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Assessing the effects of a public Wi-Fi network on the digital divide
quantifying benefits of e-government services

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Assessing the effects of a public Wi-Fi network on the digital divide:

Quantifying benefits of e-government services

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Summary

Since the early 2000s, internet and online services have become more widespread through society. Together with this development, a new field of research has been emerging, studying the digital divide: inequalities in digital access, use and benefits. The digital divide has not only concerned researchers, but "bridging" the digital divide (i.e. overcoming digital inequalities) has also been a growing subject in public policy. A multitude of different policies have emerged over the years, one of which is the promotion of free (public) Wi-Fi networks to connect citizens to lower the threshold for citizens to connect to the internet.

This thesis aims at exploring the extent to which public Wi-Fi networks are a vehicle to overcome the digital divide, thereby reflecting on the efficiency of Wi-Fi policy initiatives. It does so by identifying network costs and network benefits, the latter in the form of e-government benefits. E-government services are defined as the use of ICT by the government for the provision of services. In this thesis, the focus has been on government-to-citizen e-government services. E-government services have been selected as a source of benefit because they are named as a potential source of benefit by both researchers and policymakers, and by virtue of them directly affecting the citizens which are the intended users of public Wi-Fi networks and the ability to use them mobile (also referred to as m-government).

In the reflection on the ability of Wi-Fi to aid in overcoming the digital divide, three different subquestions are studied. First, the private and public value of a Wi-Fi network is studied by modelling costs and benefits associated with Wi-Fi and e-government use through Wi-Fi. Second, the influence of existing connectivity opportunities is studied by comparing the socio-economic contexts of different countries. Last, the influence of digital skills is studied, also by comparing the socio-economic contexts of different countries. These three subquestions are used to reflect on both the effectiveness of public Wi-Fi as a policy tool, as well as the socio-economic factors influencing that effectiveness. The questions posed will be answered with the help of an extensive literature study and a cost-benefit model.

The literature has defined the digital divide as the inequality in access to, use of and/or benefits associated with digital technologies, which are also referred to as the three levels (access, use and benefits) of the digital divide. While this definition is well established, a slightly different definition has been adopted for this study on the level of access. By defining different forms of access (fixed broadband, mobile broadband and hot-spot based access) as complementary rather than substitutive, the access divide is re-defined as the inequality in access opportunities. This re-definition has also opened up the opportunity of studying the effect of available connectivity alternatives using scenarios.

Digital divide literature has shifted over time from inequality in access to inequality in use, and the inequality in use has also been incorporated in this thesis' model. It has been shown that income, education levels and digital skills are the most important predictive factors of internet use and e-government use. Therefore, these factors are included in the model as predictive factors of the use of e-government in different user types, and the effect of digital skills is further explored by testing different scenarios.

Previous literature on e-government has not only focused on factors influencing use but also on theoretical benefits, generally without concrete empirical evidence or quantification of these benefits. These theoretical benefits have, when possible, be quantified and included in the cost-benefit model. Thereby, this thesis contributes to existing research by quantifying the potential benefits.

Previous studies on Wi-Fi have primarily focused on a techno-economic perspective (e.g. business models, technical requirements) and socio-economic and socio-demographic characteristics influencing network use. Evaluation of the value of Wi-Fi networks has primarily been done by reflecting on the number of users and the perceived usefulness of the network. This thesis aims to add to this by quantifying both network costs and network benefits as a tool for evaluating value.

Based on the review of the literature, a model of costs and benefits is created following the cost-benefit analysis method. Within this model, an attempt was made to include the socio-economic complexity of differences between users by introducing different user types, based on the access opportunities available to each user. Scenarios have been used to reflect on the influence of different socio-economic contexts and compare these socio-economic contexts. A reflection on the sensitivity of this model is done by sensitivity testing and a probabilistic risk assessment in the form of a Monte-Carlo simulation, to test the robustness of the model and sensitivity to data assumptions.

The model of Wi-Fi network costs is based on basic network components and basic operational costs. The basic components of the network are defined to be: the access points, a switch controller, a PoE injector, and wiring & support for the network equipment. Costs of these were assessed by comparing different products of similar characteristics in the public market, and installation costs were taken as a portion of equipment costs. Costs of maintenance and replacement over the lifetime of the project are based on an equipment lifetime of five years. Other operational costs included in the model are the costs of the backhaul connection (internet subscription), electricity costs and costs of network management.

To evaluate the benefits in terms of e-government, in order to reflect on the extent to which Wi-Fi can have a role in overcoming the digital divide, e-government benefits are quantified. Only those benefits that could reasonably be quantified have been included. The initial quantification of benefits leads to a level of potential benefits, assuming the e-government services are used and used successfully. These potential benefits are reduced to expected benefits by including the notion that not every person uses e-government and that use of e-government is not always successful.

The initial results of the model, based on empirical data from the area of the European Union (the EU-28 area), suggest that while the private value of a Wi-Fi network is negative, the public value is positive. However, it should be noted that the latter is depending on the degree to which e-government benefits are attributed to the use of the Wi-Fi network, as attributing a low amount of expected e-government benefits to the use of the Wi-Fi network will result in a negative public value. Other variables with a high potential influence on public value are the amount of realized network users, the value of time and the amount of time saved, and the degree to which e-government services are used.

In order to understand the influence of connectivity alternatives, different scenarios were created. In each of these scenarios, the socio-economic context of a different country was included in the model. To evaluate the influence of connectivity alternatives, comparisons are made between countries with different connectivity rates but similar levels of use of e-government services. These comparisons show that in countries with lower connectivity rates (regardless of whether this is a lower mobile connectivity rate, fixed connectivity rate of both) the expected value of a Wi-Fi network is higher. However, when all countries are compared irrespective of their level of e-government use, the difference between countries with different fixed connectivity rates disappears, and only a small effect of mobile connectivity rates remains. This suggests that the effect of connectivity alternatives is offset by the difference in e-government use, which is associated in literature with the levels of internet use.

In order to understand the influence of digital skills, a second set of scenarios was created. A first way of evaluation was to compare countries with similar digital skills, irrespective of their connectivity rates of e-government use. This comparison showed that there is no clear relation between the level of digital skill and the expected value of a Wi-Fi network. A second evaluation was done by comparing countries with fixed and mobile connectivity rates (and thus available connectivity alternatives) with different digital skills. This shows that digital skills do have some predictive value for the value of a Wi-Fi network.

This thesis concludes that a Wi-Fi network can be expected to have a positive public value if enough e-government use can be attributed to it. This public value suggests that Wi-Fi can be used as a complementary policy tool for overcoming the digital divide, because Wi-Fi provides people with an additional way of accessing the internet and thereby achieve potential benefits. The extent to which Wi-Fi is successful depends on contextual factors such as existing access opportunities and digital skills of the population.

However, in interpreting the results and the conclusion, there should be awareness of the fact that the model made for this thesis is limited in scope, and based on both assumptions and indirect data. These (data) assumptions have in part been tested by sensitivity testing, and are theorized to either lead to an overestimation or an underestimation of public value. The uncertainty in the model's results limits the conclusion, in a sense that it is still impossible to pinpoint the exact public value of a Wi-Fi network, nor can be concluded with absolute certainty that a Wi-Fi network will have a public value. This does not, however, change the conclusion that a Wi-Fi network can be used as a vehicle for overcoming the digital divide because it is still expected to enable some users to achieve potential benefits they cannot achieve without it.

The main recommendations for further research primarily include recommendations for future empirical studies on the use of e-government, e-government benefits and the use of Wi-Fi networks. The lack of empirical data in these fields was the main cause of limitations in this thesis, a better understanding of these subjects could aid further developments of e-government services as well as help understand the potential impact of Wi-Fi networks and the most optimal use of them.

In reflecting on the extent to which a Wi-Fi network can be successful in overcoming the digital divide, an implicit policy recommendation is formed concerning public Wi-Fi initiatives. As the public value of a Wi-Fi network is considered to be positive, the main policy recommendation is to continue using these networks complementary to other forms of connectivity policy (e.g. broadband). Furthermore, this thesis also stresses the importance of developing digital skills in the population and developing e-government services, and thereby not only focus on providing access but also enabling beneficial use of online services.

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1 Introduction

Since the beginning of the 21st century, connectivity and ICT implementations have been increasingly important subjects for both researchers and policymakers. The combination of ICT services and connectivity is often researched in the context of the digital divide, the difference in the access to and use of the Internet (and ICT) between people. The digital divide is especially important in the digitization of services and information, which is also referred to as e-services because it might further increase inequalities.

E-government is a specific e-service. A general and broad definition of e-government is the use of ICT (information and communications technologies, i.e. the Internet and connected services) by government agencies for providing information and services (Bonson, Royo, & Ratkai, 2015; Huang & Bwoma, 2003; Muir & Oppenheim, 2002; Weerakkody, Irani, Lee, Osman, & Hindi, 2015). Some authors perceive e-government to be part of digital government (Alarabiat & Ferreira, 2018), whereas others see digital government and e-government as the same thing (Brown, 2007). While e-government has traditionally taken the central national government as its focal point, it can also apply to local governments, or international organizations (e.g. United Nations) and agencies (e.g. the European Union) (Muir & Oppenheim, 2002).

E-government is seen by both scholars and policymakers as a tool for increasing the efficiency, effectiveness and possible uses of various government services. The effects of e-government are said to be: increased accountability and transparency, less corruption, greater convenience for citizens, decreased costs of using government services, increased citizen involvement, decreased information asymmetry, increased collaboration across government agencies, greater efficiency and effectiveness, revenue growth, and cost reduction (Alarabiat & Ferreira, 2018; Brown, 2007; Gilbert, Balestrini, & Littleboy, 2004; Huang & Bwoma, 2003; Khan, Yoon, Kim, & Park, 2014; Bonson et al., 2015; Weerakkody et al., 2015). However, these effects are difficult to make explicit, since some are intangible, multi-dimensional and/or often suffer from measurement problems (Seri, Bianchi, & Matteucci, 2014) and still subject to debate (Alarabiat & Ferreira, 2018). This is reflected in a scarcity in publications addressing the impact of e-services, especially e-government services (Arduini & Zanfei, 2014).

Even though e-government is very promising in terms of potential benefits (albeit hard to quantify), it often fails to fulfill this promise. There are four different barriers to the successful use of e-government services: awareness of the existence and potential of government e-services, usefulness of the system (ease of use, enjoyability and reliability), trust (confidentiality and safety) of the system, and the ability of people to access the e-services (Dombrowski, Hayes, Mazmanian, & Voida, 2014; Gilbert et al., 2004). Governments try to overcome these barriers by improving the design of the e-government services, promoting the use of e-government services, and facilitating connectivity of people. The challenge of connectivity as a barrier for e-services (and many other online activities) is also referred to as the digital divide and will be the main focal point of this thesis regarding the use of e-government services.

The digital divide can be described as the inequality between countries, regions and socio-economic groups in ICT investments, skills and/or availability and is often related to the economic status of a country or region (Kyriakidou, Michalakelis, & Sphicopoulos, 2011; Prieger, 2013). Scholars have worked with different levels or stages of the digital divide: (1) inequality of Internet access and (2) inequalities of Internet usage or skills to use the Internet (van Dijk, 2017; Yu, Ellison, McCammon, & Langa, 2016). van Deursen and Helsper (2015) have defined the third stage of the digital divide, which centres around the results of Internet usages, focusing on inequality of benefits and costs.

In order to bridge the digital divide, there are many national and international policies. One such policy is the Digital Single Market policy of the European Union, adopted by the European Parliament in May 2015 as part of the Digital Agenda for Europe. The main objective of this policy is to create inclusive growth, inclusive society, opportunities for citizens and businesses, and bridging the digital divide (European Commission, 2017a). One of the initiatives within the Digital Single Market policy focuses on mobile connectivity through Wi-Fi networks (the WiFi4EU initiative). And it is not just this one EU initiative, municipal Wi-Fi networks (MWNs) are often deployed to bridge the digital divide and increase access to digital (public) services (Picco-Schwendener, Reinhold, & Cantoni, 2017). Italy (WiFi Italia it, n.d.), Portugal (GoWi-Fi, 2018), Qatar (Al-Shafi & Weerakkody, 2008) and Malta (Malta Communications Authority, 2016) all have their own initiative for Wi-Fi networks. Throughout these initiatives, enabling access to e-government and other e-services is one of the goals (see European Commission, 2017b, 2018; Picco-Schwendener et al., 2017).

The different policies to promote connectivity for all people (bridging the "access" digital divide, or first level digital divide) are aimed at general socio-economic effects related to the deployment of Internet networks and the use of e-services (Gruber, Hätönen, & Koutroumpis, 2014; Lannoo et al., 2008; Prieger, 2013; Raman & Chebrolu, 2007; Stocker & Whalley, 2018; van der Wee, Verbrugge, Sadowski, Driesse, & Pickavet, 2015). The fact that connectivity is such a large topic for public policy, suggests that there is a public value (i.e. indirect benefits) to connectivity that will (together with the direct benefits) outweigh the direct and indirect costs of the deployment of networks. Similarly, Prieger (2013) states that if connectivity would only be beneficial on a private level (e.g. investment, or personal gain leading to a willingness to pay), it would not be a policy issue.

Although these policies focus on providing access to the Internet and thereby enabling citizens to use e-services, the existing literature shows that this is not effective. (Municipal) Wi-Fi networks are used less than anticipated (Lambert, McQuire, & Papastergiadis, 2018; C. A. Middleton, 2007; Picco-Schwendener et al., 2017), and might not even benefit those that suffer most from the digital divide (C. A. Middleton, 2007). The limited usage of the network is hypothesized to be related to the quality of the available network, the location of deployment, the ease of using the network, or a lack of resources (access equipment and knowledge) (C. A. Middleton, 2007).

The effectiveness of Wi-Fi and e-government use depends on a multitude of factors. Factors like education, age, income (Ferro, Helbig, & Gil-Garcia, 2011; T. E. Hall & Owens, 2011; Yu et al., 2016) are important, but also the willingness to adopt influences whether people will use e-services (Weerakkody et al., 2015), and demographics (even in equal socio-economic circumstances) influence the chance of using e-participation tools (Vicente & Novo, 2014). It is important to understand the factors influencing the access to and use of e-governments services and other services, as core societal functions are increasingly becoming digital, or even digital-only, and inequalities in access and use of e-services will thus have a growing impact in people's lives (Reisdorf & Groselj, 2017a; Sathiaseelan et al., 2014).

This thesis will focus on free public Wi-Fi networks (hotspot-based) to enable internet connectivity in municipalities by reflecting on their potential to overcome the digital divide and create economic value from the use of e-services by looking at the e-government sector specifically. The reasons for choosing e-government as a driver for economic value are that 1) e-government services have the potential to create value directly for citizens, who are the target users of public Wi-Fi networks, in contrast to other new services like e-business (where businesses are the main beneficiary) and e-procurement (where businesses and government are the main beneficiaries) (Arduini & Zanfei, 2014; van der Wee et al., 2015); 2) e-government services are less subject to a specific location of occurring and thus more likely to be used away from home (see e.g. Archer, 2015; Nica & Potcovaru, 2015); 3) other new services like e-education (largely focused on implementation within learning institutions) or e-health (focused on telemedicine in the home, and digital patient information in health institutions) have been less conceptualized (Arduini & Zanfei, 2014).

Research Question. To what extend do public Wi-Fi networks, as enablers of the use of e-government services, provide a way to overcome the digital divide?

The main research question will be explored by looking at costs and benefits, in order to create a greater understanding of why Wi-Fi seems to be such an important tool in bridging the digital divide. This leads to subquestion 1. The private value is expected to be negative because the public sector is initiating Wi-Fi projects, rather than the private sector (Hypothesis 1). Because the public sector is initiating these project, the value to society as a whole (public value) is expected to be positive (Hypothesis 2). This public value will be explored in the sector of e-government services.

Subquestion 1. *To what extend does a Wi-Fi network create public value, and what is this public value?*

Hypothesis 1. The private value of a free Wi-Fi network is negative.

Hypothesis 2. The public value of a free Wi-Fi network is positive, when considering the potential benefits from the e-government sector.

As existing literature shows, there are many uncertainties in the adoption and benefits of both public Wi-Fi and e-government, and the characteristics of the Wi-Fi network, socio-economic variables and other factors influence both the usage (and user types) of the network and the effectiveness of use in terms of e-government services. This means that the implementation of a public Wi-Fi network can be expected to have very different effects in different contexts (i.e. implementation in different public spaces). The differences between contexts are crucial to understand, as many government e-services and public policy initiatives for connectivity are aimed at reaching those that are most vulnerable in terms of socio-economic status and are often on the wrong side of the digital divide (T. E. Hall & Owens, 2011). By developing different scenarios of socio-economic contexts in which Wi-Fi networks can be deployed, the differences in the value of the network in those socio-economic contexts can be identified. As the entire spectrum of socio-economic context is too diverse and interrelated to study, two socio-economic characteristics have been chosen to be studied: connectivity alternatives and digital skills.

The availability of Internet connection opportunities and the level of Internet use (which are of course heavily correlated) in a country have a large positive influence on the use of e-government services according to literature (Nam & Sayogo, 2011; Reisdorf & Groselj, 2017a; van Deursen

& van Dijk, 2014). However, the availability of technological accessible alternatives will also decrease the potential additional social value of public Wi-Fi. Subquestion 2 is aimed at quantifying the total effect of connection alternatives, taking into account both effects.

> **Subquestion 2.** *To what extend is the public value created in the e-government sector by public Wi-Fi networks influenced by the available alternatives (i.e. uptake of fixed and mobile broadband)?*
>
> > *Hypothesis* 3. Free-to-use Wi-Fi networks will create less public value when there are more connection alternatives (i.e. fixed and mobile broadband) available.

While the availability of Internet connections is a quantification of the first level digital divide, the second level digital divide is also expected to have an influence on the use of e-government services and the value created by public Wi-Fi in the e-government sector. Digital skills are a measure of this second level digital divide.

> **Subquestion 3.** *To what extend is the public value created in the e-government sector by public Wi-Fi networks influenced by the digital skills of the population?*
>
> > *Hypothesis* 4. Free-to-use Wi-Fi networks will create more public value when digital skills of the population are higher.
> >
> > *Hypothesis* 5. As digital skills of the population are connected to the connectivity and uptake of connection technologies (e.g. broadband), the positive effect of digital skills will be strongest in countries that have similar connectivity rates.

Existing literature on the digital divide, e-government and Wi-Fi networks will be used as a basis to the determine the costs, benefits and mediating factors to be included in the model of the costs and benefits of e-government and Wi-Fi networks. The quantification of effects will be done on the basis of empirical data, assumptions and data from previous studies. In order to test the sensitivity of data assumptions and generalizations, a critical variable analysis and Monte-Carlo analysis will be conducted.

Section 2 will give an outline of the existing literature regarding the digital divide and the technological opportunities of e-government and Wi-Fi networks. Section 3 will outline the methodology used in modeling, section 4 will further explain the model, sensitivity of the model and the scenarios that have been analyzed to look at the effects of socio-economic factors and assumptions. This thesis will close with the results of the model and scenarios (Section 5), conclusion (Section 6) and discussion (Section 7), outlining the limitations of this research and the conclusions and gives recommendations for future research and policy.

2 Literature Review

This section provides an overview of the existing literature relevant to this research, the limitations of the existing research and how this thesis builds on the existing literature. Subsection 2.1 discusses the main theoretical background for this thesis, the digital divide, how it influences this study but also how this study aims to resolve some of the limitations of the current digital divide literature. Subsections 2.2.1 and 2.2.2 focus on the technological opportunities of e-government services and Wi-Fi networks respectively. This section ends with an overview of how the discussed literature is incorporated in this research and how the research expands on the literature.

2.1 Digital Divide and Diffusion

Research in the realm of the so-called "digital divide" has emerged in the late 1990s and has been a growing concept in both scientific literature and policy since the early 2000s. The term refers to the inequality of access to information and communication technology (ICT) (van Dijk, 2006) but has also been expanded to include ICT skills and investments (Prieger, 2013; Kyriakidou et al., 2011). Digital divide research has focused on inequality between countries (e.g. Kyriakidou et al., 2011; Cruz-Jesus, Oliveira, & Bacao, 2012), different degrees of urbanization (e.g. Prieger, 2013), and between and within different socio-economic and socio-demographic groups (e.g. Yu et al., 2016; Mascheroni & Ólafsson, 2016).

van Dijk (2006) identified four different types of "access" needed for adoption of ICT technologies: motivational access (wanting access), material access, skills access and use access. In later literature (e.g. Yu et al., 2016; van Deursen & Helsper, 2015; van Dijk, 2017), different levels of the digital divide are identified, with some similarities to these four types of access:

1. inequalities in internet access
2. inequalities in internet use
3. inequalities in benefits from internet use

These levels are commonly referred to as the first level, second level and third level of the digital divide. The literature review of the relevant digital divide literature will be structured along these three levels.

2.1.1 Access

Research in the first level digital divide deals with differences in physical access. The digital divide is commonly understood as a gap, with people being either on the right or the wrong side at one point in time; people either have access or do not have access. Research into the digital access divide is mainly based on observation of divides of physical access to the Internet among demographic categories (i.e. income, education, gender, age and ethnicity) (van Dijk, 2017).

Different researchers, using different methodologies have shown that there is a digital divide in terms of access in Europe. Cross-country comparative analysis of Cruz-Jesus et al. (2012), based on multivariate statistical analysis has confirmed that there is a digital 'gap' between different European countries in terms of digital access and use. Kyriakidou et al. (2011) outlined broadband penetration rates in European countries and concluded that countries not only have different access rates, but also different rates of adoption.

Another possible focus in digital access divide research is the factors influencing the likelihood of an individual being on the correct side of the digital divide. Ferro et al. (2011) found that education and income levels have a positive influence on the chance of having internet access, while age and being female negatively impact the chance of having access. It is important to note that the study by Ferro et al. (2011) was conducted in Italy, and because it is done in one similar context, factors like the availability of connections are not taken into account, nor is it clear whether these factors and their impacts will be similar in other cultural or socio-economic contexts.

From existing literature, it can be concluded that there is an existing digital access divide in Europe, both between countries and within countries (between individuals). There is a major drawback with this existing literature: digital access is defined either as a fixed (broadband) connection (i.e. internet access in the home; Kyriakidou et al. (2011)), or not clearly defined as all (i.e. referred to as 'access'; Ferro et al. (2011)), while there are many different forms of access (fixed or mobile, paid or unpaid, limited or unlimited) and while some substitution effects are proven (Prieger, 2013), mobile and fixed connections and internet use are very different in possibilities and limitations (Tsetsi & Rains, 2017).

When studying the impact of one type of access (in this case Wi-Fi), the differentiation and relation between access types, lacking from traditional digital divide research, is deemed to be very relevant. In an effort to include the differentiation of access forms in the concept of the digital divide, the concept of the digital divide will be approached differently. Rather than viewing access as a binary (yes or no) concept, different forms of access (fixed connectivity, mobile connectivity and connectivity through hotspots) will be taken into account, each form assumed to be complementary to other forms of access. Thereby, the digital access divide is no longer seen as the inequality (between individuals or countries) in physical access, but the inequality between individuals in what access opportunities (fixed, mobile or hotspot-based) they have. This notion of the relation between different types of access technologies will be further analyzed in Subquestion 2.

2.1.2 Use

It is widely acknowledged in the digital divide research that an individual needs more than just internet access, skills and competencies are also needed to use the internet and related services (Tapia & Ortiz, 2010; van Dijk, 2017). The inequality in the use of digital media and services is referred to as the second level digital divide. A central theme in the second level of the digital divide is that of digital skills; also referred to as e-skills, Internet skills or digital literacy (Scheerder, van Deursen, & van Dijk, 2017). Digital skills are a combination of different skills, such as operation, information navigation, social and creative skills, that determine the ability and ease of using the internet (van Deursen & Helsper, 2018).

Internet Use Research has shown that the factors important determinants of the likelihood of someone having internet access, are also important in determining the chance of someone using access (Büchi, Just, & Latzer, 2016; Scheerder et al., 2017). In general, the type of internet activity determines what factors are most important; e.g. economic factors are more important for the likelihood of someone using the internet for economic activities like shopping (Scheerder et al., 2017). Table A.1 outlines the factors for internet use in general, as given in existing literature. Common factors in the different studies, and thus those that are assumed to be most relevant, are the digital skills of an individual, education, and income (Anduiza, Gallego, & Cantijoch, 2010; T. E. Hall & Owens, 2011; Ferro et al., 2011; van Deursen & van Dijk, 2014; Büchi et al., 2016; van Dijk, 2017; Reisdorf & Groselj, 2017b). While multiple studies mention age and gender, there is no consensus concerning the impact of these factors (Anduiza et al., 2010; T. E. Hall & Owens, 2011; Ferro et al., 2011; van Deursen & van Dijk, 2014; Büchi et al., 2016; Reisdorf & Groselj, 2017b). It is important to note that most of these studies are based on national data, which might explain differences in results: Ferro et al. (2011) used Italian data, Reisdorf and Groselj (2017b) used British data, van Deursen and van Dijk (2014) used Dutch data, T. E. Hall and Owens (2011) used USA data, Anduiza et al. (2010) used US, British and Spanish data, and Büchi et al. (2016) used data from Great Britain, the USA and New Zealand.

In addition to socio-economic and socio-demographic characteristics of individuals, also attitudes towards the internet are determinants of internet use. Positive attitudes towards technology (in general), believing the internet will increase efficiency and the believe that internet is a good way to escape reality are all positively related predictors of internet use (Reisdorf & Groselj, 2017b). However, Büchi et al. (2016) argue that the amount of differentiation explained by socio-demographic variables is so high that differences in usage of digital media and services can largely be attributed to actual social inequalities and not mere user differentiation.

E-Government Use The second level of the digital divide can also be directly applied to digital government services, or e-services, as a specific way of using the internet. However, it can be difficult to isolate this from factors influencing general internet access and use, as these factors in large part also influence the ability of people to use e-government services.

Similar to general internet use and access, income and education are the two important and generally agreed upon socio-economic factors for e-government use (T. E. Hall & Owens, 2011; Nam & Sayogo, 2011; Taipale, 2013; Vicente & Novo, 2014; Reisdorf & Groselj, 2017a). There is no consensus concerning the effects of gender, ethnicity, and age (T. E. Hall & Owens, 2011; Nam & Sayogo, 2011; Vicente & Novo, 2014; Reisdorf & Groselj, 2017a). As with the use of (general) digital media and services, digital factors are also important: the number of locations people have to go online, whether people own a device to go online, and an individual's digital skills and internet experience (Anduiza et al., 2010; Nam & Sayogo, 2011; Taipale, 2013; Vicente & Novo, 2014; Dombrowski et al., 2014; Reisdorf & Groselj, 2017a). While all these factors, summarized in Table A.2, focus on the inequality between individuals, Seri et al. (2014) compared different countries and found many of the same factors to be influential: maturity of the ICT infrastructure (broadband penetration) and education levels, GDP, trust in government and corruption levels (Seri et al., 2014).

Similar to general usage, more sociological factors like attitude are also considered. Nam and Sayogo (2011) described the importance of perceived benefits on usage, which is also influenced by trust in the government (Nam & Sayogo, 2011; Reisdorf & Groselj, 2017a). Furthermore, it can be anticipated that the attitudes influencing the probability of (in general) using the internet, can also be applied to e-government services.

Diffusion of E-Government The use of e-government services is not only dependent on these socio-economic and demographic characteristics, but also on the availability of e-government services. Several studies on e-government have suggested different stages in which e-government is developed (e.g. Moon, 2002; Muir & Oppenheim, 2002; Huang & Bwoma, 2003; J. Lee, 2010; Rooks, Matzat, & Sadowski, 2017). J. Lee (2010) compared different models of stage-based development, and outlined five stages of development from a service perspective: information (one-way), communication (two-way), transaction, participation, and involvement. In 2017 a study of e-government services offered by different Dutch municipalities by Rooks et al. showed that e-government services tend to develop linearly through the five stages commonly used, especially in the first three stages. It is anticipated that the further e-government services are developed, the more services are available in the e-government stages, starting with an increase in the first stages, and the more e-government services can potentially be used. The technology of e-government services is seen in a maturational model, as a technology that matures and spreads over time, as is done in the tradition, which is an extension of the diffusion of innovation model by Rogers (2003) (Brown, 2007).

In short, the use of internet has been studied (often through survey data), using proxies for several basic internet-use actions (e.g. sending emails or looking information up online). The availability of e-government services is often based on telephone interviews of internet searches, while the use of services is often done through analysis of survey data (Arduini & Zanfei, 2014). Although the multitude of studies analyzed have shown that exact impact might differ on the context (country of analysis) and the service (Internet, e-service or any specific e-government service), the general trend remains that income, education (and according to some authors, age) are the most important predictive factors.

The literature of the use of online services (in general) and e-government services (specifically) will be implemented in both the model created for this research and the scenarios used. The finding that income and education levels are the two most important factors in an individuals likelihood of using e-government services will be taken into account when incorporating the use of e-government services in the model. Furthermore, the finding that digital skills are so important to the use of e-government services, and thereby the potential benefits created by using e-government services, have formed the basis for Hypothesis 4 and 5.

2.1.3 Benefits

In recent years, the concept of the digital divide has been expanded beyond access and use by introducing a third level of the digital divide, the inequality of digital outcomes given equal digital access and use. The increasing interest in digital outcomes is especially coming from countries with near total access to all, such as the Netherlands (van Deursen & Helsper, 2015). Digital outcomes are related to digital skills, which have previously been discussed as a determinant of digital use (second level) (Scheerder et al., 2017; van Deursen & Helsper, 2018). Education, age and the amount of time spend online all influence a person's capacity to create favourable outcomes for themselves by using e-government services (van Deursen & Helsper, 2015), as summarized in Table A.3. In addition, the skills that are related to outcomes in activities are partially dependent on the nature of the activity (e.g. economic skills for economic activities; personal, social and creative skills for personal use) (van Deursen & Helsper, 2018). A limitation of the factors mentioned in Table A.3 is that the factors found as influential by van Deursen and Helsper (2015) are based on self-assessment through statements such as “I am better up-to-date with government information” and “I have better contact with the government” (van Deursen & Helsper, 2015, p. 38). Furthermore, these are general effects, no research specifically focused on e-government outcomes have been found.

