Intensive Infrastructure Service Systems model (I^3S^2), to contribute to a deeper understanding of the mechanisms for the acceptance and use of the ICT-intensive systems. Additions to the hybrid model consist of additional acceptance determinants derived from the context of two case studies; the smart metering system in the energy sector, and the OV-Chipkaart system in the transportation sector. The determinants represent new inherent characteristics of these systems that emerged as a result of a systems' reliance on ICT. In addition, the determinants also represent public values of society that can potentially be influenced by the introduction of the new systems, such as the right to privacy, an adequate level of information security, and the implementation of safe technologies that do not pose health threats to society members. Therefore, the elicitation of acceptance determinant requires not only a thorough investigation of the technology to be developed, but at the same time of the society in which it is intended to be deployed, which makes the elicited determinants system and society-unique. Social media, interviews, news articles, and activists' blogs can provide clues to a comprehensive understanding of societies' reactions to novel socio-technical systems.

Initially, all acceptance determinants in the I^3S^2 model were assumed to have a significant positive or negative influence on acceptance, which was presented in a causal relationships diagram. Next, to estimate the model, public opinion regarding the elicited acceptance determinants in the context of the smart metering case study was obtained via an online survey. The survey was designed by mapping each acceptance determinant - such as: Perceived Security and Privacy Risk- into a set of questions. Following survey administration, the acquired sample was statistically analysed to test the predicted influences in the causal relationship diagram of the acceptance determinants on society's willingness to accept smart meters. This process resulted in a revised I^3S^2 model that depicted the empirically supported influences among the determinants. Remarkably, the resulting model not only falsified many of the hypothesized relationships, but it also revealed influences among the acceptance determinants that were not initially anticipated in the original I^3S^2 model. Furthermore, the significance of some anticipated and empirically supported influences was rather surprising. For example, the perceived security and privacy risks were anticipated to rank as the most significant predictor of smart meters acceptance. However, empirical evidence showed that this determinant ranked second in significance after the performance expectancy determinant, which denotes the degree to which consumers believe that using a smart meter will help them attain gains in their lives. Fundamentally, the findings presented in the resulting model were translated into social requirements – e.g. Perceived Security and Privacy Risks, and Performance Expectancy among others. Moreover, recommendations regarding both significant and insignificant acceptance predictors were given accordingly to relevant actors, such as policy makers, systems owners and developers.

The Acceptance-by-Design framework represents a generic process that aims to support the development of ICT-Intensive infrastructure systems. System owners and designers should align the framework with the overall systems' development lifecycle as a standard and integral part, so as to ensure a higher level of social acceptance, safeguard the fulfilment of the system goals, and avoid resource-consuming retrofits that in worst case scenarios could lead to the redesign and reimplementation of the entire system. Furthermore, the framework signifies a contribution to the acceptance of ICT-intensive infrastructures emerging body of literature. Yet, there is still a pressing need to exert further research efforts in this field to explore possible refinements to the framework, and discover alternative methods for the elicitation and verification of social requirements.

Samenvatting

Cruciale infrastructuren behoren tot een klasse van systemen die een palette van diensten leveren welke van essentieel belang zijn voor het functioneren van de samenleving. Voorbeelden van dergelijke systemen zijn te vinden in de energiesector en in de transportsector. Infrastructuur gerelateerde systemen maken deel uit van, en functioneren in, een multi-actor context. Daarnaast zijn deze systemen veelal gebaseerd op wijd verbreide technologie. Deze eigenschappen maakt dat infrastructuur gerelateerde systemen als sociaal technische systemen kunnen worden aangemerkt.

Omvangrijke en nog steeds voortgaande ontwikkelingen in informatie en communicatie technologie gedurende de afgelopen decennia hebben geleid tot ICT infrastructuren die het gebruik, opslag en transport van grote hoeveelheden data en informatie mogelijk maakt. Dit heeft geleid tot de ontwikkeling van geheel nieuwe, op ICT gebaseerde, infrastructuren die voor het functioneren van de samenleving steeds belangrijker zijn geworden en waarbij de afhankelijkheid van deze systemen almaar is toegenomen.

Deze ontwikkelingen hebben vele voordelen gebracht zoals een breed portfolio aan diensten voor consumenten met toenemende efficiëntie. Het leidde echter ook tot een veel grotere complexiteit van deze systemen vanwege een toenemend aantal interacties en de daarvan afgeleide transacties. Voorbeelden van dergelijke ICT-intensieve infrastructuren zijn het elektronisch patiënten dossier in de gezondheidzorg, slimme meters in de energiesector bedoeld om de consument meer bewust te maken van zijn energiegebruik, en de Nederlandse OV-chipkaart in de transportsector die de papieren kaartjes vervangt.