Since there is no research into the third level of the digital divide directly applied to e-government, it is difficult to be directly included in this research. However, the findings van Deursen and Helsper (2015, 2018) do indicate that failure to use e-government efficiently (i.e. experienced problems while using e-government) are expected to be different in groups with different education and income levels, as well as age. The third level of the digital divide will not be directly included in the model, but indirectly included in the form of experienced problems while using e-government, and analyzed partially in subquestion 3.

2.2 Technological Opportunities

There are two main technological components of relevance to this thesis: E-Government and Wi-Fi networks. Both technologies have been studied in previous literature. Subsections 2.2.1 and 2.2.2 will discuss the previous literature on both e-government services and Wi-Fi.

2.2.1 E-Government

A general and broad definition of e-government is the use of ICT (information and communications technologies, i.e. the Internet and connected services) by government agencies for providing information and services (Bonson et al., 2015; Huang & Bwoma, 2003; Muir & Oppenheim, 2002; Weerakkody et al., 2015). The provision of e-government services can target different groups, such as citizens, businesses, other (governmental) organizations (Bonson et al., 2015; Muir & Oppenheim, 2002; Weerakkody et al., 2015). These different “target” groups of e-government have been used to differentiate different types of e-government: government-to-government, government-to-citizen and government-to-business (Huang & Bwoma, 2003). Huang and Bwoma (2003) also define a fourth category of government-to-employees, which is also used by Khan et al. (2014) in their analysis, and Picco-Schwendener et al. (2017) defined government-to-visitor as a group of tourist-services. The focus of this thesis will be on government-to-citizen services, as citizens are the main target group for a public Wi-Fi network and because these services have been described most extensively in the literature.

There are many general effects attributed to e-government: increased accountability and transparency, mitigating information asymmetry, less corruption, greater convenience, less personal interaction, increased involvement of citizens and other stakeholders, increased collaboration across government agencies, greater efficiency and effectiveness, strengthening the (local) economy, revenue growth, making the city more attractive to businesses, and cost reduction (Alarabiat & Ferreira, 2018; Bonson et al., 2015; Brown, 2007; Gilbert et al., 2004; Huang & Bwoma, 2003; Khan et al., 2014; Lambert, McQuire, & Papastergiardis, 2014; Picco-Schwendener et al., 2017; Weerakkody et al., 2015). However, multiple of these effects might also be influenced by the cultural context wherein the e-government tools are used (Bonson et al., 2015; Gilbert et al., 2004). Many potential effects of e-government have been listed in the literature, these will be discussed for each of the five identified stages of e-government (J. Lee, 2010).

Information Presenting information (or e-information) is the first stage of e-government, and can be seen as a one-way process from the government to citizens (Brainard & McNutt, 2010; Huang & Bwoma, 2003; J. Lee, 2010; Muir & Oppenheim, 2002; Nam, 2014). Multiple different media are available for e-information: e-mail or website (Johannessen, Flak, & Sæbø, 2012), Yahoo groups or other interactive fora (Brainard & McNutt, 2010), or social media (Facebook, Twitter)[1] (Bonson et al., 2015; Johannessen et al., 2012; Khan et al., 2014; Mawela, 2017). The main benefits in this stage are associated with reduced time and costs for citizens because they do not have to physically go somewhere to get information (Gilbert et al., 2004; van der Wee et al., 2015), time gain on part of the government because they only have to give the information once (and then it can be found online) (Gilbert et al., 2004; Muir & Oppenheim, 2002; van der Wee et al., 2015), a decrease in the use of paper (van der Wee et al., 2015) and administrative costs (Brown, 2007), the possibility to access the information always and not just during opening hours (Huang & Bwoma, 2003; van der Wee et al., 2015; Weerakkody et al., 2015), and the possibility to personalize information (Gilbert et al., 2004; Muir & Oppenheim, 2002).

Communication Communication is a two-way process in which simple communication with the government is online, but the response is not immediate but delayed and send by email or traditional mail (Huang & Bwoma, 2003; J. Lee, 2010). Example of communication in government-to-citizen (G2C) e-government are: blogs, wiki's, social media, fora and discussion groups (Khan et al., 2014; Osimo, 2008), all these actions replace personal contact (van der Wee et al., 2015). The main benefits in this stage are similar to the presenting of information, with the added benefit of a time gain for citizens due to a faster response time (Hassan, Shehab, & Peppard, 2010). In the specific case of government-to-citizen e-government, ICT tools might increase and improve citizen contact (Brown, 2007). Mawela (2017) showed that citizens also view these platforms as an opportunity to promote their own services, products and increase their social capital.

Transaction Transaction is the stage where services and payments are conducted online (Huang & Bwoma, 2003; J. Lee, 2010). This might also include personalization of the platform (portal) used for these (financial) transactions and offered services (J. Lee, 2010). Examples of this in government-to-citizen (G2C) e-government are: online enrolment for university, scholarship applications, issuing birth certificates or driver licences, registering vehicles, tax payments and returns, checking the balance of a pension fund, and electronic payments (Hassan et al., 2010; Hayes, 2011; Moon, 2002; Muir & Oppenheim, 2002). The main benefits associated with online service provision are: reducing the amount of paper used, and more effective (or less incorrect) applications by allowing people to make changes afterwards (Hassan et al., 2010). Part of the increased efficiency in applications is not having to re-enter data for each separate transaction, if the e-government service is following the "once only" principle (Gallo, Giove, Millard, & Thaarup Kare Valvik, 2014).

[1]The use of social media by government is also referred to as social government, or s-government instead of e-government (Khan et al., 2014)

Participation Online participation (or e-participation) concerns public surveys and consultation for opinions (J. Lee, 2010; Mawela, 2017). E-participation can be done in specific phases of the decision making process, wherein citizens are used as external resources, mainly through public opinion polling or public consultations (Huang & Bwoma, 2003; J. Lee, 2010; Vicente & Novo, 2014). Social media have a great potential for participation and shaping policy development, as it allows direct contact between political or governmental figures and the public (Khan et al., 2014; Osimo, 2008). E-participation is said to improve people's development and socio-economic circumstances, encourage social cohesion, and reduce social pressure in participation (Anduiza et al., 2010; Mawela, 2017). Furthermore, it is anticipated that e-participation reduces the impact of social-economic status on the participation, decreasing inequality in participation (Mawela, 2017; Medaglia, 2012). However, these effects are not quantifiable and the impact of citizen participation on decision making is subject of discussion (Michels & De Graaf, 2010). More quantifiable effects are the reduced costs of communication (i.e. travel costs, travel time, paper consumption, government working hours), increased flexibility, and increased accessibility (Anduiza et al., 2010; Vicente & Novo, 2014).

Involvement The last stage of involvement concerns the direct involvement in decision-making processes, e.g. through voting (J. Lee, 2010; Moon, 2002). E-voting (or I-voting) is a way for people to be involved in government affairs. Although there have been many trials for e-voting in different countries (e.g. Norway, the UK, the Netherlands, the US), successful adoption is limited to Estonia and Switzerland ("Electronic Voting", 2016). The exact impact of e-voting depends on the uptake (dependent on the time since the first deployment ("Electronic Voting", 2016) and whether it is compared to post-voting of polling stations (Mendez & Serdült, 2017). In general, the effects of e-voting are likely a decreased amount of time spend on voting (transport and standing in line)(T. Hall, 2015; "Electronic Voting", 2016; Mendez & Serdült, 2017), a decrease in missed working hours due to voting (T. Hall, 2015), decrease in the effort it takes to vote ("Electronic Voting", 2016; Mendez & Serdült, 2017). Furthermore, e-voting makes it easier to detect flaws in votes before submission (T. Hall, 2015), change votes after casting by re-voting (which might avoid the "buying" of votes since it is possible to change the vote after casting it by voting again (Saglie & Segaard, 2016)). (T. Hall, 2015; Saglie & Segaard, 2016), and allows voting for remote areas and outside traditional opening hours of polling stations (Alvarez, Hall, Levin, & Stewart III, 2011). Although some studies report that voting will increase the turnout of potential voters, others dispute this or conclude that the effect is only very marginal (Alvarez et al., 2011; T. Hall, 2015); this difference might be caused by the level of diffusion of the technology, as turnout increased in Estonia where e-voting is very accepted (Alvarez et al., 2011; T. Hall, 2015) but did not increase in some other countries that had e-voting pilots without a previous e-voting history (T. Hall, 2015).

While there is a lot of literature available on e-services and the use of e-services, there are severe limitations to the existing literature. Most articles on the use and perceived benefits of e-government are based on survey data (e.g. Moon, 2002), case studies in single countries (or even cities) (e.g. Brainard & McNutt, 2010; Bonson et al., 2015; T. Hall, 2015; Hassan et al., 2010), or are purely based on what benefits theoretically might be expected from the e-government services (e.g. Huang & Bwoma, 2003; Muir & Oppenheim, 2002). A key problem with this is that each other identifies different potential or perceived benefits and that a reflection on the degree to which these benefits are realized is lacking. As such, the best way to refer to these benefits named in the existing literature would be perceived benefits or potential benefits; this paper will continue to use the terms potential benefits to refer to those benefits that are expected (but not proven) to occur.

Another important limitation is the lack of quantified potential benefits of e-service technologies. van der Wee et al. (2015) conducted a bottom-up analysis of e-government and e-business, thereby quantifying some effects, but their focus on e-government services was limited to e-information and e-transactions, excluding the rest of the spectrum of e-government services. E-service benefits are included (and thus quantified) in economic assessments of broadband projects applying for EU-funding, but only as an estimate of potential benefits per country (or the EU-27 area) without clarification on what these estimates are based on (JASPERS, 2013). This paper will aim to quantify a larger set of benefits, both in potential (maximum expected) value, as well as expected realized benefits to include the notion that realistically not all potential benefits will be full benefits (e.g. because of non-users, mistakes in use or website failure). As such, it aims to provide a realistic view of the possible monetary value associated with e-government benefits, as well as a full view of the potential benefits associated with e-government services.

2.2.2 Wi-Fi Networks

There are indications in both policy (e.g. WiFi4EU) and literature that Wi-Fi networks might be a tool to overcome (parts of) the digital (access) divide (Baker, Hanson, & Myhill, 2009; European Commission, 2018; K. L. Middleton & Chambers, 2010; Picco-Schwendener et al., 2017). Part of the allure of Wi-Fi is its technological simplicity: it is an inexpensive and unlicensed technology that can use (mainly) existing infrastructure (e.g. street lights and urban furniture), and costs associated with deployment and operations are relatively low (Bar & Park, 2006) but can also successfully be applied to deliver access to areas without other access options (Raman & Chebrolu, 2007). Many promising benefits, other than bridging the digital divide, are associated with free Wi-Fi networks: increasing (political) engagement, economic growth, attracting tourists, repopulating public spaces, increasing government efficiency, and stimulating innovation (Bar & Park, 2006; Picco-Schwendener et al., 2017). In spite of these expected benefits, Wi-Fi is often said to have failed to deliver (Picco-Schwendener et al., 2017). In this subsection, the literature concerning (municipal) free Wi-Fi networks is reviewed and how this thesis builds on the existing Wi-Fi research is outlined.

Technically, Wi-Fi can be deployed in two different ways, in this paper the term 'Wi-Fi network' will be used for a hotspot based network in one (or multiple) specific locations, while the term 'municipal wireless network' (MWNs) will be used to indicate a municipality-wide mobile network based on Wi-Fi technology. Municipal wireless networks are used to reach those enterprises and households that are beyond the reach of traditionally fixed connectivity, thereby increasing (government) efficiency through online services and promote economic development, and can also be used by the government entities itself (Sadowski, Verheijen, & Nucciarelli, 2008; Tapia & Ortiz, 2010; Tahon et al., 2011; van Ooteghem et al., 2009). On the other hand, Wi-Fi hotspots are used to provide connectivity in specific (public) spaces, sometimes targeted to a specific group of users (e.g. tourists) (Navío-Marco, Arévalo-Aguirre, & Pérez-Leal, 2018; Picco-Schwendener et al., 2017). Both types of networks are based on the same type of technology and unlicensed spectrum, and a Wi-Fi network can theoretically be expanded over time to form a municipal wireless network (by adding more and more hotspots, so the network ends up spanning the entire city). In this paper, the focus will be on Wi-Fi networks, instead of municipal wireless networks, as it is suggested that these may be more promising (Picco-Schwendener et al., 2017) and because this type of network is more of a topic in recent policy (e.g. European Commission, 2018).

Different authors have outlined potential (theoretical) business models for municipal wireless networks and Wi-Fi networks. Although there are many possibilities such as free networks, revenue from advertisements, paid subscriptions, sharing connectivity (PAWS), or public-private partnerships (Bar & Park, 2006; Rao & Parikh, 2003; Sadowski et al., 2008; Sathiaseelan et al., 2014; van Ooteghem et al., 2009). In this paper, the focus will be on free networks, as these networks are the most used in relation to overcoming digital inequalities (Picco-Schwendener et al., 2017). Not only possible revenue/investment models are studies, but multiple authors have also reflected upon the costs of networks.

Another literature focus in the field of Wi-Fi has been the cost structure of networks. Sadowski et al. (2008) has focused on the costs of a municipal wireless network (using WiMax technology, instead of Wi-Fi), identifying the backhaul network and infrastructure, service supply and access costs (internet subscription) as main costs for the network. Navío-Marco et al. (2018) have focused on the costs of Wi-Fi networks, identifying equipment and installation, maintenance, and operations (network subscription and user management) as the main costs. Both studies have in common that there is a large possible diversity in network costs and that these are difficult to estimate. In order to deal with that uncertainty in this paper, costs will be based on a sample of real market costs and a sensitivity analysis will be done to be aware of the possible causes of uncertainty in the cost model.

Case studies have commonly been used to study the use of public Wi-Fi networks and the factors influencing use. Network use has been found to be dependent on the characteristics of the Wi-Fi network and its location (Hampton, Livio, & Sessions Goulet, 2010; Lambert et al., 2014; C. A. Middleton, 2007; Potter, Mcintyre, & Middleton, 2008) and socio-economic factors (i.e. the second level digital divide) (Hampton et al., 2010). Hampton et al. (2010) has shown that the use of a network increases the longer it exists, likely because more people know of it and have used it in the past. The specific factors influencing Wi-Fi use have been summarized in Table A.4. The research on factors influencing Wi-Fi use is based on observation (Hampton et al., 2010) and data from specific cases (Potter et al., 2008; Picco-Schwendener et al., 2017)

The use of a Wi-Fi network is not only analyzed in terms of factors that influence whether a network is used, but also by the digital actions done using the network. From the literature, five main categories of Wi-Fi usage can be identified: information consumption, information creation, contact/social networking, work and personal use. While all studies and surveys have asked for different types of usage, general patterns can be observed. In general, all studies show that many people use Wi-Fi networks for social media or mailing (Hampton et al., 2010; Melton, 2017; O'Connel, 2017; Picco-Schwendener et al., 2017; Schlesinger, 2016; Thomas, 2014). About one in every five people also use Wi-Fi networks for financial business (i.e. banking, shopping, financial transactions) (Melton, 2017; O'Connel, 2017; Schlesinger, 2016; Thomas, 2014). In those studies that also focused on information provision, this seemed to be a large part of the function of a Wi-Fi network (Hampton et al., 2010; Picco-Schwendener et al., 2017). A complete overview of the findings of the different studies can be found in Table A.5.

In short, Wi-Fi has been studied from a techno-economic perspective (looking at requirements, business models and network costs) and a socio-economic and socio-demographic perspective (looking at factors influencing use and observing how people use networks). One of the primary limitations in the existing Wi-Fi literature is that there is no assessment of the value of Wi-Fi networks, beyond case-based studies on how and how much Wi-Fi networks are used which cannot be linked to the techno-economic perspective as there is no quantified value of the network. As such, it is impossible to assess whether Wi-Fi networks create public value and what factors influence the public value created by Wi-Fi. Another limitation is that many of the studies done in Wi-Fi networks are based on relatively small scale user surveys often related to specific cases (e.g. Identity Theft Resource Center, 2012) or observations (Hampton & Gupta, 2008; Hampton et al., 2010), because of these methods and the differences in results between studies, it is difficult to generalize these findings to one conclusion on how public Wi-Fi networks are used.

The aim of this thesis is to quantify the expected value a public Wi-Fi network generates through the use of e-government services, and by doing this reflecting on the ability of Wi-Fi networks to be a vehicle in overcoming (part of) the digital divide. This will be done by using the three literature foundations described in this review: digital divide literature, the technological opportunities of e-government services, and the technological opportunities of Wi-Fi networks. The digital divide literature will serve as a theoretical background for both the expectations of the socio-economic contexts in which Wi-Fi networks are expected to have the most value (see subquestions 2 and 3), and be the basis of the reasoning of which individuals are expected to benefit most from having public Wi-Fi as a connection opportunity. The costs of a Wi-Fi network, as well as the (user) potential of the Wi-Fi network, will continue to build on the basis of the existing Wi-Fi (and municipal wireless) network literature, expanding it by quantifying benefits in the form of e-government use through the network instead of expressing value in number of users. The benefits of e-government that have been described in literature are used as a basis for quantifying the potential effects of e-government, while the literature on the second level digital divide is used to move from potential benefits to expected realized benefits; by quantifying potential benefits and differentiation between potential and expected realized benefits it will expand on the current literature concerning e-government.

3 Method

The model of this thesis is based on the cost-benefit analysis method. This method has been chosen because of its known applicability in assessing both private and public value of public policy measures, and that it is often used in assessing public policy or public investment initiatives in various areas (e.g. European Commission, 2008, 2014). Secondly, as a bottom-up modelling approach, cost-benefit analysis is more suitable for cases where there is no ex-ante (economic) data available, which is the case for public Wi-Fi networks due to the lack of previous quantitative research or data. This section focuses on the exact implementation of the cost-benefit analysis method in this research, what adaptations are made to overcome some of CBA's weaknesses, and how scenarios are used with the model to explore the differences between socio-economic contexts.

3.1 Cost Benefit Analysis

There have been multiple occasions in which the (economic) costs and benefits of broadband have been quantified, both in bottom-up and top-down models (e.g. Gruber et al., 2014; van der Wee et al., 2015). The European Commission has published several guidelines to a cost-benefit analysis for investment projects, including specific instructions on cost-benefit analyses for broadband projects (European Commission, 2008, 2014). JASPERS (2013) has created a framework cost-benefit analysis for broadband, based on the requirements and guidelines of the European Commission. While public Wi-Fi is both technically and socio-economically vastly different from broadband (e.g. Wi-Fi has a shorter lifespan, is used differently then broadband, and has different possible revenue structures), the very general function remains the same (i.e. providing connectivity). Therefore, it has been assumed that the analysis of costs and benefits can follow a similar structure. Such a structure is shown in Figure 3.1.

Outcome Indicators The main outcome indicators of the model are the enpv (Economic Net Present Value) as indicator of public (economic) value over the entire project lifetime, the B/C ratio as an indicator of the ratio between created value (benefit) and investment (costs), and the err (Economic Rate of Return) which is the potential discount rate at which the project's ENVP switches (i.e. becomes zero). A positive ENPV will indicate a positive public value, a B/C ratio higher than 1 indicates that benefits are higher than costs, and an ERR indicates the sensitivity to the value attributed to future money. In this way, the first two of these indicators will indicate whether the public value is created, and how much public value is created and thereby aid in answering subquestion 1, whereas the ERR indicates to some degree the sensitivity of the outcome. Additional ways to assess sensitivity to assumptions and input data, which is important as bottom-up models are sensitive to (data) assumptions, are the sensitivity analysis done which will identify critical variables and switching values for these critical values and the probabilistic risk analysis in the form of a Monte-Carlo simulation

Scope The scope of this study is to quantify the costs of a public Wi-Fi network and expected realized benefits created through e-government use on the public Wi-Fi network. The costs of the Wi-Fi network will be dependent on equipment costs and installation costs (CapEx) and operating

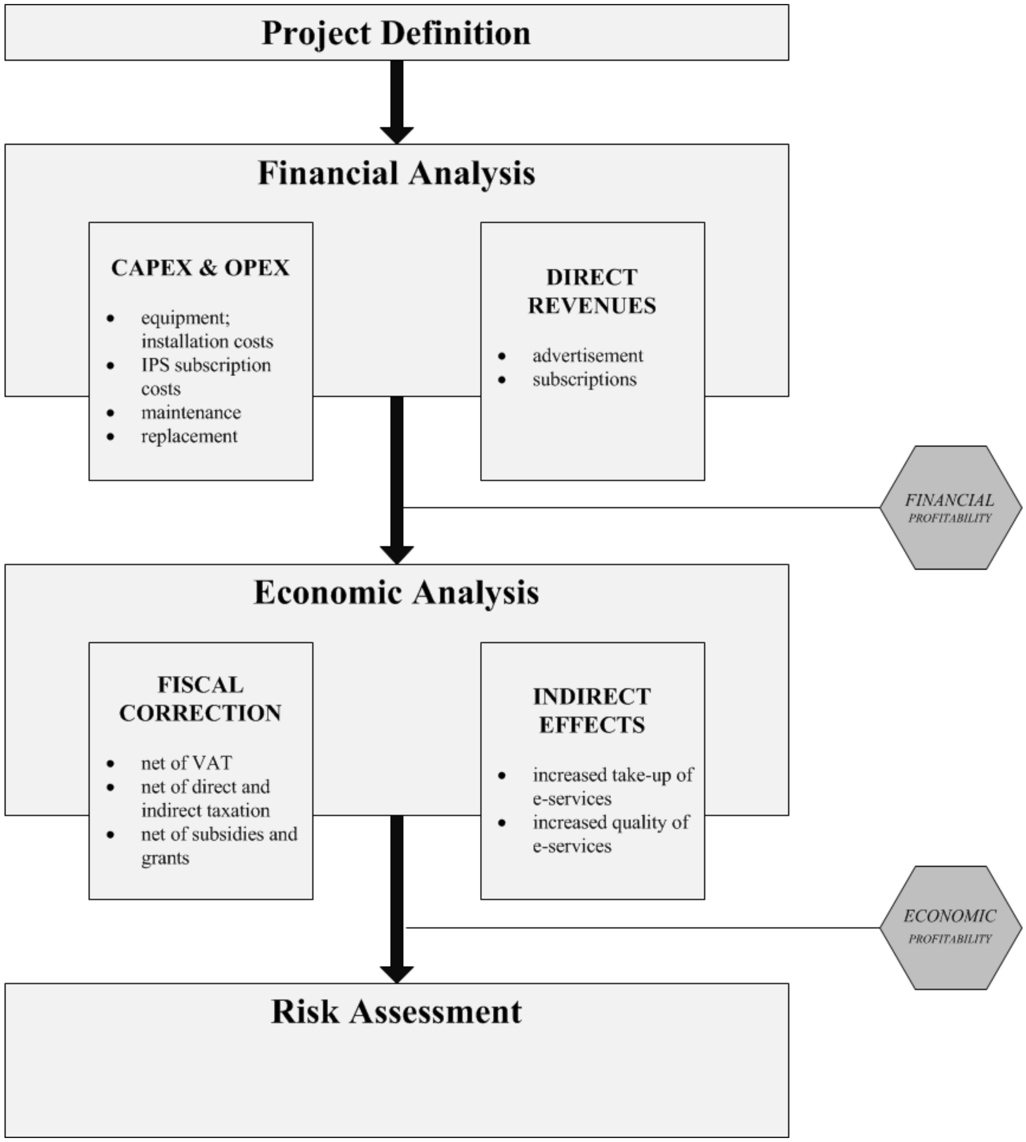

Figure 3.1: *Structure of a full CBA on public Wi-Fi inspired by the methodology proposed in European Commission (2014)*

costs (OpEx), including maintenance. These costs are determined over a course of 10 years (the assumed lifetime of the municipal Wi-Fi project), and the residual value of the equipment at the end of year 10 is seen as an income in year 11. The modelling of benefits will be based on some principles of cost-benefit analysis. Benefits of e-government services will be based on opportunity costs, the difference between the use of e-government services and the best available alternative (i.e. a common-practice non-digital based alternative) will be expressed as a benefit. These benefits, in their own unit (e.g. hours, kilometres), will be monetized using a conversion factor. The total benefit would then be calculated by multiplying this monetized benefit by the number of occurrences per person and the number of people, resulting in Equation 1 (TV is total value; U is unit benefit of the effect; O is the number of occurrences). The characteristics of this network that partially determine costs (e.g. coverage area, maximum amount of users) determine both costs and potential benefits and are therefore of interest as experimental variables, just like contextual variables (e.g. connectivity rates, e-government usage rates) that determine both costs and benefits.

$$TV = O * U * \frac{€}{U} \tag{1}$$

There is one large limitation of the standard cost-benefit analysis for assessing the benefits of e-government service use facilitated by public Wi-Fi. CBA is based on macroeconomic data (e.g. GDP), and as such treats society as if it is a homogeneous group of entities (people, firms etc.) by averaging out interpersonal differences. This is in contrast with the suggestion in the literature that user characteristics greatly influence the potential added value of another connection alternative (e.g. C. A. Middleton, 2007), and that user-specific characteristics influence the likelihood of someone using e-government services (e.g. T. E. Hall & Owens, 2011; Nam & Sayogo, 2011; Reisdorf & Groselj, 2017a; Taipale, 2013; Vicente & Novo, 2014).

The importance in differentiating between users in economic analysis has previously been acknowledged in medical cost-benefit studies (e.g. see Ramaekers, Joore, and Grutters (2013)). JASPERS (2013) acknowledges the difference in NGA broadband roll-out effects between areas that had nothing and areas that had basic broadband. However fixed (broadband) access is binary, an individual either has access or does not have access. As stated in the literature review (Section 2), in order to assess the value of public Wi-Fi and its capacity to bridge the digital divide, the digital divide is not seen as the inequality of access (in binary sense: have vs. have-not) but the inequality of access opportunities (the availability of different access technologies: fixed, mobile and hotspots). This further complicates the difference between individuals. In order to include this complexity in the cost-benefit model, a user typology will be used.

3.1.1 User Types

User typologies are commonly used in analyzing consumer behaviour by product developers or market researchers or in social science as a way of ordering complex behaviours. Dividing a group of people in different user types has also previously been used in digital divide literature to analyze media and internet use (e.g. Brandtzæg, 2010; Brandtzæg, Heim, & Karahasanović, 2011), Brandtzæg et al. (2011, p.124) even mentioned a "user type divide", to capture the way that people with access to not engage with internet services in the same way. User typologies have also been applied to Wi-Fi network use studies: Lambert et al. (2014) and Picco-Schwendener et al. (2017) have both proposed different user categories predictive of how an individual will likely use a public Wi-Fi network, based on data of Wi-Fi network usage. As the focus of this study is more towards providing access (first level digital divide), the identified user types will reflect access rather than use. C. A. Middleton (2007) proposed a (theoretical) user typology to analyze how public Wi-Fi influences the Internet access of different people, by differentiating between primary (often fixed to a location) access and secondary access (often mobile, on-the-go), and willingness/ability to pay. A similar typology will be used for this model.

For this study five different groups of users or user types have been identified: individuals with both fixed and mobile access, individuals with only fixed access, individuals with only mobile access, individuals with no access and individuals who do not want access. These five different types of users are similar to the categories proposed by C. A. Middleton (2007), with the difference that instead of access has been defined as specific access types (fixed vs. mobile) and willing non-users have been included. The user types will be used to define how much people will benefit from the use of Wi-Fi (depending on their available alternatives), but the general demographics of each group will also be used to determine the likelihood that these people will use e-government services.

In order to use a user typology in the CBA, the different user types will be treated as the different actors are treated by van der Wee et al. (2015). The total value potential (TVP) will be calculated per person, wherein the number of occurrences (O) per user type (i) will be multiplied by the total of monetized unit benefits (U) per occurrence, as described in Equation 2. The total value realized (TVR) is calculated by summing the multiple of total value potential, percentage people in the user type using e-government service ($EGov_i$), percentage of TVP attributed to the use of the Wi-Fi network, and the number of Wi-Fi network users per year (N_i), for each user type; as in Equation 3. Equations 2 and 3 are adaptations of the standard CBA Equation 1, with the addition of the percentage of e-government users and the percentage of the effect attributed to the Wi-Fi network.

$$TVP_i = O_i * U * \frac{€}{U} \tag{2}$$

$$TVR = \sum_{i=1}^{i} (TVP_i * EGov_i * WiFi_i * N_i) \tag{3}$$

While the concept of identifying different user types in connectivity or Wi-Fi network use is not new, no evidence has been found of an earlier implementation of user types as a factor in cost-benefit analysis for (digital) infrastructure investments. The main aim of including a user typology in a bottom-up model is that part of the complexity of the 'real world' can be included in the model and that thereby the impact of contextual factors (e.g. connectivity rates) can be assessed more accurately.

3.2 Scenarios

Scenario testing is used to integrate the possibility of deployment of public Wi-Fi in different socio-economic contexts. While the literature seems to agree that some socio-economic and demographic characteristics matter a great deal to the possible effect of connectivity and e-government, these relations are difficult to incorporate in a cost-benefit analysis because of the interconnectivity of different concepts. For example, the available connectivity in a country can be expressed in terms of the total population, but also in subpopulations based on e.g. educational level or income level, as the literature suggests these are large influencing factors of connectivity (Ferro et al., 2011). While the effect of most variables included in the model can adequately be tested by sensitivity testing (i.e. determining critical variables and switching values of variables), the set of connectivity rate variables is interrelated and in reality, one variable will not change value without other variables in that set changing value. Another example of interconnectivity of concepts is that connectivity rates are also related to the rate of e-government use (Reisdorf & Groselj, 2017a). As a result, the set of variables will be changed as a whole, in order to be able to evaluate the effect of changing connectivity rates. In scenario testing, different sets of connectivity rates will be compared, as a way of evaluating the impact of connectivity rates in general, based on the connectivity rates and e-government use rate in different countries and EU-regions (as defined by Eurostat).

The scenarios will be related to subquestion 2 and subquestion 3. Subquestion 2 is related to connectivity alternatives. As explained previously, the connectivity alternatives are not captured by a single variable that can be easily varied. In order to assess realistic possibilities and impacts of this, the data sets of multiple countries will be used for comparison. As the data of the different countries come from the database (Eurostat (2018c)), the data is assumed to be comparable in method of gathering and accuracy. For each test in the scenario, the first comparison will be of only the connectivity rates variables and the second test will also include the rates of e-government use in each of the countries, as these will never be fully comparable (although an effort will be made to find countries that are as close as possible to each other, to isolate the effect of the connectivity rates as much as possible). The first test is used to get an idea of the "pure" effect of connectivity, whereas the second test is more true to reality.

Subquestion 3 is related to a variable, the digital skills in a country, that is not directly included in the model. However, according to the literature, the digital skills in a country are related to the connectivity rates (higher connectivity rates being associated with higher digital skills) and digital skills are instrumental to the use of e-government and other online services and tools (Reisdorf & Groselj, 2017a; Vicente & Novo, 2014). The relation between digital skills and the public value created will be done in two steps: The first step will be to compare countries that have similar digital skills, in order to see whether there are similarities in public value of a Wi-Fi network. The second step will be to see if there is a clear effect of digital skills in comparing multiple countries with different digital skills. The comparison of countries' socio-economic context in either of the two steps will be done by changing connectivity rates, e-government use percentages and the percentages of people experiencing problems in using e-government.

4 Model

This section will outline the model of costs and benefits that have been created according to the methods described in Section 3. The model is represented as an overall conceptual model showing the interrelations between costs, benefits and user types, and is specified further in terms of costs (4.1.1), benefits (4.1.2) and user types (4.1.3) in both conceptual models, assumptions and calculations. This model description will be followed by the sensitivity analysis (4.2), which reflects both on the overall variability that can be expected in the model and the values (and variables) that are of critical importance to the model outcome. Lastly, the different scenarios used in the analysis for subquestions 2 and 3 are explained (4.3).

4.1 Base Model

Figure 4.1 represents the overall model and shows how the different parts of the model (user types, costs and benefits) together come to the calculation of the network's public value. The direct (Wi-Fi network's) costs and the indirect (e-government) benefits together determine the value of the Wi-Fi network. The user types and related (demographic) information determine how much of the potential value is realized and is thus indirectly related to the benefits. Each of the three model parts is explained in further detail in the following sections.

4.1.1 Costs

In order to compare the potential benefits of an increasing use of e-government services due to public Wi-Fi to the cost of such a network, a model of a simple set-up of such a network is created. For this, it is assumed that the model consists of the following basic components, based on Navío-Marco et al. (2018):

- Access Points [Multi-User MIMO & 802.11 ac Wave I]
- Switch Controller [Managed, PoE enabled, 16-24 ports]
- PoE injector
- Wiring & Support

Conceptual Model The total network costs consist of two main components, installation costs (CapEx) and operational costs (OpEx). Installation costs are mainly dependent on the core equipment of a Wi-Fi network: access points, a switch, a PoE injector, and wiring & support to install the nodes. Another installation expenditure is the labour costs of installation, which is assumed to be a percentage of the equipment costs. The main operational costs of the network are the ISP subscription, cloud-based management of users, maintenance, and electricity consumption. The costs of maintenance are assumed to be based on installation costs and a percentage of the network that needs replacing due to failure. The full conceptual model has been visualized in Figure 4.2.

The amount of access point needed in the system is dependent on the number of anticipated users and an assumed maximum of users per access point of 100 (Navío-Marco et al., 2018). The maximum amount of users is a function of the available backhaul network and the average bandwidth

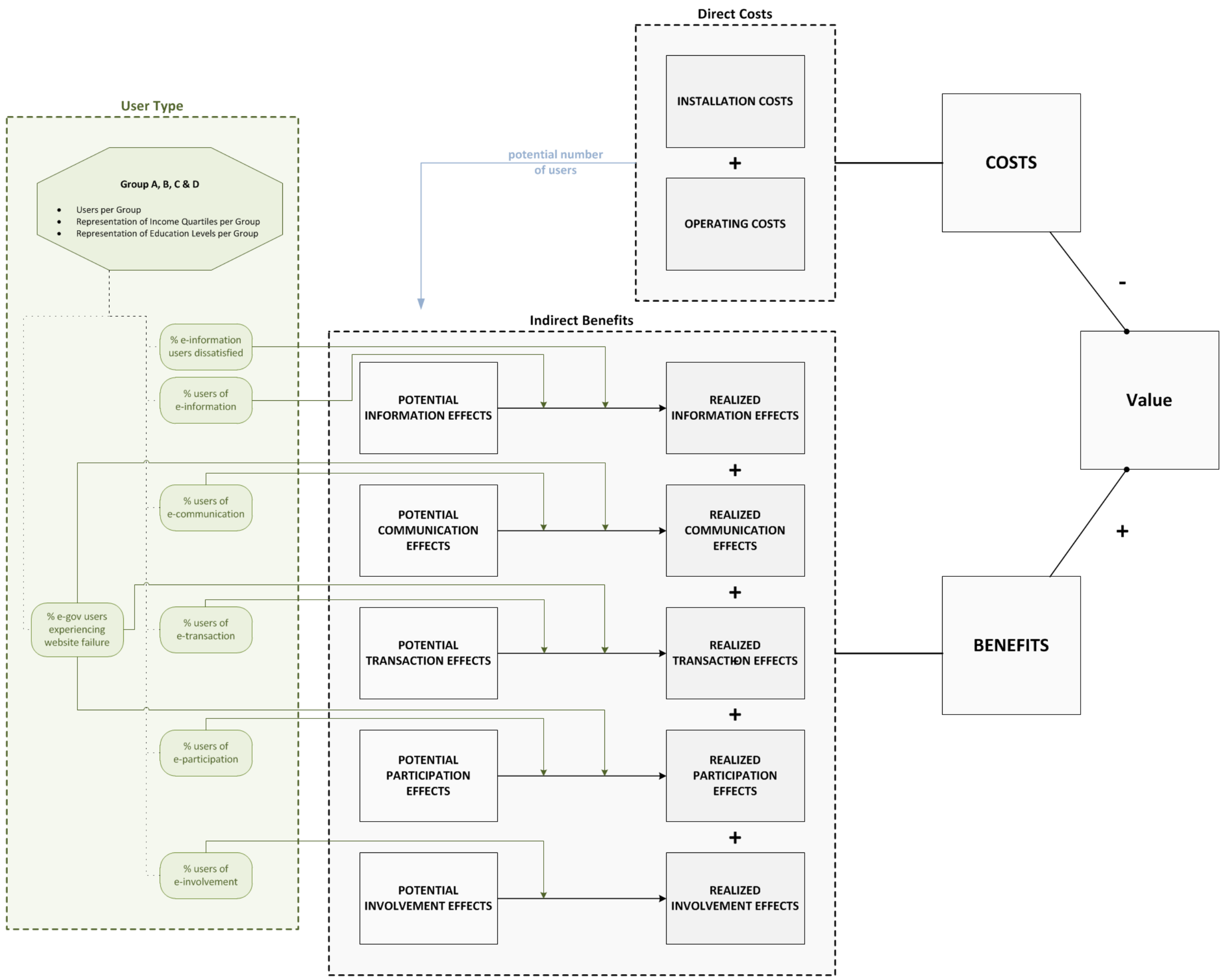

Figure 4.1: *Interaction between Model Components*

per user. In order to not over-complicate the conceptual model in Figure 4.2, these dependencies have not been included in the conceptual model.

The amount of equipment that needs to be replaced each year is based on an assumed normally distributed pattern of break-down (with a mean equal to the lifespan, and a standard deviation of half the lifespan), rather than a complete replacement of all equipment after the lifetime of the equipment (see Assumption 8, Appendix C). The residual value of the equipment is calculated using the double depreciation method (see Assumption 11, Appendix C)

Data As a detailed technical analysis of different options for Wi-Fi networks was out of scope, a set of minimum product characteristics have been identified and based on these characteristics a list of potential products (see Assumption 32). These lists have been identified using the Dutch website Tweakers, a website for comparing the prices and characteristics of technical products (Tweakers, 2018). Based on the search results on this site, for each specific piece of equipment, a list of products and prices has been created. The price used in the model is the median of these

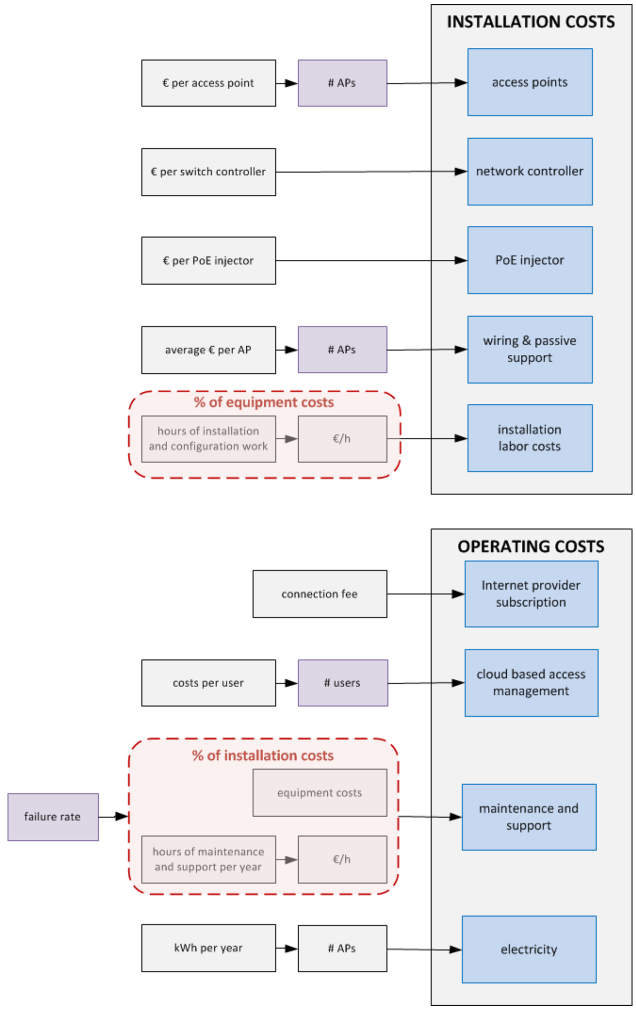

Figure 4.2: *Conceptual Model of Wi-Fi Network Costs*

lists, in order to not overestimate the likely price of equipment by the large influence of the highest prices in the lists. The price of the ISP connection has been determined in a similar way, by using the Dutch internet service provider comparison site, Prijsvergelijken.nl (Prijsvergelijken.nl, 2018). The VAT has been deducted from all the prices.

The assumptions regarding the costs of labour in installation (60% of equipment costs) and the prices of cloud-based management of customers have been adapted from Navío-Marco et al. (2018). The number of users has been calculated by taking an average use of 3MBps, and a backhaul network of 400 MBps, on the basis of which a maximum amount of user-hours are determined. Based on data from Thomas (2014) the amount of user-hours per user per year have been determined. Assuming only 10% of the network's potential is utilized, and based on the average amount of connections per year and the average connection time, a total amount of users has been determined to be 1650 per year. The data assumptions made have been reflected on in Appendix C, Table C.5, C.6 and C.7. The number of users is expected to be stable over the years (Assumption 15).

Results Since there is no revenue model, the net present value of the network, without including any indirect effects, is negative. At a discount rate of 5%, NPV is almost €-25,000, with an initial investment in year 0 of €2,203. This shows that a large part of the costs are not in building the network, but in operating and maintaining it. Since the NPV is negative, and there are no direct benefits, the rate of return and benefit/cost ratio cannot be calculated.

When these results are compared to those of Navío-Marco et al. (2018), the cost of initial installation is lower in general, however, when the model is based on the number of access points of Navío-Marco et al. (2018) instead of the dependency on the number of users the initial investment costs are higher. The difference can be explained by the fact that Navío-Marco et al. (2018) assumes lower prices of equipment. This does not only influence the initial investment, but also the costs of maintenance; leading to very different outcomes. In comparing the preliminary results of the model with Navío-Marco et al. (2018) one also has to take into account that the created model excludes all VAT and other taxes, while Navío-Marco et al. (2018) do not explicitly state doing so.

Navío-Marco et al. (2018) have based their model on the WiFi4EU initiative, an initiative focused on supplying municipalities with small grands to cover the installation costs of a Wi-Fi network. This small grand, in the form of a voucher, is of a value of 15,000 EUR (European Commission, 2018). The large difference between this assumed cost and the estimated costs of the model might be due to a couple of different reasons. Either, the European Commission has assumed higher prices for equipment, or they assume different network characteristics such as the number of access points in the network (for which they have a set minimum exceeding the amount of APs in this model). The most likely scenario is that is is a combination of both different cost assumptions and different network characteristics.

4.1.2 Benefits

E-government services have been defined in Section 2.2.1 in five different stages: information, communication, transaction, participation, and involvement. The model works based on these five stages and the potential benefits associated with each stage of e-government.

Conceptual Model Table 4.1 shows which of the possible e-government benefits defined in Section 2.2.1 have been quantified, and for which stages of e-government these effects have been quantified. The black boxes show to which of the five stages of e-government the benefit applies, the last column indicates whether the effect has been quantified (Y) or not (N). The postscript after the effect shows whether it is a benefit for the citizen (C) or government (G) or both.

The realized benefits of e-government due to the Wi-Fi network will be calculated based on Equations 2 and 3 (see Section 3, Methods). Figure 4.3 shows the complete conceptual model of the e-government benefits; a bigger version of each part of the model is given in Appendix B (Figure B.1 - B.5). Parts of the model are based on general data and are assumed to be the same for every user (the grey blocks), whereas some model inputs are dependent on the user type (the green blocks). The simplifications that have been made are shown within the red lined boxes. The main simplifications are that instead of the percentage of services of type X available as e-services and the percentage of people who use e-services, for each type of e-service the percentage of people who used internet for that type of service has been used (Assumption 20, Appendix C). This was

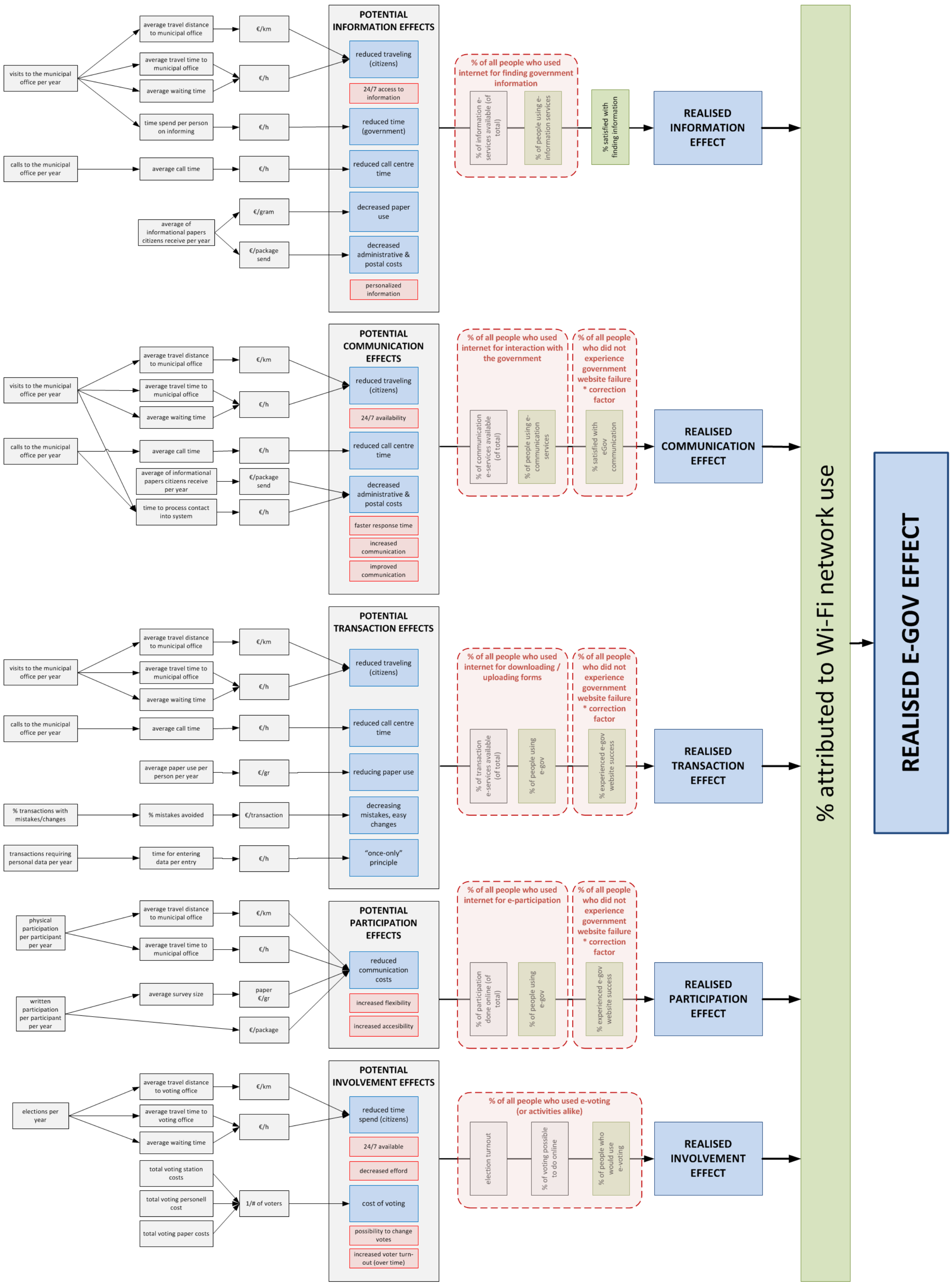

Figure 4.3: *Conceptual Model of E-Government Benefits*

	e-information	e-communication	e-transaction	e-participation	e-involvement	Quantified?
Travel Time (C)	X	X	X	X	X	Y
Travel Distance (C)	X	X	X	X	X	Y
Waiting Time, Visits (C)	X	X	X		X	Y
Waiting Time, Calls (C)	X	X				Y
Service Time, Visits (G)	X					Y
Service Time, Calls (G)	X					Y
Paper Use (G)	X	X	X	X		Y
Postal Costs (G)	X	X		X		Y
24/7 Service (C)	X	X			X	N
Personalization of Services (C)	X					N
Faster Response Time (C)		X				N
Increased Communication (C, G)		X				N
Improved Communication (C)		X				N
Information Processing Time (C, G)		X	X			Y
Avoided Mistakes (G)			X			Y
Voting Station Costs (G)					X	Y
Re-organization (G)						N

Table 4.1: *Quantified and Unquantified E-Government Effects*

done because of the availability of reliable data; there is no accurate data on the availability of some e-service types so this data has been used instead to encompass both availability and use. Another simplification is that instead of the failure rate, for e-information services the dissatisfaction rate of individuals have been used, and for the other services the general government website failure experienced by people (assuming a weighting factor because it is unlikely that everyone who experienced website failure did so for every time they used the website, resulting in the failure rate per e-government action) (Assumption 21, Appendix C).

Data

Government Services The number of government services a person is expected to use within a year in the categories information, communication and transaction is derived from the data from the UK government. GOV.UK (n.d.) publishes annual data on government transactions (which they define as providing information, government-citizen communication, and classic transactions). The number of possible participation occurrences per person is based on the data from Eindhoven and Groningen, presented by Michels and De Graaf (2010), the more general data from Eurostat (2018g), and the assumption that everyone who participates only would likely participate in 5% of the participatory activities offered. The number of involvement moments is based on an assumption of 1 election per year (local government, national government, presidential elections, European elections), which is about the election interval in many countries as proven by the dataset of IDEA (2018). All this data is generalized (the same) for all different countries and regions (see Assumption 34, Appendix C).

Unit Benefit A large part of the data on unit benefits is based on assumptions (Appendix C, Table C.5, C.6 and C.7), or assumptions based in Dutch or US data (Table C.3 and C.4); this is due to a lack of European data available. The limitations of these assumptions are that the situation in the Netherlands is not representative for the rest of Europe, as it is more densely populated (which would affect the average distance to the nearest governmental office, voting office, or costs voting). Similarly, elections throughout Europe differ largely with the US, as thereby also the assumptions based on US data are imperfect. Appendix C states the possible impact of these assumptions given their assumed reliability and the results of the sensitivity analysis.

Monetizing Factors In order to quantify the benefits of e-government economically, factors like time or travelled kilometres have to be expressed in monetary terms. For citizen time, the gross minimum wage has been taken into account (based on Eurostat (2018i)), expressing the value a citizen can be expected to minimally create should they be able to use their time differently. In contrast, government time is expressed in economic value using the gross average wage (based on Eurostat (2018h)), taking into account that this is expected to be closer to what a public officer would earn. Electricity costs are based on the average kWh electricity prices of households, without taxation (Eurostat, 2018b). The cost per travelled kilometre is largely dependent on the mode of travelling (walking and cycling being almost without costs, driving and public transport is more expensive), and for this the assumption has of 0.19 €/kilometer has been made, based on the travel allowance that can be given tax free in the Netherlands (Rijksoverheid, n.d.). All monetizing factors are generalized (the same) for all different countries and regions (see Assumption 34, Appendix C).

Use of E-Government Services The use of e-government services is dependent on the user type (see Section 4.1.3). The data on the use of e-services has been adapted from the Eurostat (2018f, 2018g): "obtaining information from public authorities websites" has been used as indicator for the use of e-information services, "interaction with public authorities" has been used as indicator for the use of e-communication services, "submitting completed forms" has been used as proxy for e-transaction services, "civic or political participation" has been used as indicator for e-participation, and "taking part in on-line consultations or voting to define civic or political issues" has been used as indicator for e-involvement. These numbers both reflect on the availability of these types of e-services, as they cannot be used if they are unavailable, and the use of the available services (see Assumption 20, Appendix C).

Failure of E-Government Provision Data on the failure of information provision has been adapted from the percentage of citizens experiencing issues with government websites (Eurostat, 2018f, 2018k) using Equation 4 (see Assumption 21, Appendix C). In this equation, F represents the failure rate, U the instances of usage, and f the number of failures assumed to be experienced by every person who reported an experience of failure. Data on failure is only available regarding non-service specific failure of government websites, failure is assumed to be evenly distributed over different services (see Assumption 22, Appendix C).

	potential effect		realized effect	% realized
	per interaction per person	per person	per person	
information	€ 4.65	€ 19.55	€ 7.71	39%
communication	€ 5.75	€ 45.73	€ 20.42	44%
transaction	€ 9.17	€ 12.59	€ 3.44	27%
participation	€ 2.92		€ 0.77	16%
involvement	€ 4.10	€ 2.21	€ 0.37	17%

Table 4.2: *Potential and Realized E-Government Effects*

$$F_{\text{service}} = F_{\text{user}} * \frac{f_{\text{TOT}}}{U_{\text{TOT}}} \quad (4)$$

Results The benefits of e-government can be described irrespective of user types and Wi-Fi network characteristics as potential benefits per person per action, potential benefits per person, and realized benefits per person (taking into account average data, instead of working with user type influenced calculations). These different results for benefits are described in Table 4.2. For participation, no potential effect per person could be determined, due to a lack of data on participation (including but not limited to e-participation).

JASPERS (2013) suggests using the European estimate of 50 billion euros in potential cost savings as a way of quantifying the potential benefits of e-government services for digital infrastructure investment CBAs (European Commission, 2015; JASPERS, 2013). This thesis opted to specifically identify and quantify different benefits, instead of using a black-box approach, in order to gain more insight in how e-government generates economic value for public Wi-Fi networks, however, this figure can be used to compare to the outcome of potential e-government effects. The European estimate of 50 billion euros per year, amounts to an average of €97.75 per person; this model amounts to a potential benefit of €80.09 per person per year. The fact that this estimate is lower than the European estimate can be due to assumptions regarding the number of services potentially used, a different way of valuing benefits (e.g. time), or the fact that not all effects have been quantified in this model. It is impossible to compare the two numbers in a more detailed way, as the European Commission does not provide more information about how this estimate has been made, and what it includes or does not include.

van der Wee et al. (2015) have quantified e-government benefits in relation to broadband networks in Eindhoven and Ghent. This resulted in about €100 per inhabitant of either city in benefits discounted over a course of 18 years (about €7 per person per year) in estimated realized benefits; an estimate which is much lower than that of the European Commission (2015) and this model. The assumed realized benefits per person per year are €31.70 (in the EU-28 region) and still, form is a large difference with €7 per person per year. The difference can in part be explained by the fact that van der Wee et al. (2015) have focused on two main e-government effects, that of e-transactions and e-information. If only the realized effects per person per year of those services are taken into account, the estimated realized benefits are €11.48, closer to the €7 of van der Wee et al. (2015).

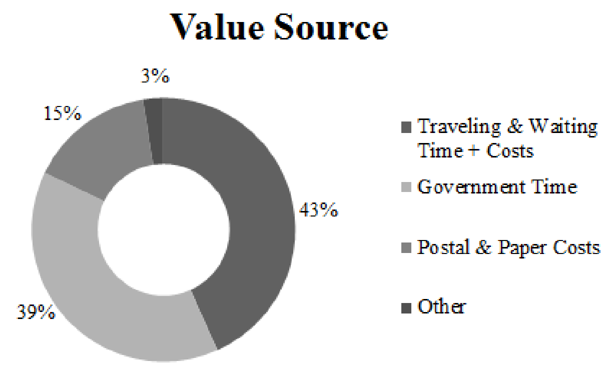

Figure 4.4: *Source of E-Government Benefits*

The fact that there is a difference in expected benefits, is in line with the finding of van der Wee et al. (2015) that studies differ greatly in the value they prescribe to e-government, which they attributed partially to differences in regional characteristics.

Source of Value van der Wee et al. (2015) have defined reduced travel time and costs as the main source of value in the use of e-government, with it accounting for over 80% of the created value. Figure 4.4 has been created to allow a similar analysis for this model. While gains in travel time and costs are a very important factor of benefit in the model created for this research, it accounts for less value (43%). 39% of monetary benefits is attributed to saving in government time (opposed to 7.3% to "reallocation administrative personnel" by van der Wee et al. (2015)), and 15% of benefits is postal and paper costs (opposed to 2.1% by van der Wee et al. (2015)). These difference can partially be attributed to the fact that the model that has been created values government time at a higher monetary value (average wage) compared to citizen time (minimum wage), that the model includes a more diverse range of e-government services (e-communication, e-participation and e-involvement), and that the model captures a different region and thus a different value of monetizing values (e.g. time, postal costs, travelling).

4.1.3 User Types

As described in Section 3.1.1 five different user types have been defined. A graphical representation of how the population is divided into these five categories is given in Figure D.1 (Appendix D). In order to calculate the shares of each of these groups in the population with the limited available data, it has been assumed that those who do not want access do not have (fixed or mobile) access. Based on T. E. Hall and Owens (2011) it has been assumed that 25% (WN) of those without access are in the category of people who do not want access. The calculations of the shares have been based on three statistical parameters defined by Eurostat (2018c): % of population with a fixed connection (F_T), % population with a mobile connection (M_T), % people with a fixed connection who also have a mobile connection (M_F). The share of the population in each of these user groups has been defined by Equations 5 - 9.

$$\text{Group A} = F_T * M_F \tag{5}$$

$$\text{Group B} = F_T * (1 - M_F) \tag{6}$$

$$\text{Group C} = M_T - (F_T * M_F) \tag{7}$$

$$\text{Group D} = (1 - F_T - M_T + (F_T * M_F)) * (1 - WN) \tag{8}$$

$$\text{Group E} = (1 - F_T - M_T + (F_T * M_F)) * (WN) \tag{9}$$

In order to differentiate the effects between user groups, the typical composition of each user group needs to be defined. In general, the literature (see Section 2) has suggested the two most important demographic characteristics are income and education, both related to internet access/use and e-government use. Using the Eurostat (2018c) database, the share of each income quartile per user group could be determined. The distribution of education levelswas not available in the database, assumptions have been made based on older (2013) data on home internet access (Eurostat, 2018d) and data on internet use (Eurostat, 2018a) and these educational differences are assumed to be the same over mobile and home-based access. An example of what the composition of the groups looks like for the EU-28 region is given in Figure D.2 (Appendix D).

Mediating Effects of User Types The composition of the users within each user type is used to estimate the e-government use and experienced problems within that group, as stated in Assumption 14 (Appendix C). The differences between user types will be based on an average of the number for that user type based on education levels and income levels (in case both are available), following Equation 10. In Equation 10 Y_X is e.g. the level of e-government use for the users with user type X, E_{Xe} is the share of people with education level e in user group X, I_{Xi} is the share of people with income level i in the user group X, and Y_e or Y_i is the level of e.g. e-government use of education/income level e/i. The calculation example in Appendix D shows that while there is a small difference between including and excluding internet access and use in the calculation, this can be neglected in the calculations.

$$Y_X = \frac{\sum_{e=1}^{3}(E_{Xe} * Y_e) + \sum_{i=1}^{4}(I_{Xi} * Y_i)}{2} \tag{10}$$

Benefit Weighting Based on User Types The user types will not only influence to what degree users are expected to use e-government services but also to what degree the benefit of e-government service use will be attributed to the public Wi-Fi network. As these numbers cannot be determined based on available empirical data, and previous research does not give any indication of how to weight the effect of Wi-Fi on e-government use, it has to be determined based on the reasoning of user types. As this weighting of benefits will be a very important determinant of the model outcome, three different weighting sets for attributing indirect e-government benefits to Wi-Fi networks have been determined: a low weighting set, a middle-ground weighting set, and a high weighting set.