De introductie van deze ICT-intensieve infrastructuren is geen sinecure, zowel de slimme meter als de OV-chipkaart kenden een moeizame start door onjuiste inschatting van socio-technische aspecten. Met als resultaat veel negatieve aandacht in de media en daardoor een initieel lage acceptatie bij de introductie. De ingebruikname van beide systemen werd aanzienlijk vertraagd vanwege problemen met de privacy en de beveiliging van de onderliggende, veelal persoonsgebonden, informatie. Zo was er behoorlijk wat ongerustheid over de privacy zowel bij slimme meter gebruikers als bij reizigers die de OV-chipkaart gebruiken. In principe bleek het mogelijk om in de eerste fase van introductie toegang te verkrijgen tot de gegevens in de slimme meters en tot de gegevens van passagiers die in- en uitcheckten met de OV-chipkaart. Ook bleek de bescherming van financiële informatie niet waterdicht en waren de systemen derhalve kwetsbaar voor manipulatie. Hierbij wordt opgemerkt dat deze kwetsbaarheden grotendeels werden veroorzaakt doordat bij het ontwerpen en ontwikkelen van deze systemen niet in voldoende mate rekening gehouden is met maatschappelijke voeling, ondanks het feit dat consumenten deze diensten vanuit een functioneel perspectief als zinvol ervaren. Dit heeft uiteindelijk geleid tot onvoldoende acceptatie van deze innovatieve diensten met als resultaat dat de beoogde maatschappelijke voordelen niet behaald werden.

Om de maatschappelijke voordelen voor de consument te kunnen behalen middels brede acceptatie van deze innovatie diensten met de juiste privacy- en beveiligings-aspecten, is een consumentgericht ontwerpproces essentieel. Hiertoe is onderzoek uitgevoerd naar maatschappelijke gevoelens, waarden en opinies. Deze zijn vervolgens gebruikt om eisen te formuleren voor de architectuur van de ICT-intensieve infrastructuren die nodig geacht worden voor innovatieve diensten gebaseerd op de slimme meter en de OV-chipkaart. Op deze wijze wordt tegemoet gekomen aan de maatschappelijke wensen met betrekking tot privacy en informatiebeveiliging. Deze socio-technische aspecten dienen in een vroeg stadium bij de systeemontwikkeling als randvoorwaardelijk meegenomen te worden. Het internaliseren van met name sociale aspecten is geen rechttoe-rechtaan proces. Het omvat meer dan de lineaire opzet van functionele en niet-functionele systeemeisen. Het incorporeren van de sociale aspecten wordt bemoeilijkt omdat deze uit de maatschappij moeten voortkomen in tegenstelling tot functionele en niet-functionele systeemeisen, die gewoonlijk door ingenieurs en systeemontwerpers worden ontwikkeld.

Dit proefschrift presenteert een Acceptance-by-Design framework (Ontwerpen-op-Acceptatie raamwerk), een nieuwe benadering voor het ontwerpen van ICT intensive infrastructuren waarbij sociale aspecten intrinsiek meegenomen worden in het gehele proces. Dit raamwerk ondersteunt een consumentgerichte ontwerpbenadering voor ICT-intensieve infrastructuren met als doel een hoog niveau van maatschappelijke acceptatie.

Deze benadering start met het onderzoeken van de factoren welke van invloed kunnen zijn op de maatschappelijke acceptatie van een bepaalde technologie. In dit proefschrift wordt deze benadering ontwikkeld aan de hand van twee case studies - de slimme meter en de OV-chipkaart - in het licht van bestaande theorieën en modellen binnen de technology acceptance literatuur. Gedetailleerd onderzoek bracht naar voren dat deze theorieën niet in voldoende mate bruikbaar waren voor ontwerpen van ICT-intensieve infrastructuren met een grote maatschappelijke impact, voornamelijk omdat deze theorieën geen rekening hielden met de unieke eigenschappen die deze infrastructuursystemen onderscheiden van conventionele IT-systemen. Een belangrijk verschil is dat de twee onderzochte ICT-intensieve infrastructuren betrekking hebben op het dagelijks leven van burgers, en daarmee als bedreigend en invasief kunnen worden ervaren, in tegenstelling tot andere IT systemen die beroepshalve gebruikt worden. Mensen hebben vaker te maken met de slimme meter en de OV-chipkaart dan bijvoorbeeld met een IT-systeem op hun werk. Teneinde de maatschappelijke acceptatie van ICT-intensieve infrastructuren te onderzoeken is er een hybride model ontworpen dat gebruik maakt van twee uit de literatuur bekende theorieën - de Unified Theory of Acceptance and Usage of Technology (UTAUT) en the Innovation Diffusion Theory (IDT). Het hybride model werd vervolgens uitgebreid tot een nieuw ICT-intensief infrastructuur-service-systeemmodel (I3S2), hetgeen heeft geleid tot een beter begrip van het mechanisme voor de acceptatie en het gebruik van ICT-intensieve infrastructuren. De uitbreidingen van dit hybride model betreffen extra acceptatiedeterminanten afgeleid uit de twee genoemde case studies.