	Low	Middle	High
Type A	0.0%	0.0%	0.1%
Type B	0.0%	5.0%	10.0%
Type C	10.0%	30.0%	50.0%
Type D	70.0%	85.0%	100.0%
Type E	not relevant	not relevant	not relevant

Table 4.3: *Weighting Sets for Attributing Benefits to Wi-Fi Networks*

The weighting sets shown in Table 4.3 have been determined based on the characteristics of each user type. User type A are those people that have both a fixed connection and a mobile connection, the only possible benefit for this group is that they use the Wi-Fi network when outside and thereby save their (limited) mobile data plan for other uses. However, this benefit is expected to be very small and not largely used, and thus the low and middle weighting factors are assumed to be 0% and the high factor 0.1%. User type B are those that have a home connection, but no mobile connection; their possible benefit is to be able to use e-government services away from home. The low weighting assumes that this never happens, the middle assumes that this happens very rarely, the high weighting set assuming it happens sometimes but not that often. User type C are those people that only have a mobile connection, and similarly to type A their benefit is to save their (limited) mobile data plan for other uses, however for this type the opportunity costs of using their data plan are assumed to be larger as their means of using the internet are more limited. User type D are those that have no way of connecting, and as such the high weighting attributes all their e-government activities to the public Wi-Fi network. The low and middle scenario attribute fewer e-government benefits to the Wi-Fi network, acknowledging that these users might use other means (e.g. Wi-Fi at a train station, or library) to connect to the internet. No weighting has been determined for user type E, as they are non-users of both the internet and e-government services.

4.2 Sensitivity Analysis

As stated in Section 3, critical variables are defined for sensitivity testing. Critical variables are those variables for which a 1% change in value (either a negative or positive change) results in a change of 1% or more in the ENPV (Economic Net Present Value, i.e. the main model outcome), following the definition by the European Commission (2014). Critical variables have been identified using the base case scenario, based on EU-28 averages, using the three different weighting sets as defined in Table 4.3. For each of the variables that could be defined as critical, a switching value has been determined. The switching valve is the numerical value of the variable where the ENPV becomes zero (with all other variables remaining the same); the main purpose of defining these values is to define how large the influence of these critical values is. The outcome of the sensitivity analysis, as shown in Table 4.4 will be discussed per category of a variable; the column C indicates whether the variable is critical in the specific weighting set, column S presents the switching value.

Area	Description	Data	Unit	Low		Middle		High	
				C	S	C	S	C	S
Wi-Fi Nework Costs	Equipment Lifetime	5.00	Years	X	12.47				
	Monthly Connection Fee	50.42	EUR	X	31.84				
	Cloud Based Management	0.84	EUR/user	X	1.21	X	2.33		
Amount of Wi-Fi Network Users	% of potential usage realized	0.10		X	0.12	X	0.04	X	0.02
	Time per Connection	0.74	H/con	X	0.60	X	1.78	X	2.99
	Connections per User per Year	95.67		X	77.11	X	230.63	X	386.15
	Backhaul Network	400.00	MBps	X	496.24	X	165.92	X	99.10
	Average Bandwidth per User	3.00	MBps	X	2.42	X	7.23	X	12.11
Connectivity Alternatives	% voluntary non-usrs	0.25	%	X	0.19				
Time & Distance	Minimum Wage	1549.99	EUR/month	X	1684.96	X	932.05	X	583.01
	Ratio Minimum and Average Wage	0.44		X	0.39	X			
	Distance to Government Office	5.00	km	X	6.47				
	Waiting Time at Government Office	0.20	H	X	0.33				
	Time per Visit	0.17	H	X	0.22				
	Time per Call	0.17	H	X	0.22				
	Time for Data Entry	0.05	H	X	0.09				
(e-)Goverment Use	Government Contact Moments	13.53		X	14.46	X	9.34	X	7.03
	% experiencing problems	0.24		X	0.07				
	% using e-information	0.41	%	X	0.53				
	% using e-communication	0.49	%	X	0.55	X	0.23	X	0.08
	% using e-transaction	0.30	%	X	0.49				

Table 4.4: *Outcome Sensitivity Analysis*

Wi-Fi Network Costs The cost of a Wi-Fi network are determined by multiple variables, and when the benefits of e-government are modestly attributed to the Wi-Fi network the equipment lifetime (the main determinant of maintenance costs), connection fee and cloud-based management (the two main determinants of operating costs) are critical variables; all with switching values in the realistic range. In the middle weighting set, only the cost of cloud-based management remains critical. These variables are all critical determinants of costs over the network's lifetime.

Amount of Wi-Fi Users A large set of critical variables is related to the number of people that will use the network, and all of these variables are critical regardless of the weighting set applied. These variables are critical because the e-government benefits (the only source of value creation in this model) are directly dependent on the number of people that use the network. As such, it is not surprising that these variables are labelled as critical. However, still an important conclusion can be drawn from this label; how well the Wi-Fi network will be used (and how, in terms of bandwidth per user, for example) determines whether it will sufficient public value to offset the cost of the network. Especially the number of realized users (of the full potential) is critical, while currently assumed to be 10% the literature suggest that uptake is often much lower than expected (C. A. Middleton, 2007). Currently, apart from a few small-scale surveys (e.g. Picco-Schwendener et al., 2017; Thomas, 2014), not enough is known about how people use public Wi-Fi networks.

Connection Alternatives The only variable related to connection alternatives that is critical is the amount of voluntary unconnected, and this is only critical when the low weighting set is applied to the model. This seems not to be in line with the premise that the available connection alternatives (alternative technological opportunities) are an important factor is the ability to create value. However, the sensitivity analysis only reflects a change in one of the connectivity variables, where in reality these are an interconnected set and will often change simultaneously. Therefore, the relationship between connectivity alternatives and public value will be explored through scenarios.

Time & Distance As already discussed in Section 4.1.2, the primary benefits are in the form of travel and waiting time (citizen) and service time (government). The importance of this is also evident in the results of the sensitivity test, as the distance and time spend for travelling and service is critical when the low weighting set is applied and the monetary value of time is critical in all three weighting sets.

Use of e-Government The main critical variable in this category is the amount of citizen-government interactions per year, as the benefit of e-government is calculated per interaction this has a large influence on the model outcome. In the low weighting set, the percentage of people that experience difficulties with e-government platforms is critical. The percentages of people who use e-information, e-communication and e-transaction services are critical when the low weighting set is applied, for the middle and high weighting set only the percentage of e-communication users is critical. This is indicative of the potential value of each service stage; e-communication has the highest potential value, followed by e-information and e-transaction, as also shown in Table 4.1.

4.3 Scenarios

This section will elaborate on the scenarios used to answer Subquestions 2 and 3, as defined in the introduction (Section 1). Two separate scenarios are created to answer the research questions, based on Eurostat country statistics. The first scenario (4.3.1) will be created to observe the difference between countries with different connection alternatives. The second scenario (4.3.2) will compare countries with varying digital skills.

The decision which country is to be used for which scenario, was made based on Eurostat statistics on broadband and mobile connections (Eurostat, 2018a), digital skills (Eurostat, 2018e) and e-government use (Eurostat, 2018g, 2018f).

4.3.1 Connection Alternatives

In order to simulate the difference between countries that have different connection alternatives without interference from other country-based statistics on e-government, sets of countries need to be found that are similar in e-government use but different in connection alternatives. As proxies for connection alternatives (and thus the differences in distribution among user groups), the percentage of mobile broadband connections and the percentage of home connections are used. There are three possible sub-scenarios:

1a. Similar fixed (home) connectivity, different mobile connectivity rates
1b. Different fixed (home) connectivity, similar mobile connectivity rates
1c. Different fixed (home) connectivity and mobile connectivity rates

Scenario 1a One set of countries has been used for this comparison: Sweden and Finland. While the countries are exactly the same in terms of fixed connectivity, there is a large difference in mobile connectivity rates. When taking into account other socio-economic contextual factors, the use of e-government is very similar; although Finland seems to be slightly lagging behind Sweden (except for e-information). The comparison between the two countries is graphically shown in Figure 4.5. A second comparison will be made between Slovakia and Slovenia, two countries who differ in a way similar to Sweden and Finland, in order to validate that the result of the first comparison (see Figure E.2, Appendix E).

Scenario 1b One set of countries has been used for this comparison: Belgium and Lithuania. These two countries are similar in mobile connectivity rates, Belgium has a much higher home connectivity rate. Furthermore, the e-government use pattern is similar, although Belgium has more e-communication and Lithuania has higher e-participation and e-involvement rates. The comparison of the two countries is graphically shown in 4.6. A second comparative set is Portugal and the EURO area, however, this is a less suitable match (see Figure E.4, Appendix E). While the mobile connectivity rates are similar, in countries with lower home connectivity rates, mobile connectivity is more biased towards those that also have a home connection, resulting in a different distribution of users over user types A, B and C.

The difficulty in finding suitable matches on the level of home connectivity rates and e-government usage rates with different mobile connectivity rates can also be seen as a consequence of the large

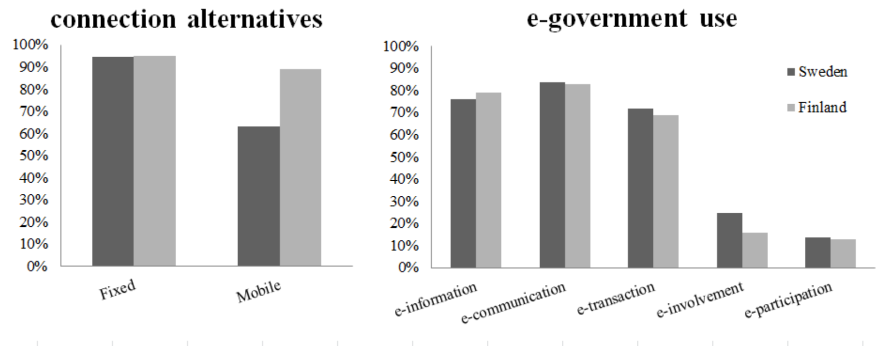

Figure 4.5: *Scenario 1a Country Comparison*

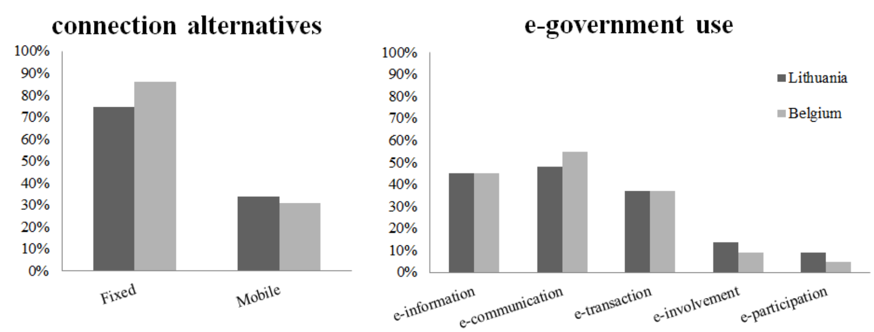

Figure 4.6: *Scenario 1b Country Comparison*

correlation between Internet access opportunities and e-government use which has been shown in literature (T. E. Hall & Owens, 2011; Reisdorf & Groselj, 2017a).

Scenario 1c Two sets of countries have been used to analyze the combined impact of a change in overall connectivity (a change both fixed and mobile connectivity rates in the same direction): Slovenia & Greece and Hungary & Portugal. Slovenia and Hungary both have higher connectivity rates compared to Greece and Portugal, as shown in Figures 4.7 and 4.8. The rates of e-government use in both comparisons are not exactly equal, however as use in the first three stages is similar and these three stages have the highest potential value per user (see Table 4.2) both comparisons are expected to yield meaningful results.

4.3.2 Digital Skills

The digital skills of a country's population are an estimate of how digitally literate they are, it is a concept traditionally used in the digital divide literature (e.g. van Dijk, 2017) and in relation to the use of e-government services (e.g. Vicente & Novo, 2014). The second set of scenario test has the objective to identify whether the digital skills of a population (which are also indicative of both the access opportunities and the use of digital services) influence the public value of a Wi-Fi network.

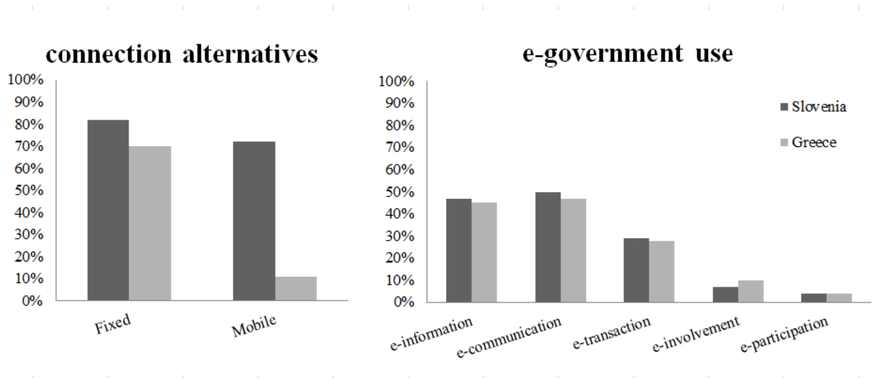

Figure 4.7: *Scenario 1c Country Comparison: Slovenia & Greece*

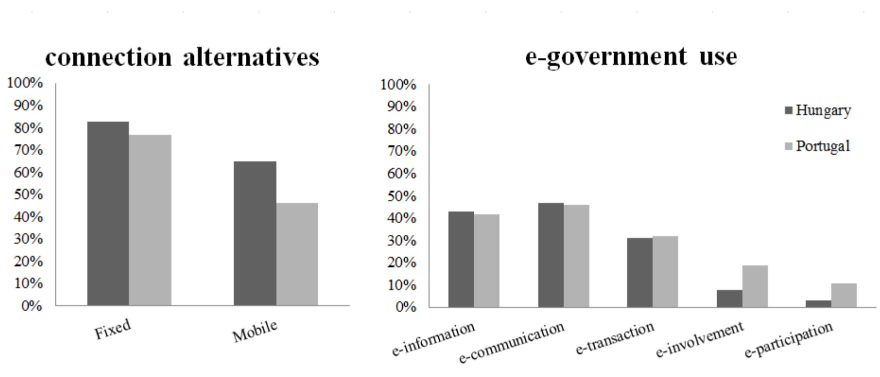

Figure 4.8: *Scenario 1c Country Comparison: Hungary & Portugal*

The influence of digital skills will be analyzed in a three-step process. The first step of this part of the analysis will be to identify whether similar sets of digital skills lead to similar model outcomes. The second step will focus on the effect of larger/smaller digital skills, by comparing countries or sets of countries with different digital skills. Lastly, because it has been suggested that digital skills together with access opportunity are a large influencing factor of e-government use (Reisdorf & Groselj, 2017a), countries with similar connectivity rates but different digital skills will be compared.

For the first step, six sets of countries to be compared have been identified, based on Eurostat (2018e) data of the digital skills per country. These are, in increasing order of digital skill: Romania & Bulgaria, Latvia & Ireland, Slovenia & Lithuania, Austria & Germany, United Kingdom & Denmark, Switzerland, Finland & Sweden. Appendix E, Figures E.13-E.18 gives a visual comparison of the digital skills, connectivity and e-government use for each of these sets of countries.

For the third step, five sets of countries to be compared have been identified, based on Eurostat (2018a, 2018e): Macedonia & Lithuania, Portugal & Croatia, Poland & Slovakia, Slovenia & Hungary, EU-28 & Ireland. Appendix E, Figures E.19-E.23 gives a visual comparison of the digital skills, connectivity and e-government use for each of these sets of countries.

5 Results

In this section, the results of the base model, as presented in Section 4.1, and the results of the different explored scenarios (Section 4.3) are presented.

5.1 Base Scenario

The result of the base model depends on the chosen weighting set. For the low weighting set, the expected ENPV (economic net present value) is negative (€-1,641.34), but the ENPV for the middle and high weighting sets are positive (€11,913.53; and €25,645.32). A probabilistic risk analysis, in the form of a Monte-Carlo analysis, has been performed to assess the spread of potential outcomes taking into account uncertainty and variability of the model's input variables. A first observation from the results, as shown in Figure 5.1 is that the spread of potential outcomes increase with the higher weighting sets, indicative of the fact that the largest part of outcome variability is due to the e-government benefits, Wi-Fi network costs. A second observation is the percentage of cases in which the ENPV is positive: for the low weighting set, 47.3% of outcomes is positive, for the middle weighting set, 94.8% of the outcomes is positive, and for this high weighting set, 99.7% of the outcomes is positive. These two observations show that the way in which e-government benefits are attributed to Wi-Fi network use does not only determine the model outcome but also largely determine the spread of outcomes.

Section 4.1.1 already included a reflection on the cost-only model, reflecting the private value of the Wi-Fi Network to be approximately €-25,000. This finding supports Hypothesis 1, stating the private value is negative. The largest portion of the private costs is operational (maintenance and running) costs. When comparing these results to those of Navío-Marco et al. (2018), their cost calculation of a Wi-Fi network in a standard park is close in outcome to this model (applying their average operational costs per year over the 10-year period and assuming the total equipment is replaced in year 5, discounted with a 5% discount rate), with the limitation that they have differentiated between applications for public Wi-Fi. Overall, the broad findings of this study (sign and order of magnitude of costs), are in accordance with the results presented by Navío-Marco et al. (2018).

In general, assuming the middle weighting set is the most realistic, it can be concluded that the Wi-Fi network yields a positive economic value and thus generates public value larger than the private costs, supporting Hypothesis 2. However, the large impact of the weighting sets shows that there is some uncertainty regarding this, as attributing e-government use to a lesser extent to public Wi-Fi network use will lower model outcome.

5.2 Scenario 1: Connection Alternatives

Scenario 1a Table 5.1 shows the results of the comparison between Finland and Sweden for both the application of connection rates (keeping the rest of the country-specific variables at EU-28 levels) and the application of all country-specific variables. If only differences in connection rates are taken into account, there is a clear difference between the countries for the middle and high weighting

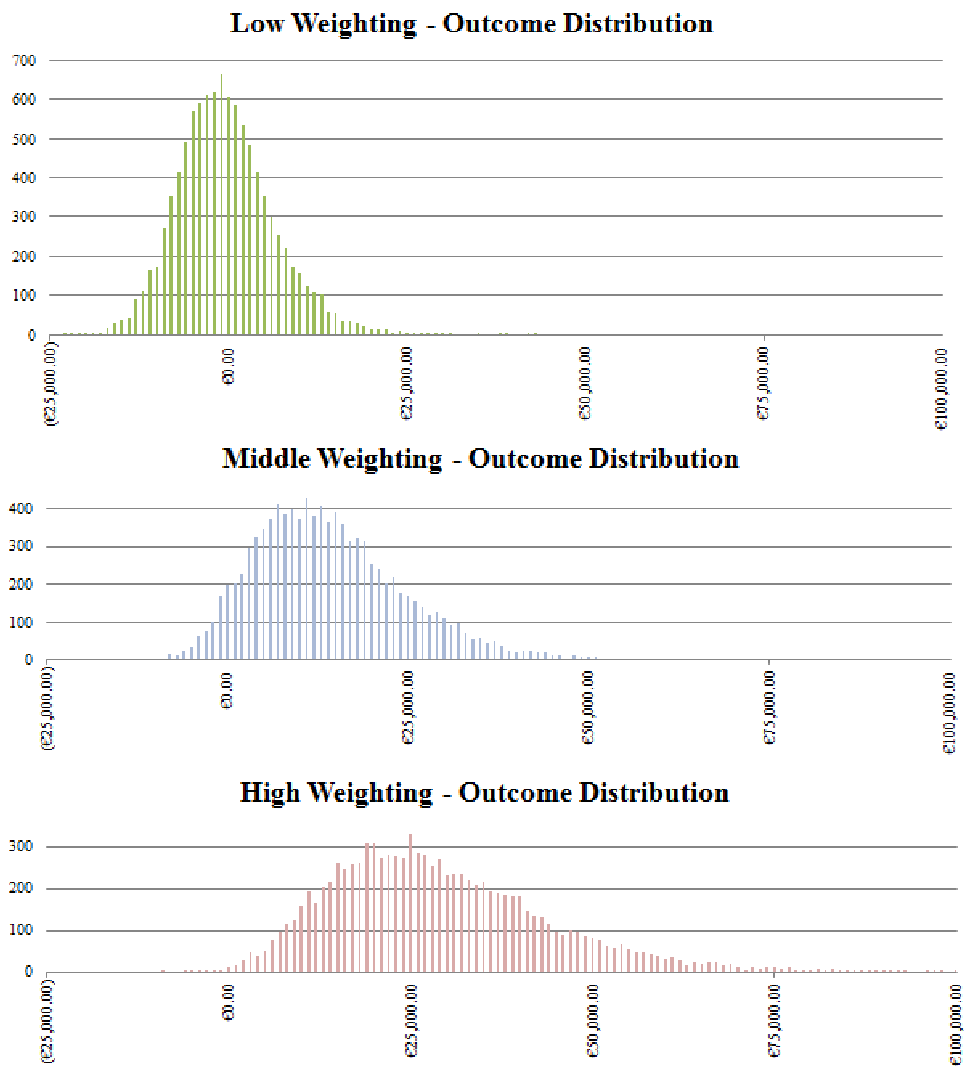

Figure 5.1: *Results of Monte-Carlo Simulation of the Base Case (10,000 iterations)*

set, whereas the difference for the low weighting set is minimal. If other country-specific variables are included, differences between the two countries become slightly larger; this can be explained by the fact that Sweden has a slightly higher overall e-government use than Finland (see Figure 4.5). In general, the effect of mobile connectivity rates can clearly be observed to have a (relatively small) negative impact on model outcome and public value. The comparison between Slovakia and Slovenia yields similar results (see Appendix E, Table E.2). The results of both country comparisons are significant, although the numerical difference is dependent on data assumptions (see Figures E.7 and E.8).

Scenario 1b Table 5.2 shows the results of the comparison between Belgium and Lithuania for both the application of connection rates (keeping the rest of the country-specific variables at EU-28 levels) and the application of all country-specific variables. If only differences in fixed connection rates are taken into account, there is a large difference irrespective of the applied weighting set.

	Finland			Sweden		
	ENPV	B/C Ratio	ERR	ENPV	B/C Ratio	ERR
Connection Rates Only						
Low Weighting	-16,701.48	0.33		-15,739.60	0.37	
Middle Weighting	-13,915.63	0.44		-7,000.04	0.72	
High Weighting	-10,776.62	0.57		1,984.89	1.08	0.22
Connection Rates & e-Government Use						
Low Weighting	-5,328.90	0.79		-2,667.05	0.86	
Middle Weighting	1,033.48	1.04	0.14	11,746.82	1.62	0.89
High Weighting	8,109.22	1.32	0.65	26,551.72	2.40	1.82

Table 5.1: *Results Scenario 1a*

	Belgium			Lithuania		
	ENPV	B/C Ratio	ERR	ENPV	B/C Ratio	ERR
Connection Rates Only						
Low Weighting	-1,137.83	0.95		20,659.27	1.82	1.45
Middle Weighting	14,871.44	1.59	1.09	38,778.51	2.55	2.58
High Weighting	31,010.87	2.24	2.10	57,048.13	3.28	3.72
Connection Rates & e-Government Use						
Low Weighting	2,745.84	1.11	0.28	21,390.08	2.27	1.50
Middle Weighting	22,330.01	1.89	1.56	38,630.73	3.29	2.57
High Weighting	42,081.42	2.68	2.79	56,040.54	4.32	3.65

Table 5.2: *Results Scenario 1b*

	Slovenia			Greece		
	ENPV	B/C Ratio	ERR	ENPV	B/C Ratio	ERR
Connection Rates Only						
Low Weighting	4,355.23	1.17	0.40	26,365.35	2.05	1.81
Middle Weighting	12,410.92	1.50	0.93	50,208.29	3.00	3.29
High Weighting	20,776.60	1.83	1.46	74,103.48	3.96	4.77
Connection Rates & e-Government Use						
Low Weighting	6,732.18	0.56	1.36	16,749.35	1.67	1.21
Middle Weighting	14,042.97	1.04	1.74	38,866.59	2.55	2.59
High Weighting	21,721.68	1.52	2.15	61,039.24	3.44	3.96

Table 5.3: *Results Scenario 1c*

These difference remain when other country-specific variables are taken into account and have no critical sensitivity to data variations (see Figure E.9). In general, the effect of fixed connectivity rates can clearly be observed to have a large negative impact on model outcome and public value; although it should be noted that the impact difference can have been impacted by the fact that Belgium has a slightly higher e-government use. The comparison between Portugal and the EURO area shows different results (see Appendix E, Table E.4), when only comparing based on connectivity rates the EURO area has lower outcomes, as is expected. However, when other country-specific variables are included, model outcomes are higher in the EURO area than for Portugal; likely influenced by the fact that the EURO area has higher connectivity rates but also slightly higher e-government use. However, it should also be noted that the difference between the EURO area and Portugal is critically dependent on data assumptions (see Figure E.10; expected inter-country differences include both positive and negative values). Overall, these results suggest that while the impact of fixed connectivity rates on the model outcome is high, this can easily be offset by differences in e-government use.

Scenario 1c Table 5.3 shows the results of the comparison between Slovenia and Greece for both the application of connection rates (keeping the rest of the country-specific variables at EU-28 levels) and the application of all country-specific variables. In both the comparison based on connectivity rates only and the comparison with all country-specific variables, there is a clearly observable difference: the country with the higher connectivity rates (Slovenia) has a lower expected outcome, although it should be noted that there is some critical sensitivity to data variations (see Figure E.11; not all differences in the Monte-Carlo simulation are positive). The comparison between Portugal and Hungary area shows similar results although the difference between the countries is smaller (as is the difference in connectivity rates) (see Appendix E, Table E.6), and this comparison has shown no critical sensitivity in inter-country difference in sensitivity testing (see Figure E.12).

Independent of e-Government Use A final comparison which is made is that between all countries used in this analysis, using all country-specific variables (connectivity rates, e-government use, experience problems). This has been done because a relationship between the connectivity rates and the availability and use of e-government services has been suggested (Seri et al., 2014), and thus the negative effect of connectivity rates on expected value might be offset by the increased availability and use of e-government services. In order to do so, scatterplots of model outcome and the main connectivity rate (i.e. the population average of either fixed or mobile connectivity) have been generated, an overview of all outcomes is presented in Table E.7 (Appendix E). Figures 5.2 and 5.3 show the scatterplots of model outcome and connectivity rates, with a linear and polynomial trendline. These plots suggest a very weak relation between fixed connectivity rates and model outcome ($R^2 = 0.0323$ for the linear trendline, $R^2 = 0.0705$ for the polynomial trendline), and a slightly more significant relation between mobile connectivity rates and model outcome ($R^2 = 0.2135$ for the linear trendline, $R^2 = 0.2579$ for the polynomial trendline) showing a clear decline in value for higher connectivity rates.

In short, Hypothesis 3 anticipated that the public value of a Wi-Fi network would be lower if there are more connectivity alternatives available. The results of scenario 1a, 1b and 1c support this hypothesis, as in all cases the country with the higher connectivity rate(s) has a lower model outcome and most of the results of the scenario tests have high robustness. However, when comparing all

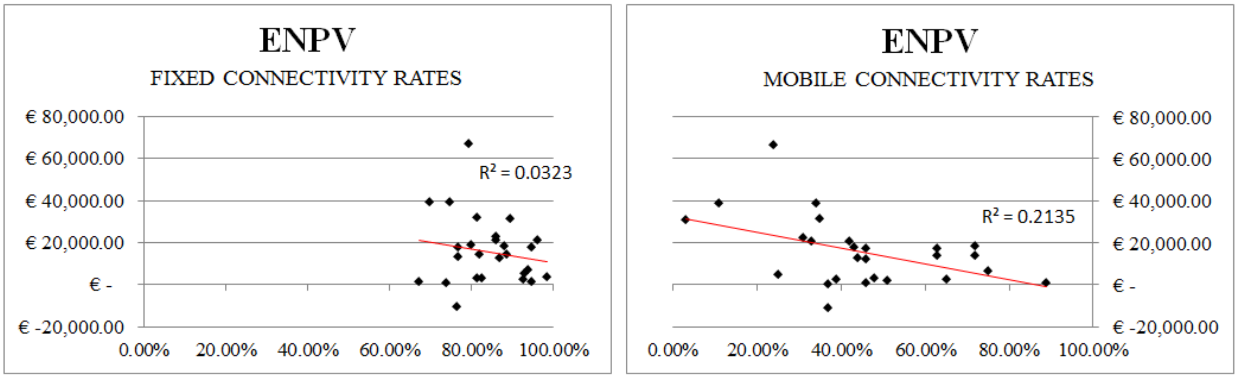

Figure 5.2: *Scatterplot of ENPV (Middle Weighting Set) outcomes over Connectivity Rates (with linear trendline)*

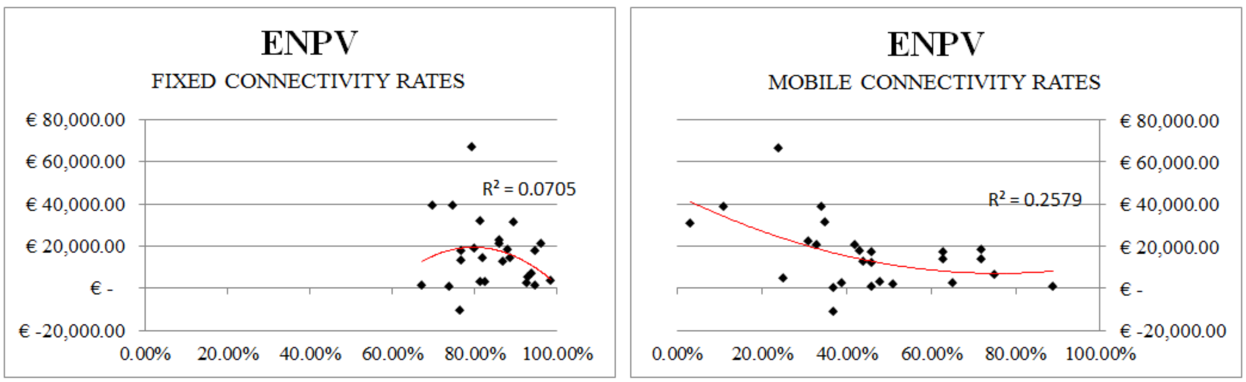

Figure 5.3: *Scatterplot of ENPV (Middle Weighting Set) outcomes over Connectivity Rates (with polynomial trendline)*

countries, irrespective of their e-government use, the correlation between outcome and fixed connectivity rates almost disappears. This shows that while connectivity rates are an important factor in the value of public Wi-Fi, contextual factors (like e-government use) are large enough to offset the effect. Essentially, while there is support for both Hypothesis 3, these results also support the notion that emphasis must be on the larger context in which public Wi-Fi is deployed.

5.3 Scenario 2: Digital Skills

Six sets of countries (five pairs and a set of three) with similar digital skills have been identified (see Section 4.3.2), however, comparison of outcomes within these sets showed no (or very limited) similarities in outcomes. A possible explanation of this lack of similarities is that the different sets of countries differ greatly in both connectivity rates and e-government use, as shown in Appendix E. While it is possible for these difference to cancel each other out (as e-government use has a positive effect of public value and connectivity rates have a negative effect on public value), this does not happen in the analyzed countries as can be observed from the results shown in Table 5.4.

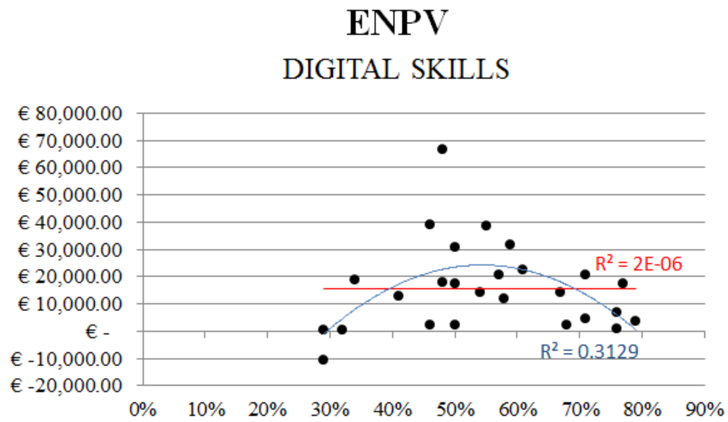

Figure 5.4: *Scatterplot of ENPV (Middle Weighting Set) outcomes over Digital Skills*

Figures E.24 - E.29 show that none of the comparisons are critically sensitive to expected data variations (i.e. none have a spread of potential differences that includes both positive and negative values; the same country always has the highest expected value).

The goal of analyzing countries with different digital skills was not only to look at the countries with similar digital skills but also to see if there was a general trend that could be observed. There is no direct observable pattern apparent in Table 5.4. Figure 5.4 shows a scatterplot of the country's (middle weighting set) ENPV with a linear trendline (in red), this line shows that there is no significant linear relation between digital skills and model outcome. The introduction of a polynomial trendline (in blue) leads to a better fit of the trendline, suggesting an inverted U-shape like relation.

As the lack of trend and comparability between countries with similar digital skills might be attributed to the difference in connectivity rates between the countries, as the literature has suggested access opportunities and digital skills as two important factors for e-government use (e.g. Reisdorf & Groselj, 2017a), countries with similar connection rates (both fixed and mobile) and different digital skills have been compared. Table 5.5 show that in four out of five comparable areas, the country with the highest digital skills in the population leads to higher model outcomes. It should, however, be noted that most of these comparisons are sensitive to data assumptions, as can be seen in Figures E.30 - E.34, where the spread of potential inter-country differences includes both positive and negative values. Therefore, while a relationship between digital skills and public value is suggested in these result, the relationship is not very robust.

Hypothesis 4 suggested that higher digital skills would lead to a higher public value of Wi-Fi networks. The results contradict this suggestion, as there is no clear positive effect of digital skills on the model outcome, and Figure 5.4 even suggest that higher digital skills might lead to lower values. Hypothesis 5 suggested that the effect of digital skills is strongest in those countries with similar connectivity rates, Table 5.5 confirms this in showing that in most cases the level of digital skills can be a possible explanation of the difference between countries with similar connectivity rates. However, for one pair of areas this is not the case (EU-28 & Ireland) and there is a lack of robustness in the results, as such the evidence of this is not indisputable.

	Digital Skills (Basic+)	ENPV
Romania	29%	-10,890.41
Bulgaria	29%	602.74
Latvia	48%	66,468.16
Ireland	48%	18,043.26
Slovenia	54%	14,042.97
Lithuania	54%	38,621.79
Austria	67%	14,102.84
Germany	68%	2,172.30
United Kingdom	71%	4,707.01
Denmark	71%	20,613.32
Switzerland	76%	6,664.80
Finland	76%	1,031.54
Sweden	77%	17,237.46

Table 5.4: *Results Scenario 2: Country Comparison based on Digital Skills*

	Digital Skills	Fixed Rate	Mobile Rate	ENPV
Macedonia	32%	74%	37%	304.90
Lithuania	55%	75%	34%	38,621.79
Portugal	50%	77%	46%	17,422.61
Croatia	41%	77%	44%	12,901.19
Poland	46%	81%	39%	2,372.12
Slovakia	59%	81%	35%	31,682.38
Slovenia	54%	82%	72%	14,042.97
Hungary	50%	83%	65%	2,327.84
EU-28	58%	87%	46%	11,925.02
Ireland	48%	88%	43%	18,043.26

Table 5.5: *Results Scenario 2: Country Comparison based on Connectivity Rates*

6 Conclusion

This thesis has focused on the ability of public Wi-Fi to support digital equality and help overcome the digital divide and the extent to which this can be expected to happen. This has been done by literature study regarding the concept of the digital divide, e-government benefits and Wi-Fi networks, and the creation of a socio-economic model of the costs and benefits associated with public Wi-Fi. This section will present the conclusion of the study, by first answering the three subquestions as defined in the Introduction (Section 1), using the literature study and the results (see Sections 2 and 5), before answering the main research question.

6.1 Public Value

Subquestion 1 focused on the costs and benefits of and Wi-Fi network and thereby the extent to which this creates public value. The potential ways of how a Wi-Fi network can create public value have been studied in literature and quantified in the socio-economic model. Although there are many possible uses of a public Wi-Fi network, the focus has been placed on e-government as e-services are suggested as one of the main sources of value creation by connectivity (Hayes, 2011; van der Wee et al., 2015), and e-government services are citizen-targeted (like public Wi-Fi) and are of all e-services most deployed mobile and thus independent of location (Archer, 2015; Nica & Potcovaru, 2015; United Nations Department of Economic and Social Affairs, 2012). The main benefit created by the use of e-government services through public Wi-Fi is time-saving (for citizens and government), and to a lesser extent decreasing postal and other administrative costs (see Figure 4.4) (van der Wee et al., 2015). Therefore, it can be concluded that public Wi-Fi creates public value by facilitating the use of e-government services resulting in time-saving and decreased governmental costs.

Subquestion 1 focuses not only on what creates value but also on the value that is created, to answer this part of the question the model outcome is important. Section 5.1 outlines the main outcome of the model, but also already stresses that there is a large dependency on model inputs, especially (1) the realized usage of the network and (2) the extent to which e-government benefits are attributed to Wi-Fi network usage. In the most base case of the model (assuming 10% realized usage and middle weighting set for e-government benefit), the economic net present value (ENPV, or public value) is positive (almost €12,000). This is further expressed the Monte-Carlo simulation across the different defined weighting set (see Figure 5.1), which shows that uncertainty in defining the public value of the network is high and it is impossible to give one value as public value of a Wi-Fi network. Although there is a large uncertainty to the exact results, the results do show that the benefits likely outweigh the costs if sufficient e-government use can be attributed to the use of the Wi-Fi network.

6.2 Connection Alternatives

Subquestion 2 focuses on the possible influence of available connection alternatives on the public value of Wi-Fi networks, this has been studied by implementing scenarios (see Section 4.3) to simulate different sets of connectivity rates. The first way to analyze the impact of the available connectivity alternatives has been to study the isolated effect by comparing context with similar e-government use. The results of this analysis (see Section 5.2) prove that both lower mobile, lower fixed (home) and lower overall connectivity (both mobile and fixed) rates result in higher net present values of Wi-Fi networks. The second way in which the influence of available connectivity rates has been studied is by comparing a larger set of countries to observe a general trend (see Figures 5.2 and 5.3). The general trend suggests that although both fixed and mobile connectivity rates have an impact when comparing contexts that are comparable regarding e-government use when there is no control for e-government use the effect of fixed connectivity disappears. As such, it can be concluded that the available fixed and mobile connectivity negatively influences the public value of a Wi-Fi network, but that this effect for fixed connectivity rates is largely offset by an increased availability and use of e-government services.

6.3 Digital Skills

Subquestion 3 is concerned with the potential effect of the population's digital skills. This potential effect has been studied by comparing countries based on digital skills. Contrary to expectations, comparison of countries showed that countries with similar digital skills result in very different model outcomes (see Table 5.4) and that there is no clear trend observable when correlating model outcome and digital skills (see Figure 5.4). In comparing countries with similar fixed and mobile connectivity rates but different digital skills, the country with the highest level of digital skills generally gives the highers model outcome but that these results lack in robustness. These results show that the exact influence of digital skills, in general, is unclear, but when the available connectivity alternatives are similar digital skills have a positive influence on the public value of a Wi-Fi network.

6.4 Digital Divide

The main research question motivating these subquestions focused to what extent public Wi-Fi networks provided a vehicle for overcoming the digital divide. In the literature study, the digital (access) divide has been redefined as the inequality between individuals regarding their available access opportunities (fixed, mobile or hotspot-based). Because the public value of a Wi-Fi network has been defined as increasing the access opportunities for those with limited or no access opportunities (see Table 4.3), the public value created by a Wi-Fi network can be used as a proxy for the degree to which the digital divide is overcome. In this way, the fact that public benefits are created by a Wi-Fi network indicates that the digital divide is overcome to some degree, and the public value of the network is indicative of the (monetary) efficiency of a Wi-Fi network in overcoming the digital divide. Regardless of the uncertainties in input variables and weighting sets, the public value (even when negative) is always higher than the private costs of the network, and in this way, the Wi-Fi network is always to some (very small) extend a vehicle to overcome the digital divide. The predicted public value of the Wi-Fi network is not positive for every weighting set (i.e. in the base case, the low weighting set results in a negative ENPV), or every context (i.e. some countries have a negative ENPV, even with the middle or high weighting set), indicating that while a Wi-Fi network has the capacity to overcome part of the digital divide this is not always efficient from an economic point of view.

The extent to which a Wi-Fi network is predicted to overcome the digital divide is based on contextual factors. As an integral part of the definition that has been given to the digital divide, a limited set of access opportunities for the population increases the possibility that Wi-Fi networks can be used by those who have limited access opportunities. However, the results (subquestion 2) have shown that the effect of limited fixed access opportunities is unclear, mainly because these are also highly correlated with the availability and use of the e-services that generate public value in Wi-Fi use. Therefore, it seems that especially low mobile access opportunities (access away from the home) creates opportunities for Wi-Fi networks.

A second contextual factor influencing the extend to which Wi-Fi can be viewed as a vehicle in overcoming the digital divide is the extend to which people will use e-government services in a way that creates benefit (i.e. use them effectively), which is in the digital divide theory related to the concept of digital skills (e.g. van Dijk, 2017). The results of subquestion 3 have shown that while there is no obvious relation between digital skills and public value (and thereby the extent to which the digital divide is overcome), in comparing different contexts with similar access opportunities but different digital skills the digital skills are associated with a higher Wi-Fi network value. Thereby, it is suggested that increasing digital skills contribute to increasing the extent to which Wi-Fi networks can overcome the access divide.

In short, Wi-Fi can be used as a vehicle to overcome the digital divide. The extent to which Wi-Fi networks aid in overcoming the digital divide is dependent on contextual factors, such as existing access opportunities and digital skills of the population. Overall the effect of a single network on the digital divide in an area or country can be considered to be relatively small, as Wi-Fi networks reach relatively few people, however the (in most cases) positive predicted public value of a Wi-Fi network suggest that is in an economically efficient way to aid in overcoming the digital divide.

As this study is based on certain assumptions and limitations, there are limits to this conclusion. These limits and their impact on the conclusion will be discussed in the discussion (Section 7), as well as the implications of these findings for further research and policy.

7 Discussion

7.1 Limitations

The main limitations from this study are based on limitations of scope and model simplifications. Those assumptions and simplifications regarding the scope and the model that pose a limitation the applicability and reliability of this research's results and conclusions will be discussed in this section. A list of the most important (data) assumptions made has been included as Appendix C.

The first limitation of the chosen scope is the exclusion of possible indirect costs, it has been assumed that there are no indirect costs related to the use of the network (assumption 1) and that everyone has the means to use the network (assumption 2). This limits the accuracy of costs and thus the value of the network, likely overestimating the network value. Secondly, only private fixed and mobile connections are taken into account as alternative access opportunities, other Wi-Fi networks or non-private fixed connections (e.g. access in the work environment) have not been taken into account (assumption 6). This limitation of scope results in more emphasis on the effect of private fixed and mobile connections, while ignoring the impact of other connection alternatives, and likely increases the expected value of the network by ignoring some access opportunities.

A rudimentary assumption of this research has been that people partially use Wi-Fi networks to use e-government services (assumption 16). Existing studies on how people use public Wi-Fi have not included e-government or e-services as studied categories of use (see Table A.5), and thus this key assumption and the reason public Wi-Fi networks are expected to create public value has no clear foundation in empirical data. This assumption and the impossibility of proving its correctness or partial correctness at this point in time results in a large uncertainty related to the outcome of this thesis. Would people be (partially) unwilling to use e-services on a public network, the potential public value of the network would diminish. Based on the fact previous studies have shown people use public networks for document sharing, financial transactions and work-related activities, it is not anticipated that all Wi-Fi users would refuse to use e-government services on a public network, but refusal of some (e.g. because of privacy concerns) can be anticipated. As such, this assumption will likely have let to an overestimation of public value.

Another limitation of the scope is the omission of other potential sources of value of public Wi-Fi networks. Other e-services might also increase create public value in Wi-Fi networks (e.g. van der Wee et al. (2015) show a large potential value of e-business; European Commission (2014) also take into account e-health benefits when assessing broadband and NGA initiatives). On top of that, factors beyond the direct effects of Wi-Fi use, such as the capacity of Wi-Fi networks to be used for mobile data offloading (K. Lee, Lee, & Yi, 2010) have been excluded. This has likely resulted in an underestimation of the potential public value of a Wi-Fi network.

The scope of the study does not only exclude indirect costs and other potential benefits but also excludes the assessment of unquantifiable costs. Table 4.2 already highlighted some benefits of e-government that could not be quantified, such as the increased quality (i.e. response time) and quantity (i.e. use of services) of government services. Related to this, changes in e-government (use) that influence benefits over time or might create new benefits (i.e. future e-government services currently not anticipated) are not taken into account (assumptions 7 and 17) while it has been proven that e-government services are constantly evolving (Rooks et al., 2017). Unquantified effects, future benefits and changes in e-government adoption are all factors that are likely to increase the potential value of internet access and e-government use. This limitation will, therefore, cause an underestimation of the network value.

Apart from potential changes in e-government services and use, other technological and socio-economic developments are not taken into account. Technical data, such as the capacity of Wi-Fi equipment and the backhaul network, technical costs, such as the price of replacing equipment, and connectivity rates are all assumed to remain stable over the ten year period used as the length of the model (assumptions 9, 11, and 12). Both historical data (e.g. Eurostat, 2018d, 2018a) and literature (e.g. Cruz-Jesus et al., 2012; Kyriakidou et al., 2011; Rooks et al., 2017; Seri et al., 2014) show that internet access opportunities and e-government use are constantly evolving, as is (wireless) access technology. The exclusion of technological development and cost of technology will likely have increased costs (as equipment costs get lower) and have decreased the potential of the network (due to technological development), leading to an overestimation of costs and an underestimation of potential value. The exclusion of increasing connectivity rates will have lead to an overestimation of value, which may in part be offset by a related increasing uptake of e-government, service use.

In regards to the CBA method used for this thesis, an effort has been made to include socio-economic diversity in the model by introducing the concept of user types. However, this inclusion of the diversity of society is still a highly simplified version of reality and based on aggregated data. Both internet access and e-government use are socio-economically complex, and there are many different factors contributing to the chance of someone having/using the internet or e-government. In this model, only education and income have been used as proxies for this complexity, thereby greatly simplifying the real-world complexity (assumption 14). This might lead to the overestimation of e-government use in user types with limited access opportunities, thereby overestimating the realized benefits of e-government through Wi-Fi network use.

A second simplification in including the diversity of society is the assumption that the subpopulation that uses the Wi-Fi network is assumed to be proportional to the total population in regards to user type representation (assumption 13). It is more likely that those people who have more online devices and the higher digital skills are more (frequent) Wi-Fi network users (McConnel & Staubhaar, 2015). The direct effect of access alternatives on Wi-Fi use is unknown. The limitation is that the model disregards that there might be any factors influencing who use the Wi-Fi network. As a result, the proportion of people with limited/no access opportunities using the Wi-Fi network may be overestimated, causing the expected value of the network and the extent to which the network is a vehicle to overcome the digital divide to be overestimated.

Lastly, and very significant limitation is imposed by the limited availability of data. Assumptions have been made and indirect data has been used to substitute data that was not available. The impact of the different data assumptions have been reflected on in Appendix C, Tables C.5 - C.7. The impact of using indirect data (either old data or generalizing data) has been reflected on in Appendix C, Tables C.2, C.3 and C.4. The combined impact of assumptions, data assumptions and the use of indirect data is difficult to assess, as every assumption and data entry can have both a positive and a negative influence on the model outcome. The overall result of the assumptions is a limit in the reliability of the model outcome and, in an extreme case of incorrect data and assumptions, the answers given to the main research question and the subquestions.

The influence of data assumptions and the use of indirect (and thereby less reliable) data has partially been assessed by sensitivity testing. This has shown sensitivities to much of the data included in the model, sometimes with large impacts (see Section 4.2 and Table 4.4). When the possible variability of these assumed data inputs is included in the model, the model has a wide variety of reasonably possible outcomes (see Figure 5.1); similarly the intercountry differences in the scenario analysis show variability in sensitivity testing (see Figures E.7-E.12; E.24-E.34). This limits the reliability of the single-number outcome, although it is demonstrated that for the middle weighting set most outcomes are positive and for the high weighting set all potential outcomes are possible. Thereby it becomes apparent that it is unlikely that the unreliabilities of data included in the sensitivity testing would change the complete outcome of the model.

To conclude, many of the limitations of this research are warning signs that the model used is likely overestimating or underestimating public value, but since the exact effects are unknown, it is impossible to determine the total effect of all of these limitations. This limits the ability to assess to which extend a Wi-Fi network provides a vehicle to overcome the digital divide, as these limitations introduce uncertainty beyond that captured in the sensitivity analysis and Monte-Carlo simulation. Furthermore, simplifications regarding socio-economic complexity have also affected the analysis of the impact of connection alternatives and digital skills on the network's value.

7.2 Recommendations

7.2.1 Future Research

The recommendations for future research are given in three parts, similar to how the literature study has been based in three parts. The first part will focus on the connectivity (in terms of the digital divide), the second part of the research recommendations focus on e-government (in terms of the digital divide and technological opportunities), and the last part focuses on Wi-Fi network research.

Connectivity After a review of the existing literature on the digital access divide, the digital access divide was defined slightly differently than commonly done in previous literature. By defining the digital divide, not in a binary (access or no access) way, but in terms of access opportunities, more emphasis was put on the different options people have to connect. This re-definition defines different access technologies (e.g. mobile broadband and fixed broadband) as complementary, rather than supplementary and also allows for emphasis to be put on the different ways of using different forms of access (second level digital divide). This gives an opportunity for research to approach the digital divide in a different way, that will be especially relevant for those countries with high levels of fixed connectivity (e.g. Denmark, Luxembourg, the Netherlands) where the availability of access in some form is no longer an issue or those cases in which a specific form of access (e.g. Wi-Fi) is studied in relation to the digital divide.

E-Government A study of previous literature showed that while many perceived effects of e-government are named, these are often theoretical or based on small case studies, and in most cases, there is no available information on whether these benefits actually occur and what the (quantified) effect of these benefits is. van der Wee et al. (2015) have quantified some e-government benefits, and this thesis has done so with a larger set of potential benefits. However, there are still many benefits that remain unquantified, and the current quantification of benefits is based on perceived benefits and not on the measured benefits of e-governments. As such, a recommendation for further research is to put more emphasis on studying not what but how benefits are realized and what of the perceived potential value is realized.

The study of e-government benefits cannot only be deepened by putting more emphasis on the realization of benefits and their value but can also be broadened by including potential future effects. In the model created in this thesis future development both in terms of new e-services for the government, increasing connectivity opportunities and technologies, and increasing use of existing e-services have not been included in the model. If it would be possible to include uncertain developments like these a better assessment of public value is possible and a better understanding can be formed of how these future e-services create value.

Lastly, e-government research would also benefit if more would be known about the use and adoption of e-government. The Eurostat data on e-government used for this research comes from from 2013. Since connectivity rates (+11%), internet use (+10%) and digital skills (+3% between 2015 and 2017) have greatly improved since then (on an EU-28 level) (Eurostat, 2018c, 2018d, 2018e), e-government use is expected to have greatly changed since then. An update of the available data would not only aid in quantifying the potential benefits that can be expected to be realized but also aid in monitoring whether progress in providing connectivity does result in increased use of e-services like the literature suggests (e.g. Seri et al., 2014).

Wi-Fi Networks Future research regarding Wi-Fi networks would greatly benefit from the availability of more (reliable) data. Currently, very little is known about the use of a Wi-Fi network, both in terms of who the users are and in terms of what they use Wi-Fi for. The data which is available often stems from small-scale survey-based studies (Melton, 2017; O'Connel, 2017; Schlesinger, 2016; Thomas, 2014) or observational data (Hampton & Gupta, 2008; Hampton et al., 2010), the results of which may heavily depend on time, location and contextual factors. Additional data on how people use networks might give additional insights into their effectiveness as a vehicle for overcoming the digital divide and including people digitally. However, with stricter privacy regulations it might become increasingly more difficult to gather data about people's online behaviour.

The value of Wi-Fi networks have previously been assessed in terms of the number of users (C. A. Middleton, 2007; Potter et al., 2008; Sathiaseelan et al., 2014), perceived value (Sathiaseelan et al., 2014), or theoretical user typologies (C. A. Middleton, 2007; Picco-Schwendener et al., 2017), but the value has not been quantified (other than in terms of costs (e.g. Navío-Marco et al., 2018)). This thesis has aimed to add to these studies, by quantifying the value in terms of potential e-government use through public Wi-Fi networks. Quantifying benefits and value based on other e-services or online activities was beyond the scope of this research, but is a potential for future research and will aid in forming a more complete overview of the ways in which Wi-Fi networks can create value and aid in overcoming the digital divide. Also beyond the scope of this research was the identification of costs based on the specific type of network (e.g. indoor and outdoor), as was done by Navío-Marco et al. (2018), and the possible influence on realized benefits of different Wi-Fi network implementations; this could aid in further understanding how the use of a Wi-Fi network may be optimized to generate more public value.

7.2.2 Policy Recommendations

The first relevant finding of this study for policy making, is that Wi-Fi has the potential to have public value and aid in overcoming the digital divide. While the vast number of public Wi-Fi initiatives with government funding implied that there would be a public value to such networks, the model outcomes have further underlined this. On the other hand, the results of the model and the sensitivity analysis also show that the realized public value of a network is largely dependent on the number of users and what these users use the Wi-Fi network for. Some forms of usage by users may be restricted when the network is often at maximum capacity (restricting the number of possible users) to avoid the tragedy of the commons, for example by setting a maximum bandwidth per person or the maximum connection time per user. While these measures might restrict users, it is unlikely to block users from performing the most basic online tasks (like sending e-mails, submitting forms, browsing) that are part of many e-services, but will stop continuous users (e.g. those connecting to the network from home) and/or those users using a lot of bandwidth (i.e. using the network for streaming videos or large downloads).

Although this study suggests public Wi-Fi networks have the potential to overcome the digital divide on a very small scale, it is not expected to replace broadband (or other forms of home access) policy but seen as a complementary intervention to other forms of Internet-access policy. This is partially also due to the fact that those people who have limited access might not have the skills or means (i.e. devices) to benefit from public Wi-Fi networks. Furthermore, other and more stable types of connectivity, such as home broadband, and non-mobile devices might be more suitable for e-services as people might prefer using these services in the environment of their own home.

While this study has largely focused on the isolated effects of Wi-Fi networks a second important finding is that the value of Wi-Fi is largely dependent on the context surrounding it, especially in term of e-government use. E-government use is a combination of the degree to which services are available as e-services and the degree to citizens use available e-services. While Wi-Fi networks might be a vehicle in overcoming the digital divide, if those on the wrong side of the digital divide do not have the skills or experience to use e-services (or even Wi-Fi in general), the effectiveness of Wi-Fi as a policy tool suffers. As such, it is important for policy to not only focus on different ways of providing access (one of which may be Wi-Fi) but to also focus on ensuring people are able to use access opportunities effectively. The development of digital skills and competencies necessary for the use of the Internet and e-services should be just as much part of the digital divide policy as providing access to people.

Lastly, in modelling the difference between potential benefits created by e-services and realized values, vast differences between the two were observed (see Table 4.2). The limited amount of people using e-government services and the relatively high amount of people experiencing failure when using government websites are large contributors to the difference between potential and realized benefits. This is in line with earlier findings that simply providing connectivity and online services are not enough if people are unable to use those services (e.g. Dombrowski et al., 2014). The last recommendation to policymakers would thus be to not only focus on the digital access and skills of the citizens, but also on the quality of the e-services provided, to avoid the encounter of (technical) difficulties in using e-government services.

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A Literature Overview

Table A.1 outline the most important impact factors for internet use in general, in which a + indicates a positive correlation, − indicates a negative correlation, ∩ indicates an inverted-U shape correlation and / indicates that there is no clear correlation between the factor and likelihood of being connected.

Digital		
Internet access	++	(Ferro et al., 2011)
Digital skills[2]	+	(van Deursen & van Dijk, 2014; Büchi et al., 2016; van Dijk, 2017)
Demographics		
Education	++	(Anduiza et al., 2010; T. E. Hall & Owens, 2011; Ferro et al., 2011; Büchi et al., 2016; Reisdorf & Groselj, 2017b)
Income	++	(Anduiza et al., 2010; T. E. Hall & Owens, 2011; Ferro et al., 2011; Reisdorf & Groselj, 2017b)
Age	- ∩	(Anduiza et al., 2010; T. E. Hall & Owens, 2011; Ferro et al., 2011; van Deursen & van Dijk, 2014; Büchi et al., 2016; Reisdorf & Groselj, 2017b)
Gender (F)	-/	(T. E. Hall & Owens, 2011; Ferro et al., 2011; van Deursen & van Dijk, 2014; Büchi et al., 2016; Reisdorf & Groselj, 2017b)
Speaking English	+	(Ferro et al., 2011)
Being Disabled	+	(van Deursen & van Dijk, 2014)
Urban Area	+	(van Deursen & van Dijk, 2014)
Traditional Skills	+	(Anduiza et al., 2010)
Lifephase		
Employed	/+	(Büchi et al., 2016; Reisdorf & Groselj, 2017b)
Student	-/	(Büchi et al., 2016; Reisdorf & Groselj, 2017b)
Race and Ethnicity		
Asian	+	(T. E. Hall & Owens, 2011)
White non-Hispanic	+	(T. E. Hall & Owens, 2011)
Hispanic	-	(T. E. Hall & Owens, 2011)
Black non-Hispanic	-	(T. E. Hall & Owens, 2011)
Native American non-Hispanic	-	(T. E. Hall & Owens, 2011)

Table A.1: *Internet Use Factors*

The factors influencing the use of e-services are listed in Table A.2, in which a + indicates a positive correlation, − indicates a negative correlation and / indicates that there is no clear correlation between the factor and likelihood of being connected.

Digital		
Owning device(s)	+	(Reisdorf & Groselj, 2017a)
Multiple "online" locations	+	(Reisdorf & Groselj, 2017a)
Perceived e-gov benefits	+	(Gilbert et al., 2004; Nam & Sayogo, 2011; Reisdorf & Groselj, 2017a)
Digital Skills[3]	/+	(Anduiza et al., 2010; Nam & Sayogo, 2011; Taipale, 2013; Vicente & Novo, 2014; Dombrowski et al., 2014; Reisdorf & Groselj, 2017a)
Demographics		
Income	+	(T. E. Hall & Owens, 2011; Taipale, 2013; Reisdorf & Groselj, 2017a)
Education	+	(T. E. Hall & Owens, 2011; Nam & Sayogo, 2011; Taipale, 2013; Vicente & Novo, 2014; Reisdorf & Groselj, 2017a)
Age	-+	(T. E. Hall & Owens, 2011; Nam & Sayogo, 2011; Vicente & Novo, 2014; Reisdorf & Groselj, 2017a)
Gender (F)	-/	(T. E. Hall & Owens, 2011; Vicente & Novo, 2014; Reisdorf & Groselj, 2017a)
City Size	+	(Taipale, 2013)
Race and Ethnicity		
Hispanic	-/	(T. E. Hall & Owens, 2011; Nam & Sayogo, 2011)
Black	-/	(T. E. Hall & Owens, 2011; Nam & Sayogo, 2011)
Lifephase		
Student	-	(Reisdorf & Groselj, 2017a)
Unemployed	-	(Reisdorf & Groselj, 2017a)
Employed	+	(Reisdorf & Groselj, 2017a)
Living alone	-	(Nam & Sayogo, 2011; Reisdorf & Groselj, 2017a)

Table A.2: *E-Government Use Factors*

The factors influencing an individual's ability to benefit from the use of online media and services are listed in Table A.3, in which a $+$ indicates a positive correlation and $-$ indicates a negative correlation between the factor and likelihood of being connected.