De determinanten betreffen nieuwe inherente systeemkarakteristieken die naar voren kwamen als resultaat van de afhankelijkheid van ICT-intensieve infrastructuren. Verder betreffen de determinanten publiek maatschappelijke waarden die mogelijk beïnvloedbaar zijn door de introductie van de systemen zoals het recht op privacy, een adequaat niveau van informatiebeveiliging, en veilige en betrouwbare technologieën, die niet bedreigend zijn voor de gezondheid en het welzijn van consumenten. Het vaststellen van acceptatiedeterminanten vereist niet alleen grondig onderzoek naar de techniek zelf maar tegelijkertijd ook naar de maatschappij waarin deze techniek zal worden ingezet. Om deze reden moeten de determinanten toegesneden zijn op het systeem én op de maatschappij, derhalve een socio-technische benadering. Sociale media, interviews, krantenartikelen, en blogs van activisten zijn bijvoorbeeld bronnen die informatie kunnen leveren over hoe een maatschappij zal reageren op nieuw sociaal-technologische systemen.

Aanvankelijk werden alle acceptatiedeterminanten in de I3S2 model verondersteld een positieve of negatieve invloed te hebben op acceptatie hetgeen in een causaal relatiediagram werd gepresenteerd. Om het model te testen zijn vervolgens de voorgestelde acceptatiedeterminanten in de context van slimme meters onderzocht middels een online enquête. De uitkomsten van deze enquête vormden de grondslag voor het selecteren en verder aanscherpen van acceptatiedeterminanten om te komen tot een model waarmee de maatschappelijke bereidheid om slimme meters te accepteren vastgesteld kan worden. Dit proces resulteerde in een nieuwe versie van het I3S2 model dat de empirisch gevonden invloeden tussen de determinanten representeert.

Opmerkelijk is dat het nieuwe model niet alleen veel van de vooraf veronderstelde relaties ontkrachtte maar ook invloeden onthulde tussen de acceptatiedeterminanten, die niet waren voorzien in het I3S2 model. Voorts bleek het belang van sommige verwachtte en empirisch ondersteunde invloeden discutabel. Bijvoorbeeld, verwacht werd dat de belangrijkste voorspeller van de acceptatie van slimme meters de waargenomen veiligheids- en privacy-risico's zouden zijn. Empirisch gevonden bewijs liet echter zien dat deze determinant minder belangrijk was dan de performance expectancy determinant oftewel de mate waarin consumenten geloven dat er voordelen te behalen zijn bij het gebruik van slimme meters.

De resultaten verkregen met het nieuwe I3S2 model vormen de grondslag voor het formuleren van maatschappelijke eisen/randvoorwaarden waaraan voldaan dient te worden voor de acceptatie van ICT-intensive infrastructuren. Verder zijn er uit dit onderzoek aanbevelingen gekomen over significante en niet-significante acceptatie-voorspellers voor beleidsmakers, handhavers, systeembeheerders en ontwikkelaars. Het Acceptance-by-Design framework betreft een generiek proces om de ontwikkeling van maatschappelijk acceptabele ICT-intensieve infrastructuren te ondersteunen.

De toepassing van het Acceptance-by-Design framework in de gehele ontwikkelingscyclus van ICT-intensieve infrastructuren zal leiden tot een grotere maatschappelijke acceptatie. Hiertoe dienen ontwerpers en systeembeheerders, naast beleidsmakers en handhavers, deze methodologie zo vroeg mogelijk in het ontwerp mee te nemen. Het zou dure retrofits of in het slechtste geval het mogelijk herontwerpen en herintroductie van het complete systeem kunnen voorkomen. Daarnaast levert het Acceptance-by-Design framework een bijdrage aan de toenemende hoeveelheid bruikbare literatuur over de acceptatie van ICT-intensieve infrastructuren. Niettemin zal er wellicht nog een flinke research inspanning nodig blijken te zijn voor de verdere verfijning van het Acceptance-by-Design framework, en om alternatieve methoden voor de maatschappelijke acceptatie van socio-technische systemen te ontdekken.

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