Demographics		
Education	+	(van Deursen & Helsper, 2015, 2018)
Age	-	(van Deursen & Helsper, 2015, 2018)
Income	+	(van Deursen & Helsper, 2018)
Digital Information/Competence		
Internet use	+	(van Deursen & Helsper, 2015)
Task specific skills	+	(van Deursen & Helsper, 2018)

Table A.3: *E-Government Benefit Factors*

The factors influencing the usage rates of a Wi-Fi network are listed in Table A.4, in which a $+$ indicates a positive correlation and $-$ indicates a negative correlation between the factor and likelihood of being connected.

Network		
Network Age	++	(Hampton et al., 2010)
Location		
Seating available	++	(C. A. Middleton, 2007; Potter et al., 2008; Lambert et al., 2014)
Electricity available	+	(Potter et al., 2008)
Exposed to weather/sun	-	(Potter et al., 2008; Lambert et al., 2014)
Visitor density	-/+	(Hampton et al., 2010; Lambert et al., 2014)
Demographic		
Age		(Hampton et al., 2010)
Education	++	(McConnel & Staubhaar, 2015)
Digital		
Digital Skills	++	(McConnel & Staubhaar, 2015)
Perceived Usefullness	+	(Al-Shafi & Weerakkody, 2008)

Table A.4: *Wi-Fi Use Factors*

Table A.5 shows the different patterns of Wi-Fi usage, as studied by Hampton et al. (2010) and Picco-Schwendener et al. (2017) and found in the surveys published by Thomas (2014), O'Connel (2017), Schlesinger (2016) and Melton (2017). The table lists the percentages of people reported to be using public Wi-Fi for the specific purpose. It is difficult to compare, as each study has reported different types of usage. Furthermore, all of these are based on self-reported Wi-Fi usage behaviour, and therefore difference may be caused by people using different definitions or asking a different group of people to report on their behaviour.

		Hampton et al. (2010)	Picco-Schwendener et al. (2017)	Thomas (2014)	O'Connel (2017)	Schlesinger (2016)	Melton (2017)
Information Consumption	News and Politics	43%					
	Tourism		18%				
	Event		14%				
	Maps		16%				
Information Creation	Blogging	8%					
Contact/Social Network	Communicating with Social Network	66%					
	Communicating outside Social Network	19%					
	Social Media	29%			66%	56%	56%
	Sharing Pictures/Videos						44%
	Sharing Travel Plans/Locations						22%
	E-mail		61%	87%	71%	58%	59%
Work	Work (general)			27%			
	E-mail						26%
	Sharing Documents						19%
Personal	Bank and Financial			17%	20%	22%	25%
	Providing Financial Information				20%		16%
	Shopping				20%		
	Managing Home Devices						9%

Table A.5: *Wi-Fi Usage Patters*

B Conceptual Model - E-Government Effects

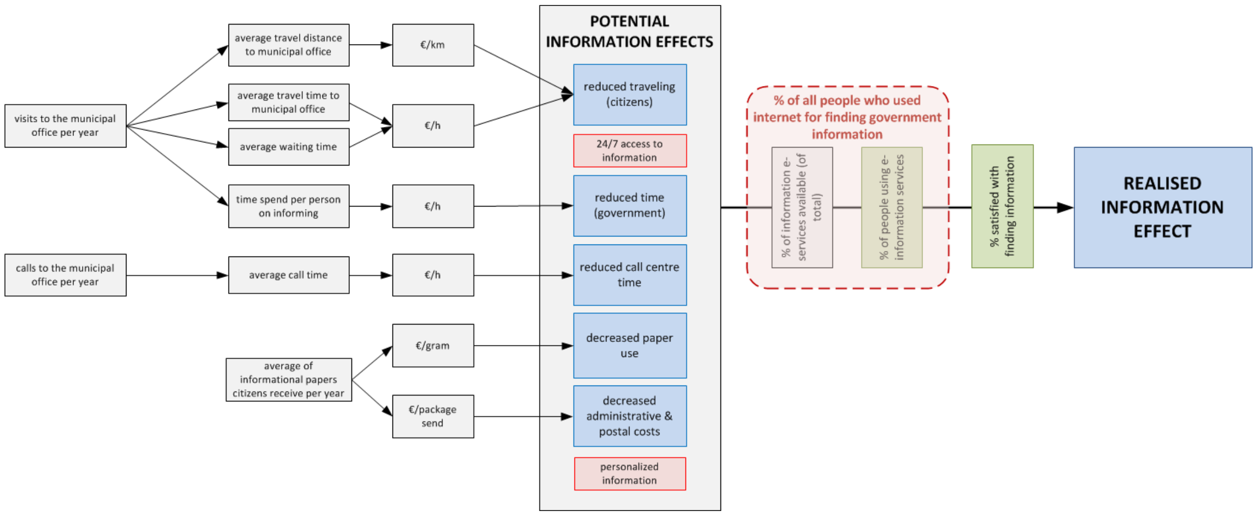

Figure B.1: *Conceptual Model of E-Government Information Effects*

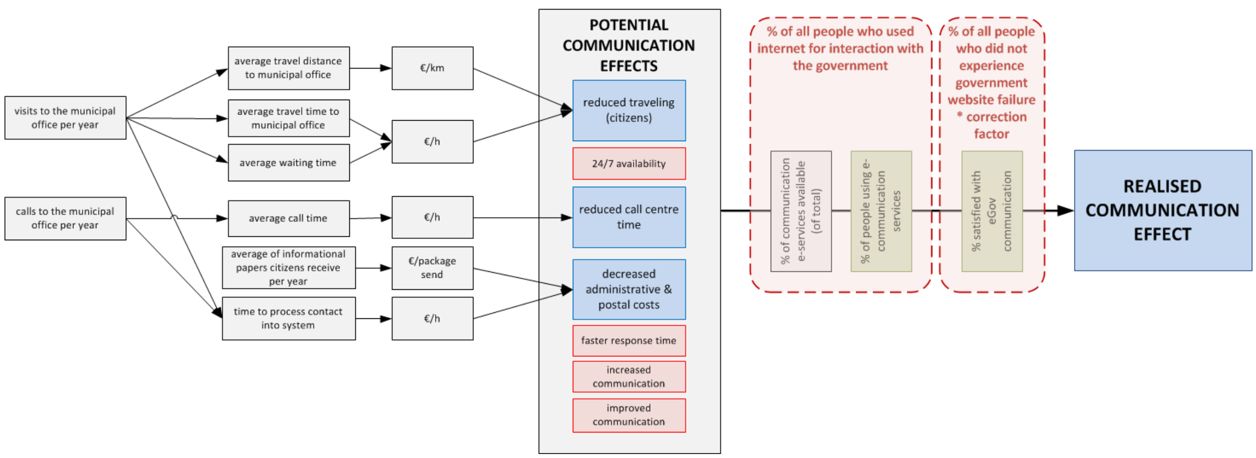

Figure B.2: *Conceptual Model of E-Government Communication Effects*

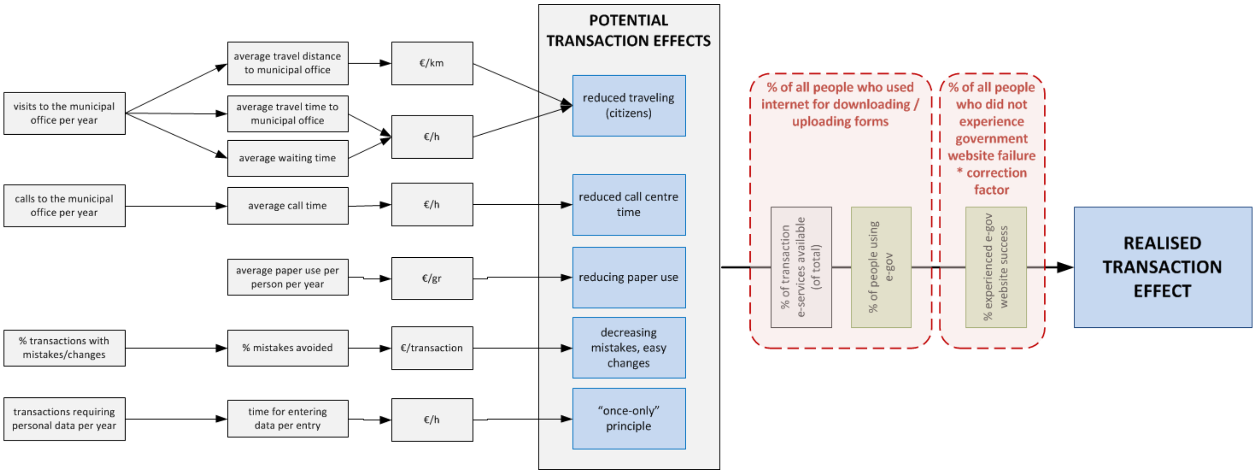

Figure B.3: *Conceptual Model of E-Government Transaction Effects*

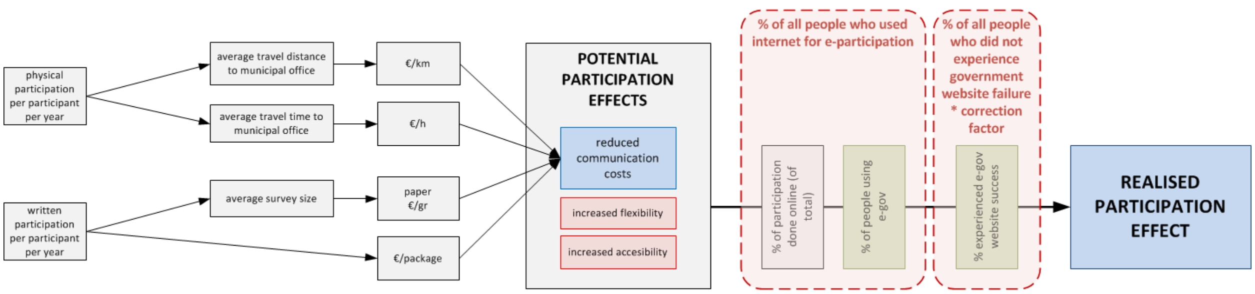

Figure B.4: *Conceptual Model of E-Government Participation Effects*

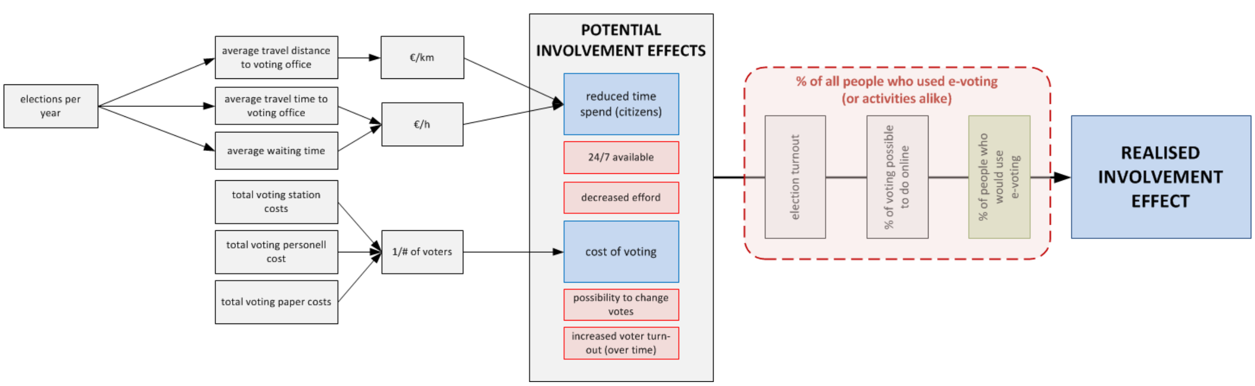

Figure B.5: *Conceptual Model of E-Government Involvement Effects*

C Assumptions

Scope

Assumption 1: Users have no (indirect) costs associated with the use of the Wi-Fi network.

This assumption entails that there are no indirect costs such as travel costs to go to the Wi-Fi network, assuming it is in a location which is widely used and accessible for people in their daily lives.

The most obvious costs that could have been included are travel costs since gains in travel times are such a large factor in the benefits of e-government use through the Wi-Fi network (see Figure 4.4). However, even if travel benefits are excluded (assuming the costs of travelling to the municipal office or voting office are the same of those travelling to the Wi-Fi network), the network is still expected to have a positive public value in the middle and high weighting set of benefits, though much larger than given in Section 5.1. The difference between results, also given in Table C.1, demonstrate that while the differences in model outcome are significant these changes are not large enough to change the conclusion.

	Including Travel Benefits			**Excluding Travel Benefits**		
	ENPV	B/C Ratio	ERR	ENPV	B/C Ratio	ERR
Low Weighting	-1,639.32	0.93		-7,344.60	0.71	
Middle Weighting	11,935.02	1.48	0.90	2.865.97	1.11	0.29
High Weighting	25,666.11	2.02	1.77	13,209.82	1.53	0.98

Table C.1: *Assumption 1: Including and Excluding Travel-Cost Benefits*

Assumption 2: Potential users are not restricted from using the network by any constraints (i.e. everyone who wants to use the network, has the means to do so).

Assumption 3: The network is operational 100% of the time. Downtime due to maintenance or equipment failure is not taken into account.

Assumption 4: There is no revenue structure for the public Wi-Fi network. Possibilities of advertisements, use of data gathered, or asking people to pay for connectivity (or better access) are not taken into account.

There are two possible ways in which a Wi-Fi network can generate income: through advertisements and through subscriptions. Asking citizens to pay for a subscription would conflict with the goal of providing access to those who do not have access (for financial reasons), therefore this possibility is not considered in the model. Advertisements are something that can be considered but is not included in this model, as the main philosophy behind public Wi-Fi networks is to create a network that is as accessible as possible.

Assumption 5: Characteristics of the location of the Wi-Fi network are not specified, nor are location-specific characteristics taken into account.

Assumption 5 is a simplification of reality, as research by Potter et al. (2008); C. A. Middleton (2007); Hampton et al. (2010) suggest that characteristics of the location (i.e. seating availability, exposure to sunlight and rain, availability of electricity and visitor density, see Table A.4) are influencing the degree to which Wi-Fi is used. Alternatively, in this model, the use of the Wi-Fi network will be presented as a percentage of the total potential (maximum amount of) users.

Assumption 6: The only connection alternatives taken into account are private fixed and mobile connectivity.

Assumption 7: The Wi-Fi network is such a small part of the entire system that it has no influence on e-government use (or digital skills) of the population.

Model

Assumption 8: Equipmentment failure is expressed as a normal distribution with the mean time between failure as the mean, and half the mean time between failure as the standard deviation.

Assumption 8 has been made because it is unrealistic that all equipment will fail after the exact lifetime, it is more realistic that some will fail before and some after.

Assumption 9: The prices of equipment, backhaul connections, and user management do not change over the years and are not subject to inflation.

Assumption 10: The capacity of Wi-Fi equipment is stable over time, there are no new technical developments increasing technological performance or lifetime.

Assumption 11: Depreciation of equipment is based on double-declining depreciation, with the mean time between failure as the equipment lifespan, as given in Equation 11.

$$RV_{t=11} = \sum_{t=0}^{10} EV_t * (1 - \frac{2}{l})^{(10-t)} \tag{11}$$

Figure C.1 shows the difference between the double declining depreciation method and linear depreciation. In this model, double declining depreciation has been used as a faster decline in value at the beginning of use and a slower decline towards the end of the lifespan (and afterwards, assuming the equipment is still operational) is deemed to be more realistic than a linear depreciation where the equipment has no value at the end of its assumed lifespan.

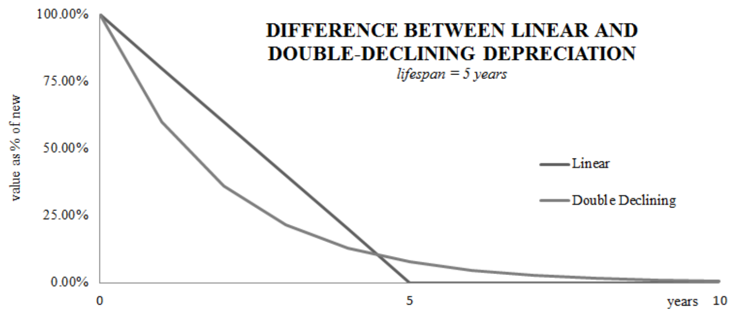

Figure C.1: *Depreciation: Double Declining versus Linear*

Assumption 12: Connectivity rates do not change over time.

Assumption 13: The proportion of user types in Wi-Fi network users are equal to the proportions of user types in population for user types A-D.

The option that people who are higher Internet users might more often use public Wi-Fi (or are less likely to do so, as they might be more understanding of the risks associated with public Wi-Fi networks (see e.g. (Identity Theft Resource Center, 2012)). This assumption also implicitly assumes everyone who wants to use the Wi-Fi network has a device that enables him/her to use Wi-Fi (e.g. a laptop, tablet or smartphone); this is in contrast with the findings of T. E. Hall and Owens (2011) and Reisdorf and Groselj (2017a) who state that having an access device is a factor in e-government use which can be reasonably assumed to also apply to Internet and Wi-Fi use in general. Assumption 13 can thus be said to be a gross simplification of reality.

Another potential effect of this is that societal diversity based on geo-location are ignored within the country's context. Literature suggests those people living in urban areas are often better connected, leading to better digital skills and an increased use of e-services. Wi-Fi networks are likely to be located in urban areas, not rural areas. As a result, those who might benefit the most from Wi-Fi (those who have least connection alternatives) can be expected to live out of reach of the Wi-Fi network, and may not visit the public place where the network is located frequently. As such, the proportion of people in the lower connected user types that use the Wi-Fi network can be expected to be lower in reality than predicted in the model.

Assumption 14: The representation of different income groups and education groups within a user type can be used to estimate the use of e-government within that user type based on e-government use in different income and education categories.

As there is no statistical data available on who of the e-government users have a mobile or fixed internet connection and who do not have such a connection, the estimate of e-government use (and failure) rates have been calculated based on the composition of each group of users within a user type regarding income quartiles and education levels; taking the weighted average of the estimates based on income and education level, multiplying with a correction to get the correct population average (which might occur because of Eurostat numbers are rounded of to full percentages). This might be a gross oversimplification, likely underestimating the differences in e-government usage between different user types.

Furthermore, the amount of voluntary non-users (want-nots) is assumed to be the same percentage of those people that do not have any access opportunity within a context (EU-28 region, or a specific country), whereas it could be argued that this percentage is likely higher when there are fewer have-nots.

Assumption 15: The amount of Wi-Fi network users is stable over the years.

Hampton et al. (2010) found that the use of a Wi-Fi network increases as more people know it. This effect is not taken into consideration in the model. In 2010 Wi-Fi was less common, and as a result, people had to know there was Wi-Fi somewhere to use it, currently, many people have a smartphone that automatically detects possible available Wi-Fi networks. As such, it is assumed that this period has become shorter. As exact data of what this adoption period of the network would look like, and what the appropriate period until adoption would be was unavailable, this effect has been left out of the model.

Assumption 16: People use public Wi-Fi networks partially for e-government services.

It could be speculated that the use of e-government services through Wi-Fi is limited because of privacy concerns, but on the other hand, the existing studies have shown people have little problem with other privacy-sensitive activities such as using financial services and providing financial information (Melton, 2017; O'Connel, 2017; Schlesinger, 2016; Thomas, 2014). Based on the fact previous studies, though limited, have shown people use public networks for document sharing, financial transactions and work-related activities, it is not anticipated that all Wi-Fi users would refuse to use e-government services on a public network, but it may be anticipated.

Assumption 17: The connection rates and e-government rates do not change over the years of the model.

Both historical data on connection rates (Eurostat, 2018c, 2018a) and government (and corporate) plans to expend (broadband) networks will indicate that connectivity rates are constantly changing. The potential increase in connectivity rates has not been included in the model, as this is difficult to predict in advance, as the change is dependent on policy and market conditions that will differ throughout the European Union. Should an estimate of an increase in connectivity rates have been included, this would have likely lead to declining e-government benefits over the project lifetime (as in later years more people would have connectivity alternatives), and thereby a lower public value.

There was no historical data on e-government use available, only data based on a research conducted in 2013 (see Assumption 33). As such, it is not possible, based on data, to assess the growth in e-government use. However, as Internet use, access and digital skills have increased since (Eurostat, 2018c, 2018a, 2018d, 2018e) and these three factors are according to the literature positively related to e-government use (T. E. Hall & Owens, 2011; Nam & Sayogo, 2011; van Deursen & van Dijk, 2014; Dombrowski et al., 2014; Reisdorf & Groselj, 2017a) it can be assumed that e-government use has since increased and will continue to increase throughout the years. Should an estimate of this increase since 2013, and the continuous increase (because of an increase in the adoption of e-government services) of e-government use have been included in the model, the realized e-government benefits over the project lifetime would have increased, thereby increasing public value.

Assumption 18: Everyone who uses e-government services uses it for all of their government interactions.

Since there is no data available for how many e-government interactions there are per year, the amount of government interactions (from GOV.UK (n.d.)) and the usage rates of e-government services (from Eurostat (2018d, 2018j, 2018k, 2018g)) have been used, under the assumption that everyone who uses e-government services for one type of interaction (e.g. e-transactions) uses it for all interactions of that type. This might lead to a slight overestimation of the number of e-government interactions as many people will likely participate in a mixture of traditional and e-government interactions.

Assumption 19: The next best alternative for information e-government services is either calling or visiting the government or receiving information papers. These alternatives are equally likely to be used, and their costs are the opportunity costs of information e-government services.

Assumption 20: The percentage of people who use online services for certain tasks reflects both the availability of that service as an e-service, as well as the percentage of potential users using that service.

Assumption 21: The failure of e-government action can be based on the total percentage of people experiencing failure and an assumed percentage of failed e-government activities per person who has experienced failure (with a minimum of one activity).

Assumption 22: Government website failure accounts for all type of e-government failure, and that this failure is evenly distributed over the different e-government services offered.

Assumption 23: Looking up information online takes the same amount of time for the citizen as visiting or calling the government (excluding travel and waiting time), or reading an information pamphlet.

Assumption 24: The next best alternative for communication e-government services is either calling or visiting the government or receiving information papers. These alternatives are equally likely to be used, and their costs are the opportunity costs of communication e-government services.

Assumption 25: The next best alternative for transaction e-government services is either calling or visiting the government. These alternatives are equally likely to be used, and their costs are the opportunity costs of transaction e-government services.

Assumption 26: The next best alternative for participation e-government services is paper surveys or visits to the government.

Assumption 27: There is no increase in participation of citizens due to the introduction of e-participation.

Assumption 28: Citizens only participate in a portion of the participatory activities offered.

While the literature suggests that e-government participation might increase participation rates because the costs of participation become lower (Mawela, 2017), this effect is not taken into account in the model because no data or research showing such a relation was available.

Assumption 29: The time the government has to spend on participatory activities and services does not change.

Assumption 30: The next best alternative for e-voting is voting at a voting station.

Assumption 31: There is no increase in voter turnout due to the introduction of e-voting.

Data

Assumption 32: The costs of equipment can be assessed by taking the median of the equipment available in the Netherlands fitting the requirements as described in Section 4.1.

Assumption 33: Older data can be applied to the current situation.

The data to for which Assumption 33 applies, is explained in Table C.2, including their impact (based on the sensitivity analysis, see Section 4.2).

Assumption 34: Data from specific countries/regions can be applied to the entire European Union.

The data which has been taken from one specific country or region, and been applied to a different or larger geo-location is given in Table C.3 and C.4, including an impact assessment (based on the sensitivity analysis, see Section 4.2).

Lastly, there is some data which is purely based on educated guesswork; these data and their respective impacts (based on the sensitivity analysis, see Section 4.2) are outlined in Table C.5, C.6 and C.7.

Description	Source	Adaptation	Impact
Amount of e-government users	(Eurostat, 2018k)	Data is from 2013 and directly applied, without correcting for possible changes that have occurred since then.	E-government use likely has increased since 2013, since internet access, use and digital skills have increased since then. This would lead to underestimating the public value created by Wi-Fi.
Amount of e-government users for specific types of services	(Eurostat, 2018f) (Eurostat, 2018g)		
Available participation activities per year	(Michels & De Graaf, 2010)	Data is from 2010 and based on Dutch municipalities.	Since no other information has been found to compare this to, it is difficult to assess the impact. However, the impact of the variable in the model is very small and thus the impact of this is deemed to be very small.
Problems experienced with using government websites	(Eurostat, 2018j)	Data is from 2013 and directly applied, without correcting for possible changes that have occurred since then.	It is difficult to evaluate the impact of this, since there is no historical data it is difficult to see whether experienced problems would have increased or decreased.
Amount of users dissatisfied with information on government websites.	(Eurostat, 2018k)		It is difficult to evaluate the impact of this, since there is no historical data it is difficult to see whether dissatisfaction would have increased or decreased.

Table C.2: *Data Assumptions: Using Older Data*

Description	Data	Unit	Source	Adaptation	Impact
Minimum Wage per Month	1550	€/month	(Eurostat, 2018i)	EU average based on 2017 data has been calculated, and generalized for all countries.	In countries with lower (minimum) wages, the value of time, and thus the public value will be overestimated.
Ratio Minimum:Average Wage	0.44		(Eurostat, 2018h)		
Electricity	0.08	€/kWh	(Eurostat, 2018b)	Electricity prices have been assumed to be stable over the EU.	This variable has such a small impact on the model outcome, that any misassumptions will not have any substantial effect on the model outcome.
Equipment Costs			(Tweakers, 2018)	Euipment prices are based on the median price of the available equipment fitting the requirements set out in Section 4.1.	The impact of individual pricing is rather small, none of the variables are critical.
Government interactions per person			(GOV.UK, n.d.)	Amount of government interactions, based on data from GOV.UK (n.d.) and UK population data.	The impact of this data is high, as the amount of interactions greatly influences the total e-government benefit potential.

Table C.3: *Data Assumptions: Generalizing Single-Country Data (A)*

Description	Data	Unit	Source	Adaptation	Impact
Average costs per transaction for the government	19.86	€	(GOV.UK, n.d.)	Calculated average per government transaction, based on data from GOV.UK (n.d.).	The impact is low, but can change the potential benefit of e-participation.
Distance to voting office	2.00	km	(Dyck & Gimpel, 2005)	Based on 2005 average of a study in the USA; thus generalizing both over time and over geo-location.	The impact of this variable is very small, but does change the potential benefit of e-voting.
Average Time spend in line for Voting	0.13	H	(Agadja-nian, 2018)	Based on USA data.	The impact of this variable is very small, but does change the potential benefit of e-voting.
Voting station costs			(Dahl & BlazHoff-ski, 2012)	Based on 2012 calculations done for the Netherlands.	The impact of these variables are low, but changes in this data can be anticipated, both because inflation is not taken into account (and this data is 6 years old), and because wages, population density and the way elections are organized will influence election costs.

Table C.4: *Data Assumptions: Generalizing Single-Country Data (B)*

Description	Data	Unit	Source	Adaptation	Impact
% Wi-Fi network usage realized (of potential usage)	10	%		Pure assumption, not based on previous data.	This is a critical variable, with switching values in the range of what can be reasonably be expected. This demonstrates that this variable is very influential, and the risk of incorrectly estimating is very large.
Time users spend on Wi-Fi per time they connect	0.74	H/con	(Thomas, 2014)	Based on a survey done by Purple with 2540 respondents, mainly in the UK.	This is a critical variable, greatly impacting the amount of users of the Wi-Fi network and thus the potential benefits created.
Connections per Wi-Fi users per year	95.7	con/user/Y	(Thomas, 2014)		
Bandwidth usage per Wi-Fi user	3	MBps	(Navío-Marco et al., 2018)	Adaptation from the paper of Navío-Marco et al. (2018).	This is a critical variable, switching values are in relatively normal ranges (i.e. values associated by using the network for streaming videos), as such the risk of incorrectly estimating is very large.
Maximum amount of users per access point	100	users	(Navío-Marco et al., 2018)		Relatively low impact, although it does determine the amount of access points in the Wi-Fi network.
Labor costs relative to equipment costs	60	%	(Navío-Marco et al., 2018)		Relatively low impact, although it does determine a large amount of the costs.
Mean time between failure for equipment	5	Years		Assumption based on various online sources recommending how long a Wi-Fi network would work before needing replacement.	Relatively low impact, determining maintenance costs.

Table C.5: *Data Assumptions: Educated Guesses (A)*

Description	Data	Unit	Source	Adaptation	Impact
Cloud based management	0.84	€/user	(Navío-Marco et al., 2018)	Adaptation from the paper of Navío-Marco et al. (2018).	This is a critical variable, it has a great impact on the operational costs per year.
% population voluntarily not using the Internet	25	%	(T. E. Hall & Owens, 2011)	Adaptation from the paper of T. E. Hall and Owens (2011). This data was from a different time period (especially since changes in connectivity/Internet are fast, and in a different context (US instead of Europe).	This is not a critical variable, although it impact the amount of people classified as usertype D (those who relatively create most public value because they have no connection alternatives).
E-government use rates attributed to Wi-Fi usage				See Section 4.1.3.	The calculations with multiple possible "sets" to slightly decrease the dependence on model results on this variable.
% of government participation through activities	20	%		Pure assumption.	This determines whether people would need to travel for participatory activities, and thus the amount of benefits associated with participatory activities.
Elections per year	1	election	(IDEA, 2018)	Average of most countries according to IDEA (2018).	Relatively low impact, it is not reasonable for the value to be much higher or lower.

Table C.6: *Data Assumptions: Educated Guesses (B)*

Description	Data	Unit	Source	Adaptation	Impact
Travel speed (average)	15	km/h		Pure assumption, based on the average speed of cycling.	This is not a critical variable, but will affect benefits in in terms of time saved (partially due to decreased travel times).
Distance to the government office	5	km	(CBS Statline, 2018)	Assumption based on the Dutch average distance to the nearest medical centers (the Netherlands has about as much medical centers as offices of the local government).	This is not a critical variable, although it can have an impact on the monetary benefit of e-government in terms of time savings for citizens.
Waiting time at the government office	0.2	H	(De Utrechtse Internet Courant, 2015)	Assumption based on data from Utrecht (the Netherlands)	
Time spend per visit	0.167	H/user		Assumption based on samples from average appointment lengths of different Dutch municipalities.	
Waiting time per call	0.05	H/user	(Belasting-dienst, 2016)	Assumption based on Dutch data from the Belastingdienst and their phone services.	
Time spend per call	0.167	H/user		Assumed to be the same as appointment time.	
Time spend entering personal data	0.05	H/user		Pure assumption, based on experience.	

Table C.7: *Data Assumptions: Educated Guesses (C)*

D User Types

Figure D.1 shows a tree structure of how the five different user types are defined.

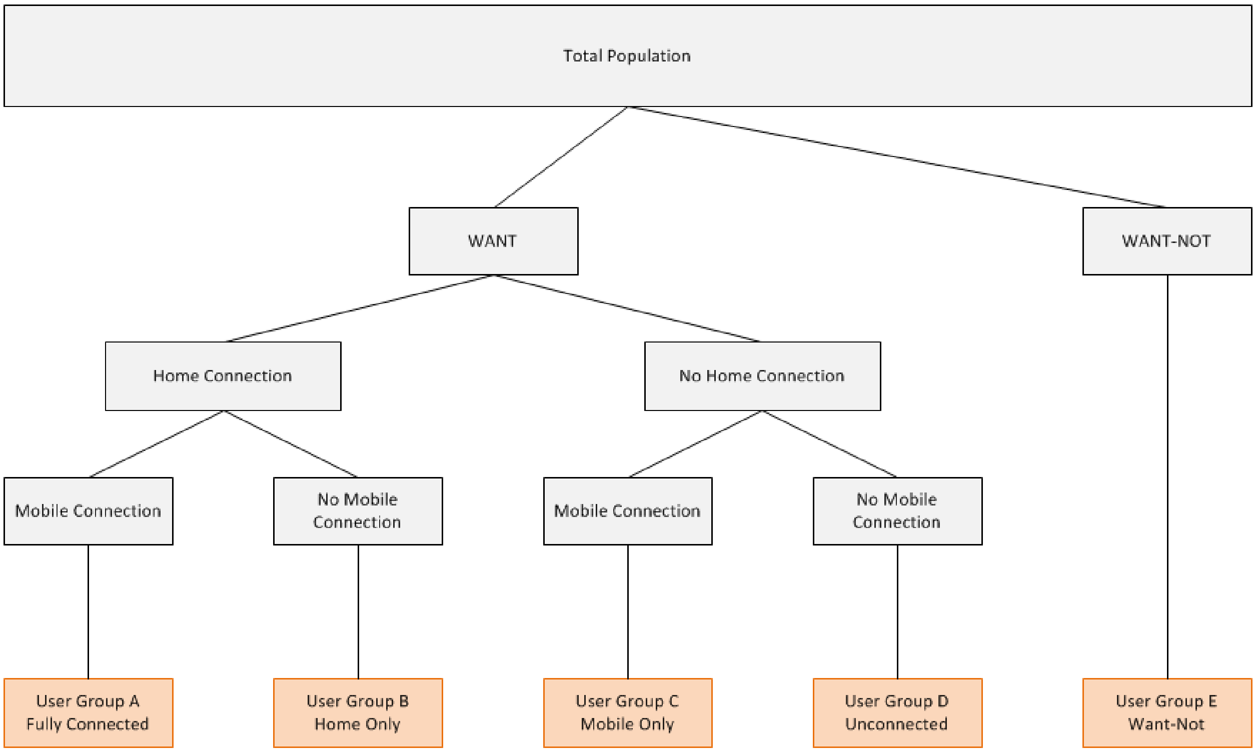

Figure D.1: *Tree Diagram of User Types*

Figure D.2 shows how the population of the EU-28 (the current composition of the European Union) area would be divided among these groups of user types, and what the typical composition of these groups regarding income and education would roughly look like. It is important to note that the figures education are estimates based on the statistical data and that the possible interaction effects of income and education have not been taken into account. Figure D.2 shows that there seem to be no people that have a mobile connection but no home connection. Furthermore, it reflects the points made in the literature concerning income and education, as the shares of people with higher income and education are larger in groups A and B (fully and home-only connected), whereas groups D and C (unconnected) are characterized by lower income and low education levels.

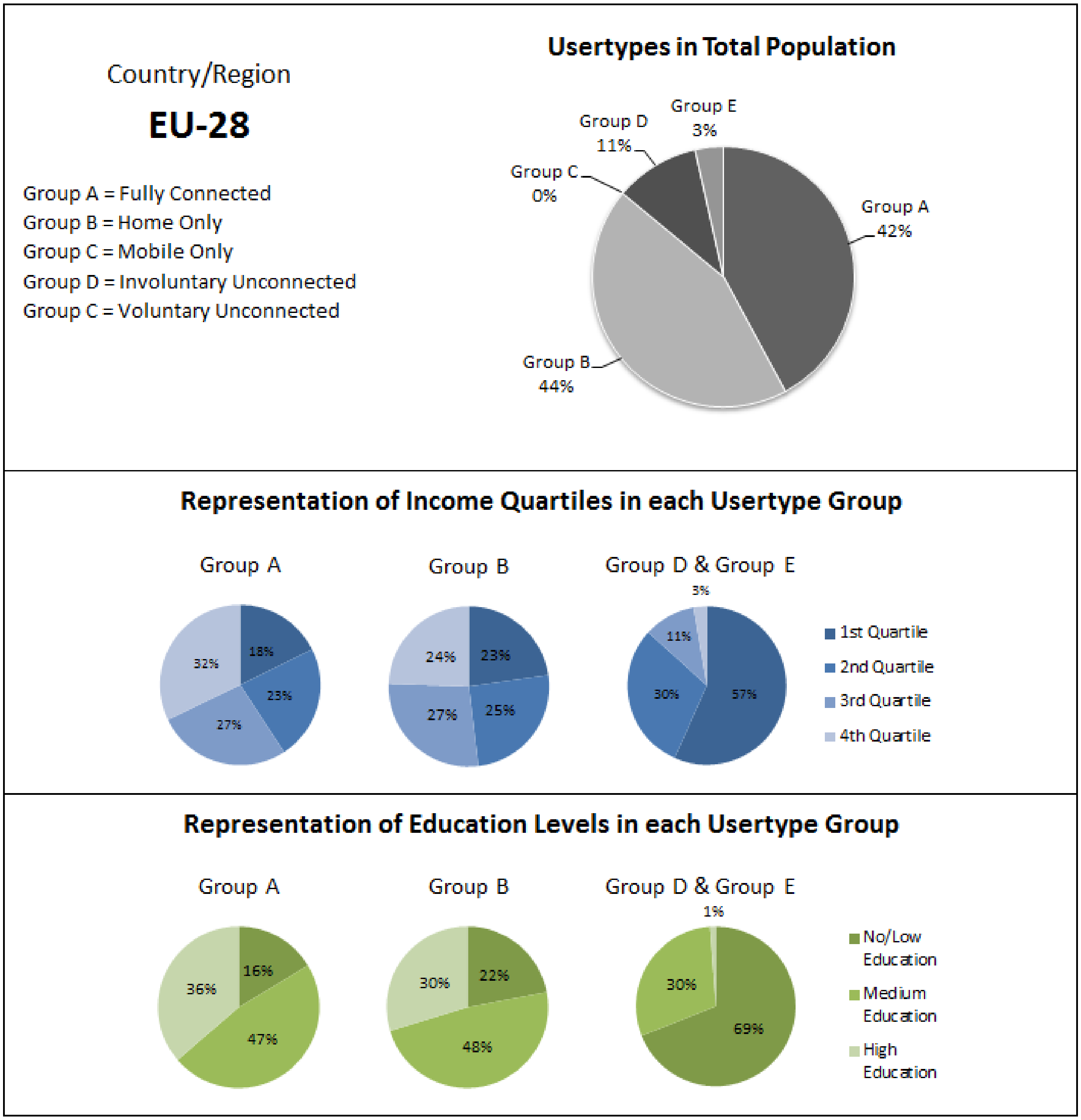

Figure D.2: *Different User Types in the EU-28 Area*

Example Calculation

The data used in this example calculation is based on the Eurostat Databases on connectivity rates and internet usage (Eurostat, 2018c, 2018f).

Based on the distribution of the population over the identified user types (see Section 4.1.3 and Figure D.2), and the data concerning the use of the internet for interaction with the government (see Eurostat (2018f)), the expected use of e-government within a user type (U_X) based on different user characteristics has been determined. The calculation based on Internet access is based on the difference between e-government use of those with and without fixed internet access; the figure for those with fixed access (U_F) is given by Eurostat (2018f) and the percentage of those without fixed access that use e-government (U_{NoF}) has been calculated using Equation 12. Similarly, the shares of people who use the Internet have been calculated, and the use of e-government per internet user following the data provided by Eurostat (2018f) and Equation 12. Equation 13 is the calculation of the e-government use per user type (X) based on the distribution of education groups (EDU, $1 =$ low $2 =$ medium $3 =$ high) and corrected so that the population average based on education equals the population average given by Eurostat. Similarly, Equation 14 calculates the e-government use per user type (X) based on the distribution of income quartiles.

$$\mathrm{U}_{NoF} = \frac{\mathrm{U}_{TOT} - (\mathrm{U}_F * \%_F)}{\%_{NoF}} \tag{12}$$

$$\mathrm{U}_{X-EDU} = \%_{X-EDU} * \mathrm{U}_{EDU} * \frac{\sum_{EDU=1}^{3} (\%_{X-EDU} * \mathrm{U}_{EDU})}{\mathrm{U}_{TOT}} \tag{13}$$

$$\mathrm{U}_{X-INC} = \%_{X-INC} * \mathrm{U}_{INC} * \frac{\sum_{INC=1}^{4} (\%_{X-INC} * \mathrm{U}_{INC})}{\mathrm{U}_{TOT}} \tag{14}$$

Table D.1 shows the outcome of the calculations of e-government usage shares between different user types. It can be observed that for user types A and B, the difference between the different methods of calculating the usage shares is minimal ($SD_A = 0.68$ and $SD_B = 1$). For types D and E, that outcomes differ a bit more ($SD_D = 3.76$ and $SD_E = 3.76$), with the calculations based on education and income giving a slightly higher estimate of the e-government use.

While a slight difference between the calculations based on access opportunities and use of the internet, relative to education and income, is shown, this is not deemed to be a reason to not use education and income as determining factors for the estimate of e-government use and e-government effectiveness throughout the model. This because the Wi-Fi network works influence access opportunities (by providing access) and for users possibly also internet use (as it might attract those that previously did not use the internet due to a lack of access opportunities).

	User Type				
	A	**B**	**C**	**D**	**E**
Fixed Connection	**X**	**X**			
Mobile Connection	**X**		**X**		
want-not					**X**
Share of Population	**42.2%**	**44.0%**	**0%**	**10.5%**	**3.5%**
Group Composition					
Low Education	16.4%	22.0%	N/A	69.0%	69.0%
Medium Education	47.3%	48.2%	N/A	29.9%	29.9%
High Education	36.3%	29.7%	N/A	1.2%	1.2%
1st Quartile Income	17.7%	22.7%	N/A	56.7%	56.7%
2nd Quartile Income	23.1%	25.4%	N/A	30.0%	30.0%
3rd Quartile Income	27.1%	27.4%	N/A	10.6%	10.6%
4th Quartile Income	32.1%	24.5%	N/A	2.7%	2.7%
E-Goverment use based on					
Fixed Connection	43.8%	43.8%	N/A	23.1%	23.1%
Internet Use	43.1%	43.1%	N/A	27.2%	27.2%
Education Level	44.8%	42.0%	N/A	25.9%	25.9%
Income Level	43.1%	41.2%	N/A	33.4%	33.4%
Average	**43.7%**	**42.5%**	**N/A**	**27.4%**	**27.4%**

Table D.1: *Example Calculation of e-Government Usage Shares between User Types*

E Scenarios

Scenario 1: Connectivity

Country Comparison

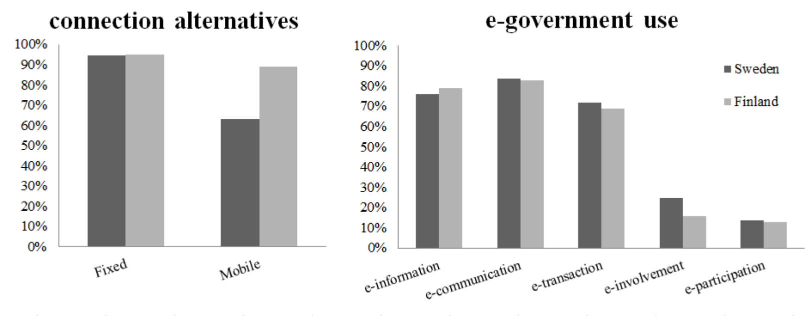

Figure E.1: *Country Comparison Scenario 1a: Sweden & Finland*

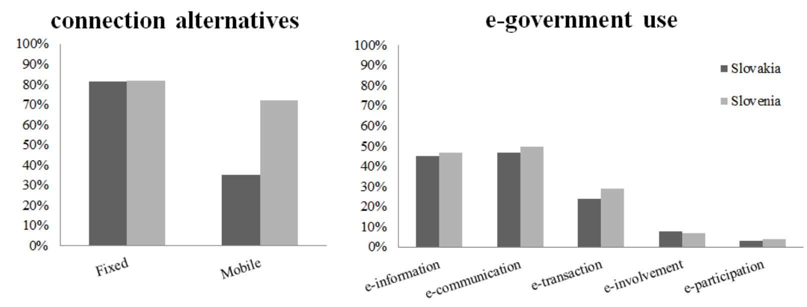

Figure E.2: *Country Comparison Scenario 1a: Slovakia & Slovenia*

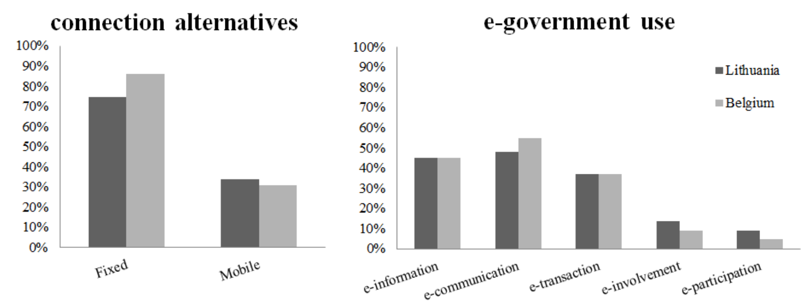

Figure E.3: *Country Comparison Scenario 1b: Belgium & Lithuania*

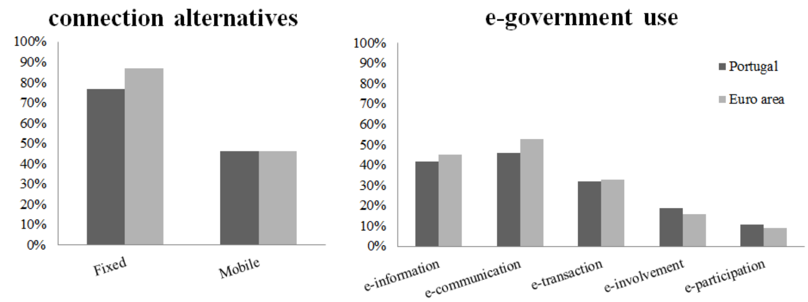

Figure E.4: *Country Comparison Scenario 1b: Portugal & EURO area*

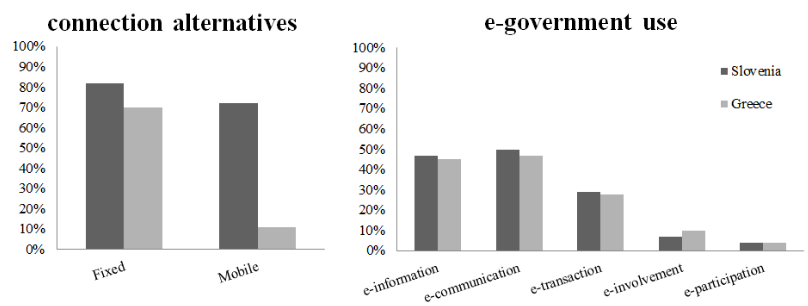

Figure E.5: *Country Comparison Scenario 1c: Slovenia & Greece*

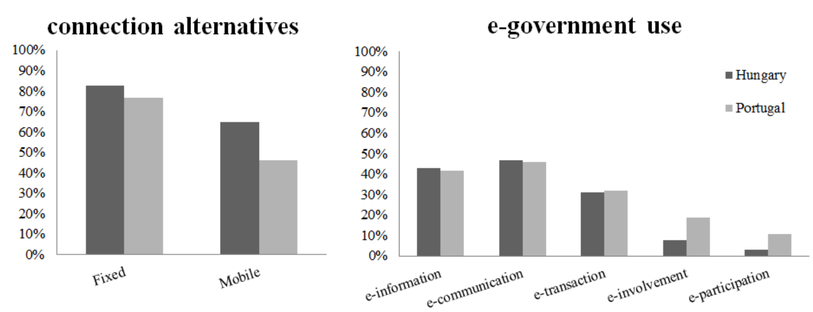

Figure E.6: *Country Comparison Scenario 1c: Hungary & Portugal*

Results

	Finland			Sweden		
	ENPV	B/C Ratio	ERR	ENPV	B/C Ratio	ERR
Connection Rates Only						
Low Weighting	-16,701.48	0.33		-15,739.60	0.37	
Middle Weighting	-13,915.63	0.44		-7,000.04	0.72	
High Weighting	-10,776.62	0.57		1,984.89	1.08	0.22
Connection Rates & e-Government Use						
Low Weighting	-5,328.90	0.79		-2,667.05	0.86	
Middle Weighting	1,033.48	1.04	0.14	11,746.82	1.62	0.89
High Weighting	8,109.22	1.32	0.65	26,551.72	2.40	1.82

Table E.1: *Results Scenario 1a: Sweden & Finland*

	Slovenia			Slovakia		
	ENPV	B/C Ratio	ERR	ENPV	B/C Ratio	ERR
Connection Rates Only						
Low Weighting	4,355.23	1.17	0.40	9,683.48	1.39	0.76
Middle Weighting	12,410.92	1.50	0.93	26,391.02	2.05	1.81
High Weighting	20,776.60	1.83	1.46	43,245.78	2.73	2.86
Connection Rates & e-Government Use						
Low Weighting	6,732.18	0.56	1.36	15,261.88	1.81	1.11
Middle Weighting	14,042.97	1.04	1.74	31,682.38	2.67	2.14
High Weighting	21,721.68	1.52	2.15	48,246.58	3.55	3.17

Table E.2: *Results Scenario 1a: Slovakia & Slovenia*

	Belgium			Lithuania		
	ENPV	B/C Ratio	ERR	ENPV	B/C Ratio	ERR
Connection Rates Only						
Low Weighting	-1,137.83	0.95		20,659.27	1.82	1.45
Middle Weighting	14,871.44	1.59	1.09	38,778.51	2.55	2.58
High Weighting	31,010.87	2.24	2.10	57,048.13	3.28	3.72
Connection Rates & e-Government Use						
Low Weighting	2,745.84	1.11	0.28	21,390.08	2.27	1.50
Middle Weighting	22,330.01	1.89	1.56	38,630.73	3.29	2.57
High Weighting	42,081.42	2.68	2.79	56,040.54	4.32	3.65

Table E.3: *Results Scenario 1b: Belgium & Lithuania*

	EURO area			Portugal		
	ENPV	**B/C Ratio**	**ERR**	**ENPV**	**B/C Ratio**	**ERR**
Connection Rates Only						
Low Weighting	-3,557.46	0.86		13,982.91	1.56	1.03
Middle Weighting	9,189.61	1.37	0.73	28,327.05	2.13	1.93
High Weighting	22,129.64	1.88	1.55	42,879.10	2.71	2.84
Connection Rates & e-Government Use						
Low Weighting	3,518.59	1.14	0.34	4,765.89	1.19	0.43
Middle Weighting	20,463.05	1.82	1.44	17,422.61	1.70	1.25
High Weighting	37,663.83	2.50	2.51	30,328.97	2.21	2.06

Table E.4: *Results Scenario 1b: Portugal & EURO area*

	Slovenia			Greece		
	ENPV	**B/C Ratio**	**ERR**	**ENPV**	**B/C Ratio**	**ERR**
Connection Rates Only						
Low Weighting	4,355.23	1.17	0.40	26,365.35	2.05	1.81
Middle Weighting	12,410.92	1.50	0.93	50,208.29	3.00	3.29
High Weighting	20,776.60	1.83	1.46	74,103.48	3.96	4.77
Connection Rates & e-Government Use						
Low Weighting	6,732.18	0.56	1.36	16,749.35	1.67	1.21
Middle Weighting	14,042.97	1.04	1.74	38,866.59	2.55	2.59
High Weighting	21,721.68	1.52	2.15	61,039.24	3.44	3.96

Table E.5: *Results Scenario 1c: Slovenia & Greece*

	Hungary			Portugal		
	ENPV	**B/C Ratio**	**ERR**	**ENPV**	**B/C Ratio**	**ERR**
Connection Rates Only						
Low Weighting	3,688.08	1.15	0.35	13,982.91	1.56	1.03
Middle Weighting	13,066.29	1.52	0.98	28,327.05	2.13	1.93
High Weighting	22,724.40	1.91	1.58	42,879.10	2.71	2.84
Connection Rates & e-Government Use						
Low Weighting	-4,934.15	0.80		4,765.89	1.19	0.43
Middle Weighting	2,327.84	1.09	0.25	17,422.61	1.70	1.25
High Weighting	9,881.00	1.39	0.77	30,328.97	2.21	2.06

Table E.6: *Results Scenario 1c: Hungary & Portugal*

Country	Fixed Rate	Mobile Rate	ENPV
Austria	88.74%	63.00%	14,102.84
Belgium	86.14%	31.00%	22,330.01
Bulgaria	67.24%	46.00%	602.74
Croatia	76.64%	44.00%	12,901.19
Cyprus	89.58%	3.00%	30,715.38
Denmark	96.01%	33.00%	20,613.32
EU-28	87.00%	46.00%	11,925.02
EURO	85.96%	42.00%	20,463.05
Finland	94.84%	89.00%	1,031.54
Germany	92.68%	51.00%	2,172.30
Greece	69.94%	11.00%	38,866.59
Hungary	82.63%	65.00%	2,327.84
Ireland	87.93%	43.00%	18,043.26
Latvia	79.51%	24.00%	66,468.16
Lithuania	74.75%	34.00%	38,621.79
the Netherlands	98.47%	48.00%	3,384.64
Macedonia	73.90%	37.00%	304.90
Poland	81.29%	39.00%	2,372.12
Portugal	76.63%	46.00%	17,422.61
Romania	76.61%	37.00%	-10,890.41
Slovakia	81.40%	35.00%	31,682.38
Slovenia	81.87%	72.00%	14,042.97
Sweden	94.72%	63.00%	17,237.46
Switzerland	93.79%	75.00%	6,664.80
Turkey	80.00%	72.00%	18,595.59
United Kingdom	93.10%	25.00%	4,707.01

Table E.7: *ENPV (Middle Weighting Set) outcomes over Connectivity Rates*

Sensitivity

The sensitivity of each scenario test has been determined through a Monte-Carlo simulation of 500 iterations, for each iteration comparing the difference between the two countries in the middle weighting scenario. The comparison is sensitive to data sensitivity and assumption if the spread covers €0 or if the spread is very large.

Mind that not all graphs have the minimum and maximum value of the X and Y axis.

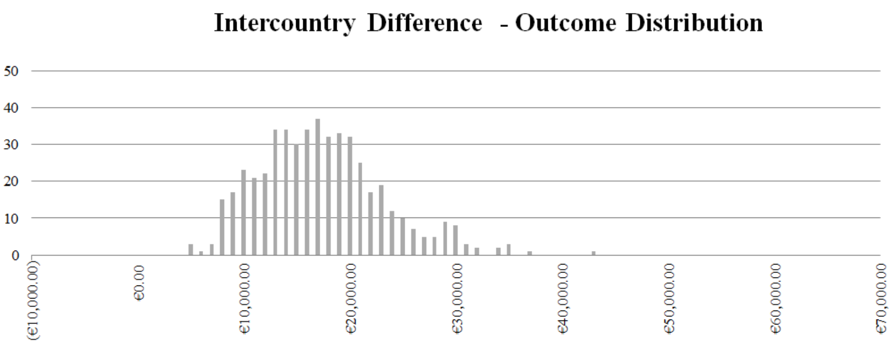

Figure E.7: *Sensitivity Scenario 1a: Sweden & Finland (based on 500 iterations)*

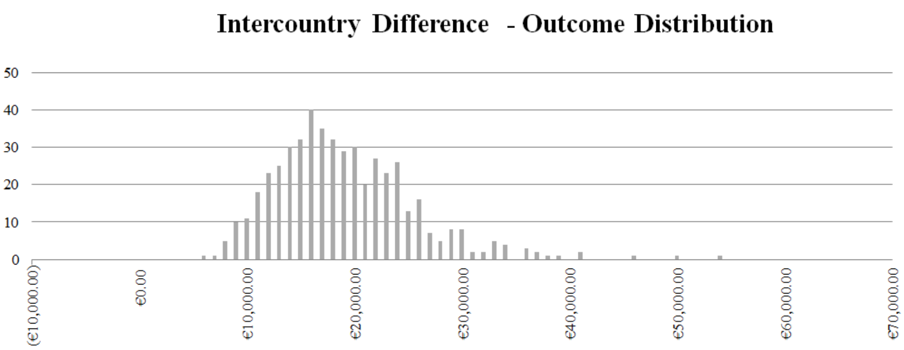

Figure E.8: *Sensitivity Scenario 1a: Slovakia & Slovenia (based on 500 iterations)*

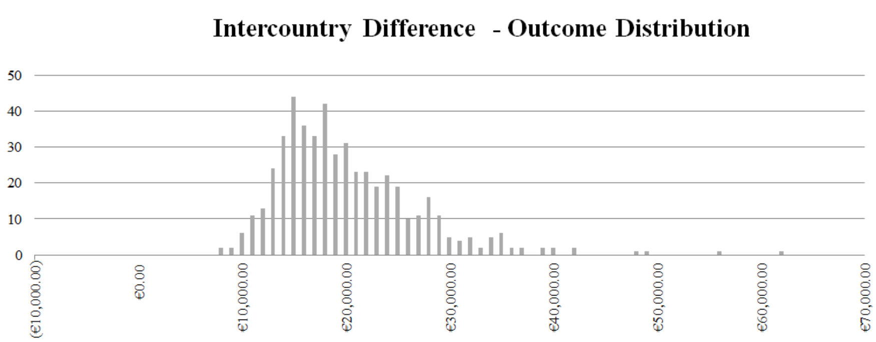

Figure E.9: *Sensitivity Scenario 1b: Lithuania & Belgium (based on 500 iterations)*

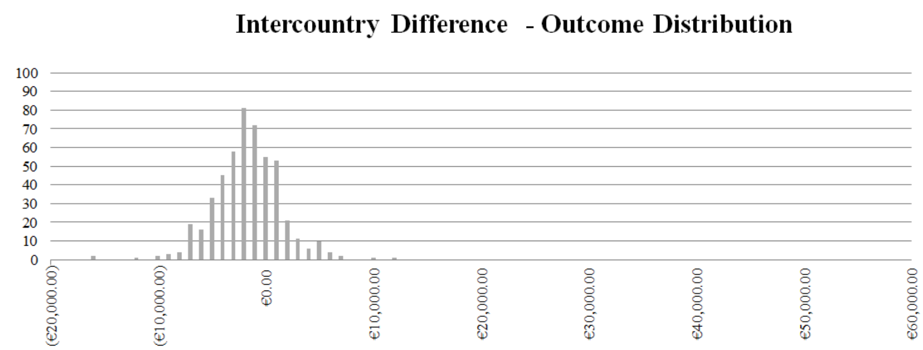

Figure E.10: *Sensitivity Scenario 1b: Portugal & EURO area (based on 500 iterations)*

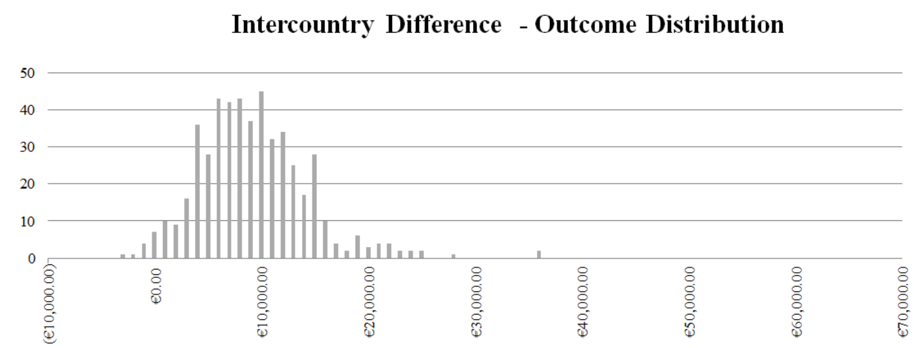

Figure E.11: *Sensitivity Scenario 1c: Greece & Slovakia (based on 500 iterations)*

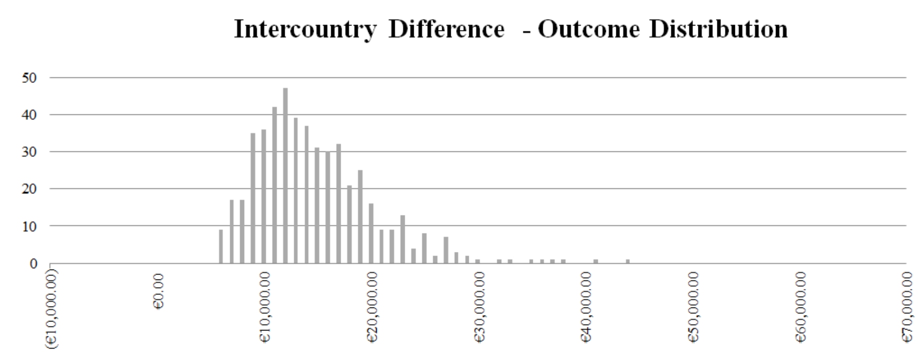

Figure E.12: *Sensitivity Scenario 1c: Portugal & Hungary (based on 500 iterations)*

Scenario 2: Digital Skills

Country Comparison

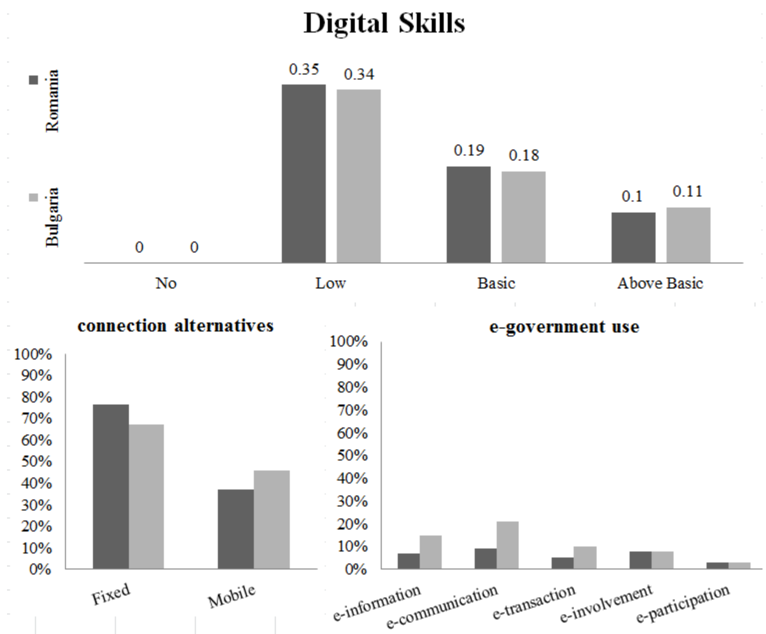

Figure E.13: *Country Comparison Scenario 2.1: Romania & Bulgaria*

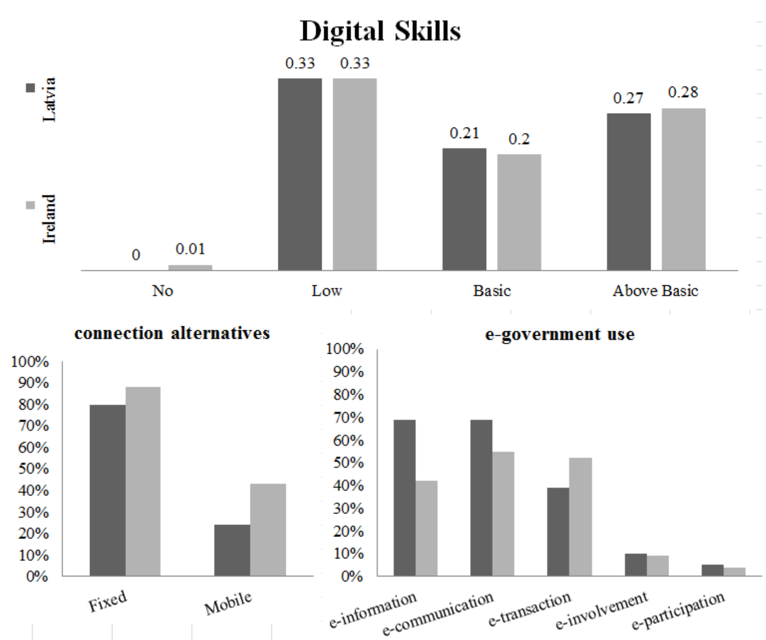

Figure E.14: *Country Comparison Scenario 2.1: Latvia & Ireland*

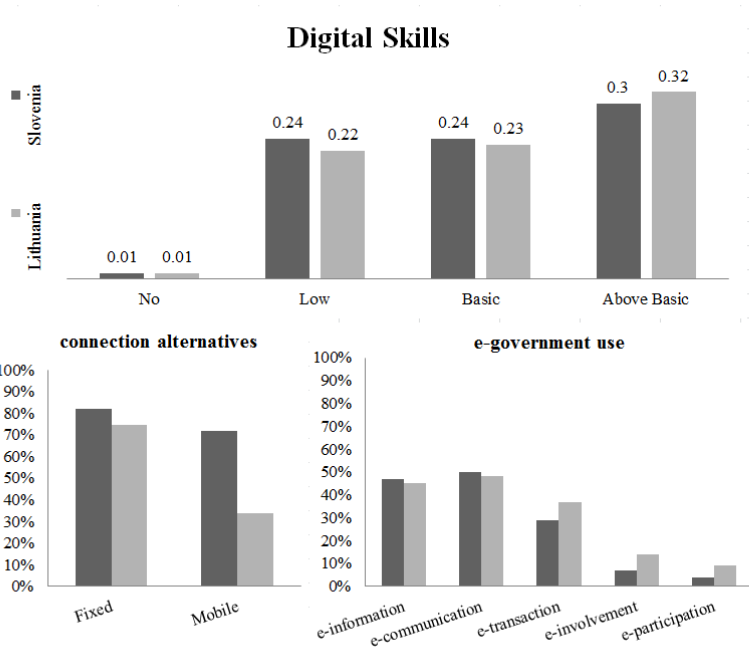

Figure E.15: *Country Comparison Scenario 2.1: Slovenia & Lithuania*

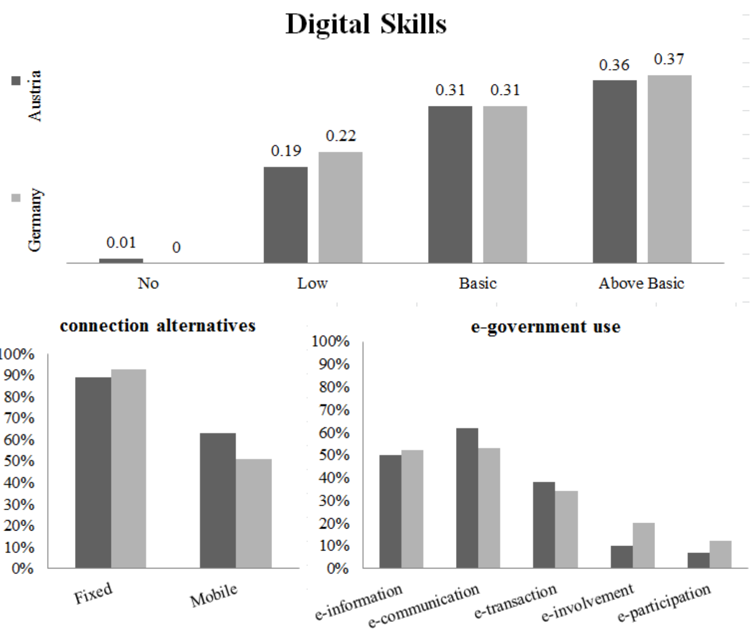

Figure E.16: *Country Comparison Scenario 2.1: Austria & Germany*

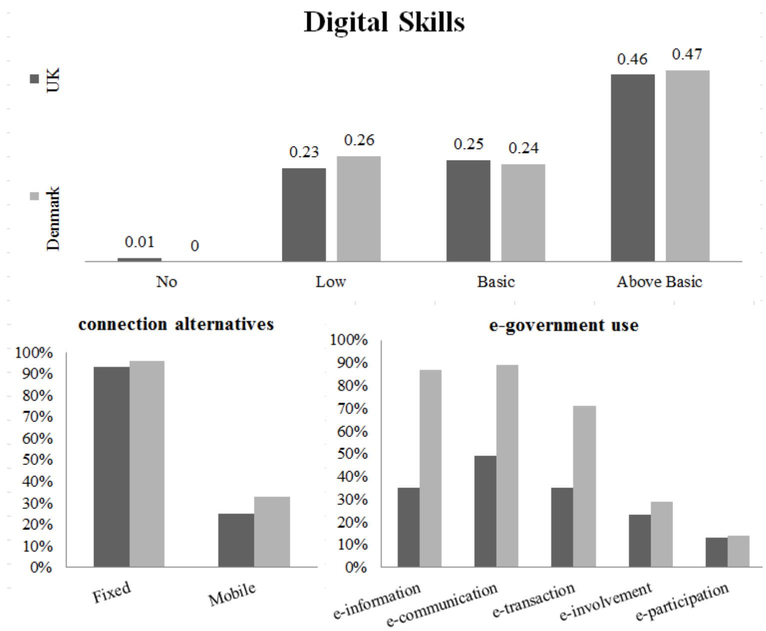

Figure E.17: *Country Comparison Scenario 2.1: United Kingdom & Denmark*

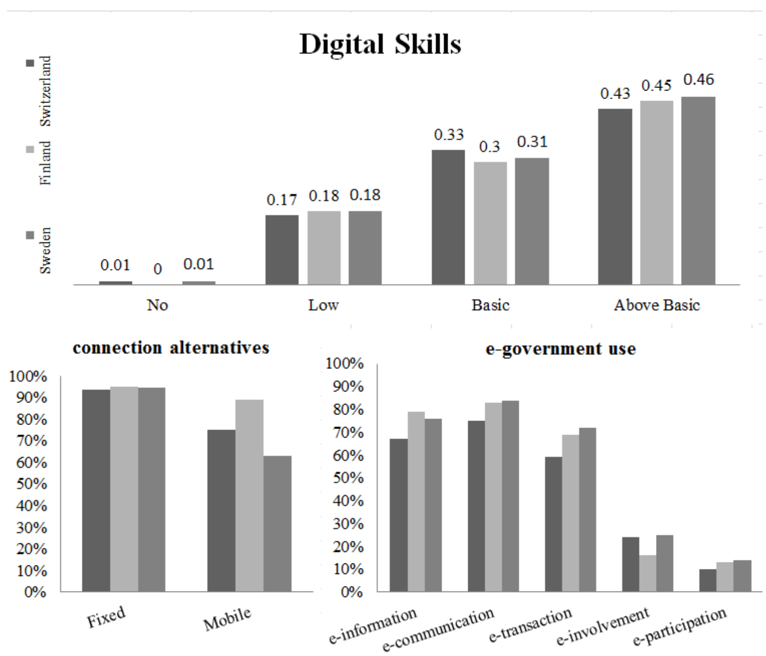

Figure E.18: *Country Comparison Scenario 2.1: Switzerland, Finland & Sweden*

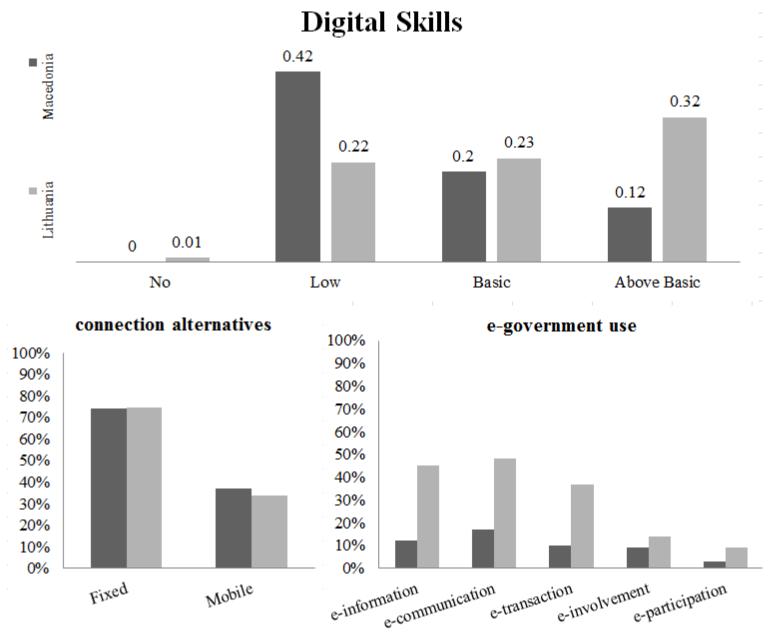

Figure E.19: *Country Comparison Scenario 2.3: Macedonia & Lithuania*

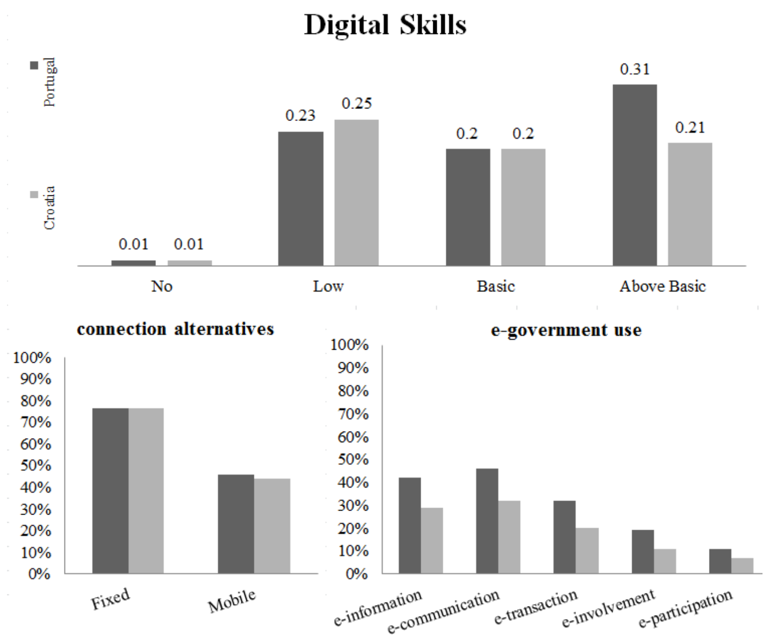

Figure E.20: *Country Comparison Scenario 2.3: Portugal & Croatia*

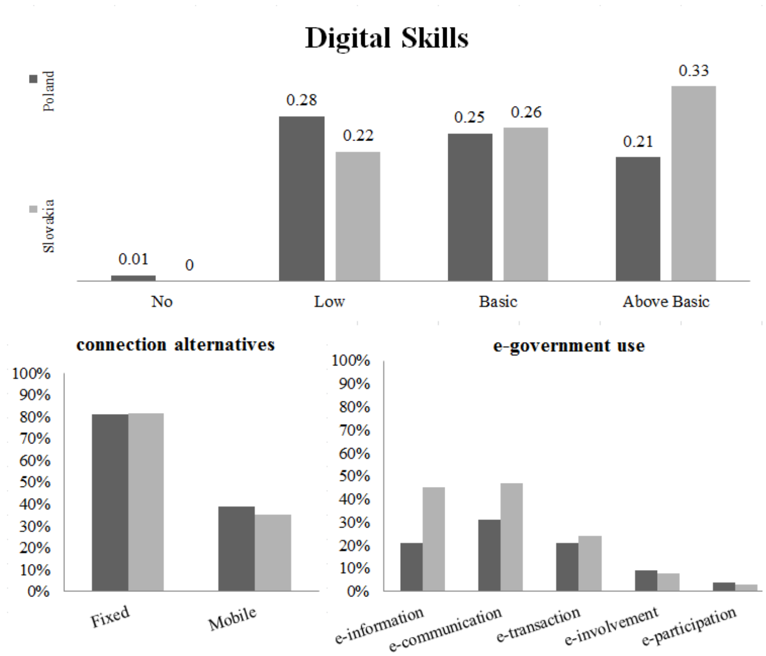

Figure E.21: *Country Comparison Scenario 2.3: Poland & Slovakia*

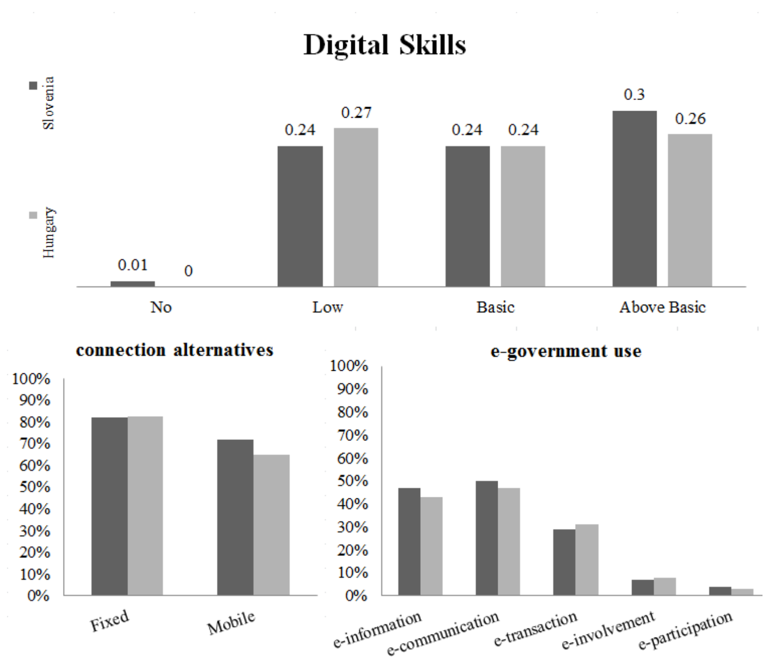

Figure E.22: *Country Comparison Scenario 2.3: Slovenia & Hungary*

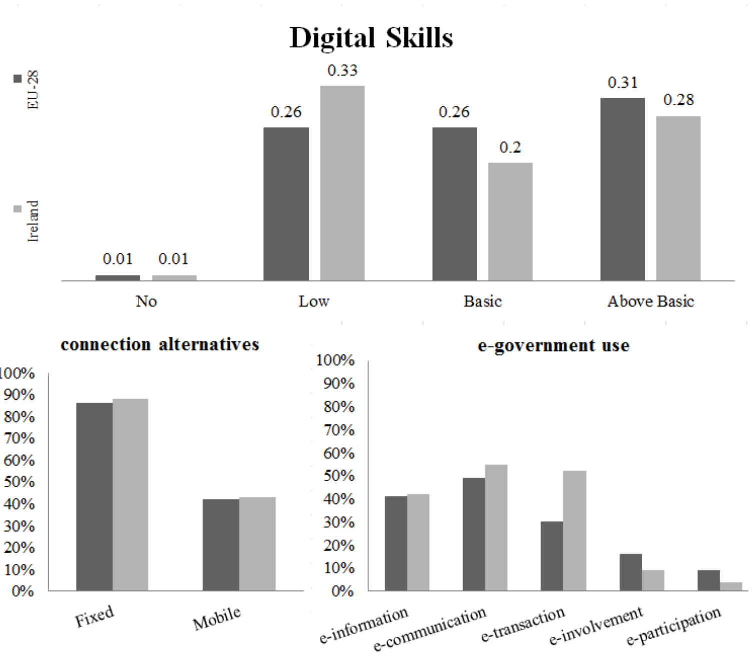

Figure E.23: *Country Comparison Scenario 2.3: EU-28 & Ireland*

Results

	Digital Skills (Basic+)	Low	Middle	High
Romania	0.29	-13,492.11	-10,890.41	-8,251.64
Bulgaria	0.29	-4,287.63	602.74	5,603.05
Turkey	0.34	10,890.76	18,595.59	26,599.83
Croatia	0.41	1,875.65	12,901.19	24,076.36
Latvia	0.48	36,244.85	66,468.16	96,851.49
Ireland	0.48	3,916.00	18,043.26	32,375.71
Slovenia	0.54	6,732.18	14,042.97	21,712.68
Lithuania	0.54	21,384.04	38,621.79	56,028.66
Austria	0.67	1,553.44	14,102.84	27,015.41
Germany	0.68	-9,930.17	2,172.30	14,504.10
United Kingdom	0.71	-9,422.11	4,707.01	18,937.80
Denmark	0.71	-6,135.54	20,613.32	47,624.56
Switzerland	0.76	-2,502.93	6,664.80	16,342.31
Finland	0.76	-5,330.36	1,031.54	8,106.74
Sweden	0.77	9.55	17,237.46	34,938.43

Table E.8: *Results Scenario 2: ENPV per Country per Weighting Set*

Sensitivity

The sensitivity of each scenario test has been determined through a Monte-Carlo simulation of 500 iterations, for each iteration comparing the difference between the two countries in the middle weighting scenario. The comparison is sensitive to data sensitivity and assumption if the spread covers €0 or if the spread is very large.

Mind that not all graphs have the same minimum and maximum value on the X and Y axis.

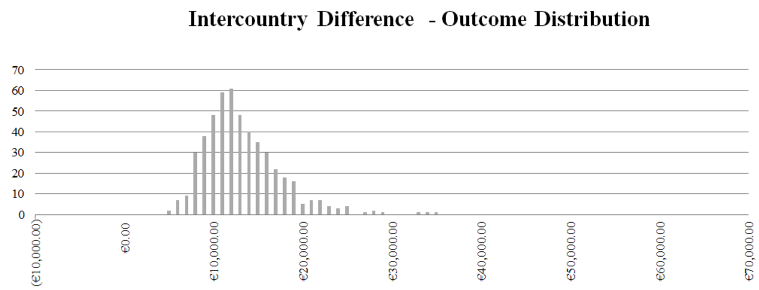

Figure E.24: *Sensitivity Scenario 2.1: Bulgaria & Romania (based on 500 iterations)*

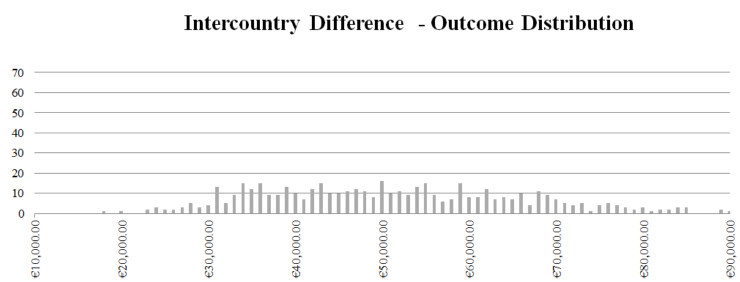

Figure E.25: *Sensitivity Scenario 2.1: Latvia & Ireland (based on 500 iterations)*

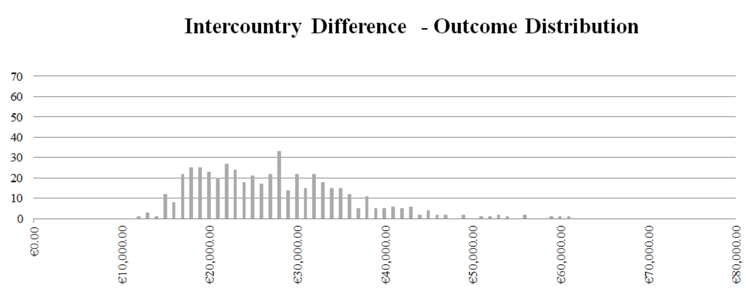

Figure E.26: *Sensitivity Scenario 2.1: Lithuania & Slovenia (based on 500 iterations)*

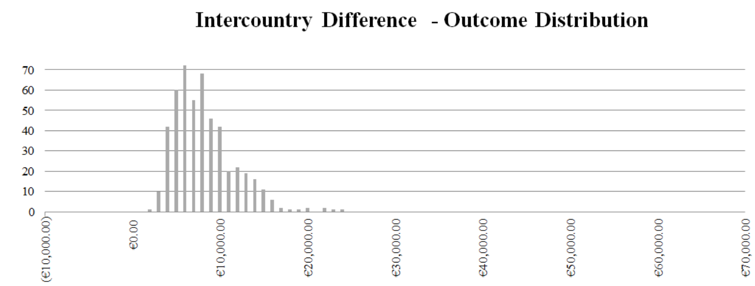

Figure E.27: *Sensitivity Scenario 2.1: Austria & Germany (based on 500 iterations)*

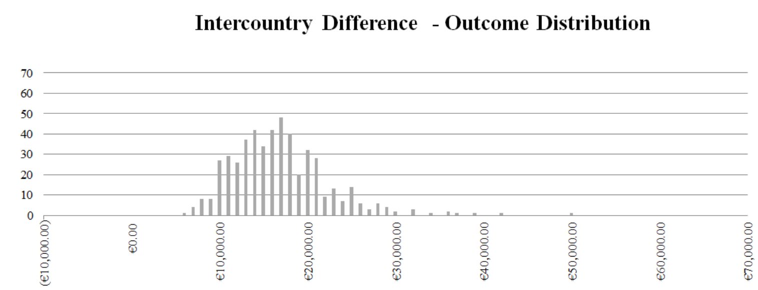

Figure E.28: *Sensitivity Scenario 2.1: Denmark & United Kingdom (based on 500 iterations)*

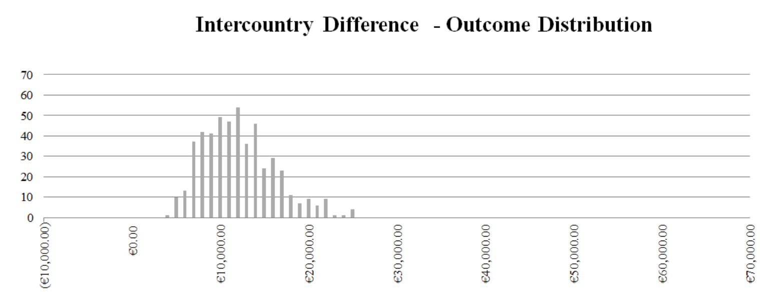

Figure E.29: *Sensitivity Scenario 2.1: Sweden & Switzerland (based on 500 iterations)*

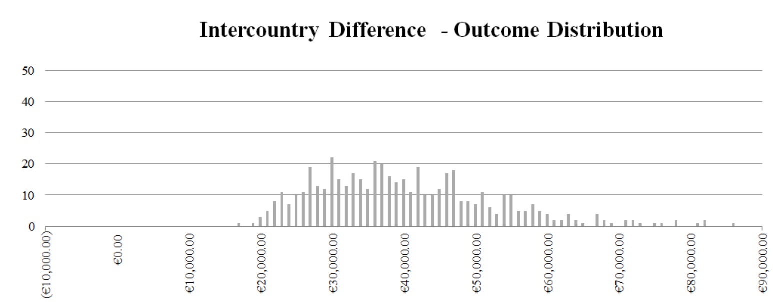

Figure E.30: *Sensitivity Scenario 2.3: Macedonia & Lithuania (based on 500 iterations)*

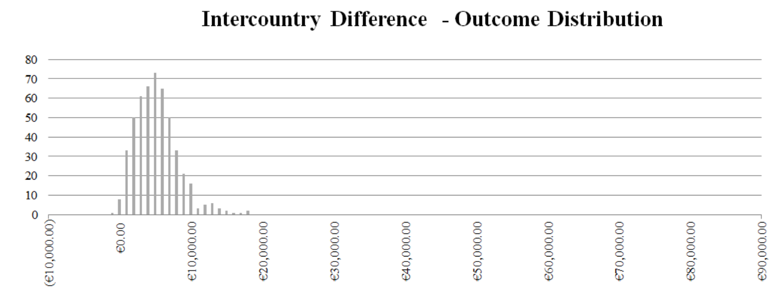

Figure E.31: *Sensitivity Scenario 2.3: Portugal & Croatia (based on 500 iterations)*

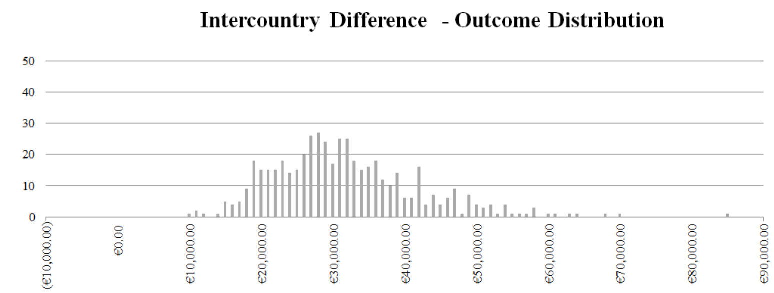

Figure E.32: *Sensitivity Scenario 2.3: Poland & Slovakia (based on 500 iterations)*

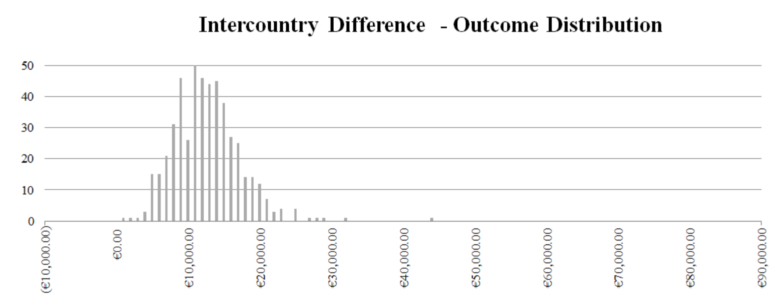

Figure E.33: *Sensitivity Scenario 2.3: Slovenia & Hungary (based on 500 iterations)*

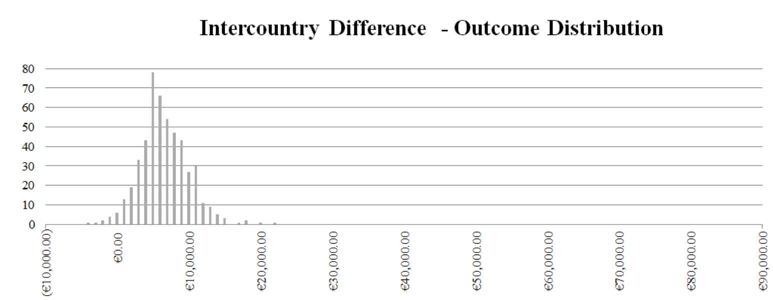

Figure E.34: *Sensitivity Scenario 2.3: EU-28 & Ireland (based on 500 iterations)*